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A Learning by Construction Approach for Higher Order Cognitive Skills Improvement

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. mr. S.C.J.J. Kortmann,

volgens besluit van het college van decanen
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A Learning by Construction Approach for Higher Order Cognitive Skills Improvement

Doctoral Thesis

to obtain the degree of doctor
from Radboud University Nijmegen
on the authority of the Rector Magnificus, prof. dr. S.C.J.J. Kortmann

according to the decision of the Council of Deans
to be defended in public on Tuesday, 02 October 2012
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Preface

Higher Order Cognitive skills (HOCS) relate to the perception that an individual has acquired skills to make a decision under various conditions of uncertainty and time limit. The importance of graduates' HOCS for problem solving and decision making has been highlighted by academia and practitioners. Traditional learning approaches have been criticized for failure to improve HOCS in science education, which suggests the need for new approaches to address this dilemma. In addition to this, there is shortage of ICT capacity and infrastructure especially in the Least Developed Countries. HOCS can be improved if content is designed following the elements we recommend in this thesis. In our research we carry out a comprehensive theoretical review of published studies that examine the current methods for improving HOCS, which provide the HOCS improvement requirements. This research proposes the Learning by construction approach for introducing an ICT education program for HOCS improvement, building capacity and infrastructure in Least Developed Countries.

This research could not have been successful without the guidance, mentorship, friendship and support of the following people. First and foremost I offer my sincerest gratitude to my supervisors Prof. dr. ir. Theo P. van der Weide, Dr. H.A.T. Henry van der Meijden and Prof. Victor W. A. Mbarika who supported me throughout my research with their wisdom and knowledge. Special thanks to Theo, who stood by me, believed in me through thick and thin and offered me encouragement, advice, insight, patience and effort. Thank you Victor for introducing me to the research area, providing materials, facilitating my research visit to the US to carry out experiments and work with several scholars. Thank you Henny for taking time off your busy schedule to read through my thesis and provide so many ideas on how to improve it.

I am grateful to the NUFFIC project for the scholarship and support for my research visits to the Netherlands and conference attendance in different countries. I also extend special thanks to the Vice Chancellor, Makerere University, Prof. V. (Barya) Baryamureeba who provided administrative and financial assistance that enabled me succeed. I would like to thank colleagues at Radboud University and School of Computing and IT, Makerere University for their friendship, moral and social support. Thank you Nicole, Irma, Peace and Consolate for the help with administration issues throughout my research.

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THANK YOU ALL AND MAY GOD BLESS YOU ABUNDANTLY!!!
Associated Publications


1. Introduction

This chapter launches the subject area of the thesis by discussing the research background on learning, Higher Order Cognitive Skills (HOCS) improvement, building capacity and infrastructure. The goal of the thesis which includes the problem definition, research objectives, questions, significance, research approach and design is highlighted. Then we finally discuss the research contributions and thesis outline.

1.1 Background

Learning is a process by which one’s behavior and ways of thinking change as a result of experience gained (Maples & Webster, 1980; Anderson, 2006; Alissa, 2011). ‘Learning is a cognitive process of taking in information, processing, organizing, and storing it in a richly connected schema in ways that knowledge formed is easily recalled when required’ (Akdemir & Koszalka, 2007, pp 1452). Generally, learning is the ability to retain skills and knowledge acquired from the learning situation. Learning occurs in several ways and is delivered using different methods that include traditional, electronic or blended methods. We compare and contrast the three learning methods below.

The traditional learning approach is a structured clear method that allows face to face interaction of students and their lecturers. The lecturers and students use material from textbooks to aid learning which takes place in the same physical location at the same time. The advantages of this approach include the ability to trigger questions in relation to the subject, learner interaction with others which enhances ability to learn from fellow students, knowledge of the lecturers and putting the individual needs of students into consideration. This approach encourages knowledge acquisition about the basic concepts; therefore, students recall knowledge as it is given to them without comprehending it. This approach poses several limitations that include limited learning space - time and physical space boundaries, being inflexible and teacher – centered, i.e. the teacher is the one and only source of information. Educators call this method “instructor-centered teaching” because students strongly depend on the teacher hence it encourages passive learning which is ineffective. This approach has been criticized for enabling the acquisition of Lower Order Cognitive Skills and therefore needs to be enhanced to accommodate students Higher Oder Cognitive Skills improvement through blended and e-learning.

The E-learning approach is an interactive method for transmitting educational information, with the aid of the Internet and Information and Communication Technologies (ICT's) (Rosenberg, 2001) to improve the quality of learning, by enabling students to learn using online resources. It is a learner-centered, flexible, convenient, collaborative learning approach that accommodates for learner difference. This learning environment encourages student engagement, free participation of timid students and active involvement of students in the learning process due to interaction with computers, thereby emphasizing active learning. Students can access learning material anytime, anywhere at any pace through an electronic learning environment. E-learning aims at learner satisfaction by encouraging active self-paced and directed learning, from different perspectives and peer learning, thereby enhancing student responsibility for learning. Researchers and practitioners have over emphasized the importance of e-learning and encourage its introduction by clearly illustrating the advantages over the traditional learning approach (Mohd, 2002). Therefore there has been an evolution in teaching and learning methods from the traditional learning to e-learning approach.
Blended learning approach is a mixture of more than one learning method during teaching e.g. traditional learning and e-learning. Blended learning utilizes e-learning and maintains part of traditional learning, thereby, utilizing the advantages of both methods. Therefore students attend classes physically and also use the electronic learning environment for discussions, class notes etc. This learning approach has been adopted today in many higher institutions of learning because it solves many of the problems students face e.g. it is a motivating factor to part time students, distance education etc. Table 1.1 highlights the differences between the three learning approaches.

<table>
<thead>
<tr>
<th></th>
<th>Traditional learning</th>
<th>E-learning</th>
<th>Blended learning</th>
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<tr>
<td>Main instructor</td>
<td>Teacher</td>
<td>Teacher, fellow students and learning resources</td>
<td>Teacher, fellow students and learning resources</td>
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<tr>
<td>Instruction</td>
<td>Teacher centered</td>
<td>Learner centered</td>
<td>Learner centered</td>
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<td></td>
<td>Teacher directed</td>
<td>Self directed</td>
<td>Self directed with teacher intervention</td>
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<td></td>
<td>Single perspective</td>
<td>Multiple perspectives</td>
<td>Multiple perspectives</td>
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<tr>
<td></td>
<td>Face to face</td>
<td>Computer assisted</td>
<td>Face to face + computer</td>
</tr>
<tr>
<td>Research if teacher assigns</td>
<td>Research encouraged</td>
<td>Research encouraged</td>
<td>Some research</td>
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<tr>
<td>Assessment of learning</td>
<td>Teacher</td>
<td>Self, Peer</td>
<td>Self, peer and teacher</td>
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<td>Student involvement</td>
<td>Passive</td>
<td>Active</td>
<td>Partially Active</td>
</tr>
<tr>
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<td>ICT</td>
<td>ICT</td>
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<tr>
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<td>Non interactive</td>
<td>Interactive</td>
<td>Interactive</td>
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<tr>
<td>Flexibility</td>
<td>Classroom / lab</td>
<td>Anytime, anywhere</td>
<td>Flexible</td>
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Table 1.1: Comparison of Traditional, E-learning and Blended Learning Approaches

In the next section, we discuss cognitive skills; Lower Order Cognitive Skills (LOCS) and Higher Order Cognitive Skills (HOCS), the improvement of HOCS using the traditional learning approach and the significance of ICT in HOCS improvement.

1.2 Lower and Higher Order Cognitive Skills

Cognitive skills are the ability for students to acquire or reorganize cognitive structures through which they can process, store information and apply knowledge acquired from the learning situation in different scenarios (Good & Brophy, 1990). The need for the ability to acquire, process, store and apply knowledge acquired in class to solve real life problems is acknowledged. Patel & Kinshuk, (2001) p.502 emphasize that ‘cognitive skills are the ability to perform the procedural tasks, involving situational analysis, interpretation of information, orderly execution of subtasks and decision making’. These skills are needed in application of knowledge to solve problems and enhance the decision making process.

LOCS refer to the general knowledge attained by students in class, however, cannot be used for problem solving. LOCS involve memorizing and reciting a series of facts (Zoller, 1993; 1999; 2001). A student with LOCS can reproduce the knowledge attained from the learning situation without comprehending it. In general, the students cannot apply this knowledge to solve real life problems. For example, students can answer questions in a test but are unable to do a practical related to the test. The traditional learning methods emphasize LOCS teaching, where the
learner knows one correct answer to a problem or question. Therefore it emphasizes exercise solving and not problem solving; where is synonymous with HOCS.

HOCS are skills that go beyond basic comprehension of a problem or concept (Lou et al., 2008; Bradley et al., 2007). They refer to the skills that students can use for problem solving, analysis and decision making within different situations. HOCS consist of rational, system critical - evaluative thinking, question asking, decision making, problem (not exercise) solving and transfer in both science disciplines and real interdisciplinary life situations (Zoller, 2001; Zoller et al., 2002). HOCS are interpreted as the capability for making connections, analysis and decisions based on the students’ understanding and conceptualization beyond knowledge per se (Lubezki et al., 2004). The HOCS concept entered the general education literature as a way to enhance learning and has been re-emphasized in the last decade, especially in nursing and medical education (Bradley et al., 2007). There is tremendous research currently being undertaken to devise new learning methods that can enable learners to achieve HOCS needed for the workforce for decision making and problem solving. We discuss the methods for HOCS improvement in the next chapter.

1.2.1 HOCS Improvement using the Traditional Learning Approach

The traditional learning approach is not compatible with promotion and improvement of students’ HOCS (Zoller, 1993; Juwah, 2003). Therefore it does not favor improvement of problem solving and decision making skills needed by the employer (Ball & Garton, 2005; Bradley et al., 2007; Mbarika et al., 2010). As earlier noted, this approach favors LOCS e.g. theoretically lecturing about computer memory without illustrating how a memory chip looks like, how to install or upgrade it, does not give the students good grounding of the practical concepts. Due to the limitations above, this approach has been criticized for insufficiency of problem solving and decision making skills in real life situations. Although educators typically understand the learning objectives of their courses, the reality is that these objectives are rarely attained. Introductory courses have been taught using this approach, during which the instructor lectures on these technical topics but HOCS are not imparted. It is a common complaint for educators that science students were not well prepared to take upper-level classes and they often have to redo topics that were supposed to be attempted in the introductory classes. This wastes educators’ time and resources thereby making the traditional learning approach ineffective. This societal dilemma is reflected in many science graduates e.g. engineering, chemistry and IT, today, who lack HOCS of decision making, critical thinking and problem solving, among others.

The complexity for students to deal with decision making situations that require HOCS is a concern in both academia and industry (Bagarukayo & Mbarika, 2008; Bagarukayo et al., 2007). The decision making process involves challenges such as selecting among alternatives that could have slight differences but with multi-million dollar implications. Therefore making a decision among the possible alternatives or a combination of alternatives is complex and requires that the decision makers apply HOCS during the selection process. A broader approach than simply seeking a single solution to a problem is taken. It involves identifying options or alternatives and then selecting one that is best for meeting the desired outcome. In other words, the outcome directs and gives meaning to the task. Anyone can learn critical thinking, which is one of the HOCS attributes but it is a long-term development process that must be practiced, nurtured, and reinforced over time (Ignatavicius & Workman, 2001). Dornheim, (2000) observes that decision errors are second to procedural errors as the direct causes of flight crew involved in accidents. For example, NASA (NAE, 2002) has undertaken an initiative to boost flight crews’ HOCS as one way to improve their problem solving, analytical and decision making skills. It is therefore crucial to provide an education that improves HOCS to prepare students for today’s workforce. Employers expect students to sharpen their HOCS and
make quick technical decisions that translate into business profits (England & Suits, 1998). Therefore employers' aim at recruiting persons with average skills for problem solving, decision making and team playing that will profit the organization (Bargeron et al., 2002). As a result, employers have emphasized over time on preparing students to graduate as proficient problem solvers, decision makers, and team players with good analytical skills, reasoning, problem identification, so as to enhance their performance in the real world work environment (Riley & Crossley, 2000; King, 2000). Since graduates lack these skills, there is need for new teaching and learning methods, frameworks, tools or technologies, for HOCS improvement to prepare future university graduates to address this dilemma.

1.2.2 The Significance of ICT in HOCS Improvement

As noted in the previous section, the traditional learning approach does not improve HOCS. Therefore there is a need for a new approach to improve HOCS. The impact of ICT on learning is still being explored (Punie et al., 2006). ICT improves progress of weaker students if the programs utilized are designed properly and are appropriate to the students level (Kennisnet, 2010). ICT seems to offer the flexibility to handle these challenges with new methods, tools and frameworks. There is a continuous search by educators for new approaches that can capture students' attention and enhance HOCS improvement. Educators have, therefore, invested much to prepare students to be successful as they go to the work force, enabling them to become productive, responsible members of society by providing an education that encompasses good decision making and problem solving skills needed to be qualified employees.

The need to create active customized learning environments for learner motivation and continuous learning desire, for different ICT tools, is acknowledged. ICT tools such as Decision Support Systems (DSS) and Expert Systems (ES) have been developed to help managers in decision making (Cole et al., 2000; Tan & Thoen, 2000). In addition, MM instructional materials have been recognized for enabling understanding of complex engineering and IT decision making situations that require HOCS (Raju & Sankar, 1999; Bradley et al., 2007; Mbarika et al., 2010). The use of MM case studies to convey real-world technical concepts and applications such as those taught in engineering and IT courses has been increasingly advocated for in the education literature. The past decade has seen a clear growth in the use of MM case studies in practical oriented courses. Studies based on perceptions show that MM instructional materials improved students' HOCS, but can hardly prove if actual HOCS in the subject area improved. However it is necessary to understand if actual HOCS improved.

Moreover, the need for capacity and infrastructure building especially in Least Developed Countries (LDCs) is acknowledged (Weide & Flipsen, 2010). The UN Development Programme (UNDP) has defined "capacity" as "the ability of individuals, institutions and societies to perform functions, solve problems, and set and achieve objectives in a sustainable manner." "Capacity building" describes the task of establishing human and institutional capacity, like training for community workers, strengthening local government delivery with adequate staffing is a recurrent theme, as is the establishment of research and policymaking bodies. Therefore, Capacity building is the development of knowledge, skills and attitudes in individuals and groups of people relevant in the design, development and maintenance of institutional and operational infrastructures and processes that are locally meaningful (Groot and Mooien, 2001). Another challenge in LDCs is unemployment, which has led to a big percentage of the graduates from the university seeking for jobs for years. These graduates have the potential to be job creators, and to introduce new technology and opportunities in their countries. Therefore an educational approach that promotes the usage of ICT for HOCS improvement and encourages job creation is required.
IT infrastructure consists of the equipment, systems, software, and services used in common across an organization, regardless of mission/program/project, which also serves as the foundation upon which mission/program/project-specific systems and capabilities are built.

We discuss the goal of the thesis by defining the problem, research questions and objectives, in the next section.

1.3 Problem Definition, Research Questions and Objectives

1.3.1 Problem Definition

HOCS are significant for students to apply the knowledge acquired in class in real-life situations for problem solving and decision making. The importance of HOCS improvement has also been stressed by employers who want to hire graduates who possess skills to solve real-life problems and make decisions that will profit the organizations. The difficulty for students to deal with decision making situations that require HOCS for problem solving and decision making is acknowledged. The failure to improve students’ HOCS remains a challenge in education and the instructional method has been identified as one of the causes. As noted previously, the traditional learning approach has been criticized for failure to improve HOCS. There is insufficient research on the effectiveness, and impact of technology, in particular multimedia (MM) instructional materials on HOCS improvement. Moreover, there is shortage on capacity and infrastructure in the LDC’s. Therefore there is need for more research on the impact of technology on HOCS improvement, building ICT capacity and infrastructure.

1.3.2 Research Questions and Objectives

The aim of the research is to develop an approach for HOCS improvement, building capacity and infrastructure using a Digital Learning Environment.

The following research questions guide us to achieve this aim:

1. What are the requirements for an approach for HOCS improvement during learning?
2. What are the requirements for digital learning tools to support an approach for HOCS improvement during learning?
3. How can a DLE as a tool support HOCS improvement during learning?
4. What approach is used to introduce ICT education to improve HOCS, build capacity and infrastructure in a LDC using the DLE tool?
5. What is the impact of technology on HOCS improvement and the learning process?

To answer the research questions, we pursued the following objectives:

1. To establish the requirements for an approach for HOCS improvement.
2. To determine the requirements for digital learning tools to support the approach for HOCS improvement.
3. To determine how a DLE tool can be used to support HOCS improvement.
4. To develop and validate an approach to introduce ICT education to improve HOCS, build capacity and infrastructure in a LDC using the DLE tool.
5. To determine the impact of technology on HOCS improvement and the learning process.

In the next section we discuss the relevance of this research to society.

1.4 Societal Relevance of the Research

The research is important because of the following reasons:
1.4.1 Research Gap
The past decade has seen a clear growth in the use of technology in science courses like engineering and IT. There is insufficient research on the impact of technology on teaching, learning and assessment, in particular on HOCS improvement through technology and instructional delivery strategies. The impact of MM instructional materials on “perceived” learning has been studied (Bradley et al., 2005; Bradley et al., 2007), however their impact on actual HOCS improvement is not thoroughly documented. In summary, despite the successes in implementing MM materials at several universities, there is no clear evaluation of the effectiveness and impact of MM in enhancing students’ HOCS and the instructors’ creative teaching strategies. One of the research outcomes is significant contribution to the body of knowledge relative to how students learn in the science disciplines and to develop research methodologies for assessing the effectiveness of technology in enhancing learning outcomes. We fill the gap identified in literature by providing literature and an approach to foster HOCS improvement using technology. We also address the insufficiency of building capacity and infrastructure by presenting an approach for introduction of an ICT education program in a LDC.

1.4.2 Employer Satisfaction
As noted previously, studies show the difficulty for people to deal with decision-making situations that require HOCS. Therefore providing an education that encompasses HOCS to prepare students for today’s workforce is vital. Moreover, the need for qualified managers with high technical skills is a concern for both academia and industry (Bradley et al., 2007). Employers expect students to sharpen their HOCS and make quick technical decisions that translate into business profits in areas such as competitiveness, performance and sustainability (England & Suits, 1998). Graduates have to understand and speak the language of management, in addition to making decisions in their technical area of expertise. As a result, employers and top executives in companies want their managers and workers to be trained to become proficient problem solvers, decision makers, and team players (Rieley & Crossley, 2000). The research is significant considering the qualities employers look for in graduates (King, 2000). The need for new teaching and learning methods, tools or technologies that impact on HOCS improvement to prepare future university graduates is recognized. Besides its strong potential contribution to students, developers and instructors, results of this research have significant impact on prospective employers. Therefore there is need for research on the instructional content and methods to develop HOCS needed by the employer. The approach we propose also provides a solution for the shortage of capacity and infrastructure especially in LDCs. It aims at producing job creators and not seekers who solve the shortage of jobs problem for the employers.

1.4.3 Teaching and Curriculum Improvement
The effectiveness of technology like MM instructional materials, videos, Digital Learning Environments, as teaching / learning tools enhance the emergence of best practices that guide their successful implementation to foster HOCS improvement for critical thinking, problem solving and decision making skills (Bradley et al., 2007). The research aims at investigating the existing effectiveness and impact of ICT on creative teaching strategies and HOCS improvement. The research and education activities further extend the usability of technology like MM instructional materials. It contributes in developing a distinctive teaching competence and facilitates major direct curriculum improvement for Computer Science and IT courses. The proposed education activities result in up-to-date courseware and comprehensive assessment tools to measure the students’ learning outcome. It leads to the development and implementation of cheap content for the Least Developed Countries like Uganda. MM content is developed and implemented in the DLE as we shall discuss in chapter 5.
We discuss the research design and approach, followed to answer the research questions in order to develop the theory and evaluate the approach in the next section.

1.5 Research Design and Approach

We examine the state of art and practice by reviewing existing literature on the methods of HOCS improvement to find the gaps in the existing models and methods used to investigate and identify the characteristics of the proposed approach. The methods identified to facilitate students’ development, improvement and utilization of HOCS include online debates and peer tutoring, personalized systems of instruction and project based learning (Bradley et al., 2007). The other methods for HOCS improvement include Problem Based Learning, HOCS promoting teaching and assessment strategies, and MM case studies, which we discuss in chapter 2. We develop elements of the learning profile, MM instructional content design, HOCS promoting teaching and assessment strategies for actual HOCS improvement, from the theoretical background that form the basis of the research design.

1.5.1 Before - After (Pre test - Post test) Control Group Research Design

It is one of the types of true experimental designs in which the experimental group is exposed to the treatment or independent variable but the control group is not. The research design is a control-group design - Pre-test and Post-test control experiment. Pre-test (before) and post-test (after) measures are taken on both groups as shown below:

<table>
<thead>
<tr>
<th>Randomly Selected</th>
<th>Experimental</th>
<th>Pre-test</th>
<th>Treated</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomly Selected</td>
<td>Control group</td>
<td>Pre-test</td>
<td>Not Treated</td>
<td>Post-test</td>
</tr>
</tbody>
</table>

Two parallel experiments are set up, identical in all respects except that only one includes the MM treatment being explored. The students in both groups are similar, randomly selected using the simple random sampling assignment and assigned into the experimental and control group. The control group is taught by the conventional traditional text book content and the experimental group use MM content. The pre-test and post-test control experiment was chosen so that the control group would aid in identifying additional factors that may have an effect on the learning process since we aim at discovering the effects of MM instructional materials. Both groups were measured with an independent standard t-test. In design notation, the selection with pre-and post-tests is:

<table>
<thead>
<tr>
<th>R</th>
<th>O</th>
<th>X</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>O</td>
<td></td>
<td>O</td>
</tr>
</tbody>
</table>

Where “O” is the symbol for an observation or measurement, “X” is the symbol for a program or treatment group, R is a random assignment. Next, we discuss the data collection methods to achieve the research objectives.
1.5.2 Research Approach

We review literature on methods for HOCS improvement and assess the impact of technology on learning and HOCS improvement. The research hypotheses were tested by conducting field experiments where students engaged in small group collaborative learning activities while using the instructional materials. Previous studies indicate that there is need for an improved process that takes the students’ needs and profile into consideration. We measure the impact of technology like videos, Digital Learning Environment and MM instructional materials on HOCS improvement by using a multi-metric approach. We assess the students’ HOCS improvement using the results (chapter 6).

We carry out experiments on the impact of MM on HOCS improvement in Uganda, a LDC for the first time to fill the knowledge gap identified by developers, instructors, researchers and students. Therefore, there was need for multiple assessment tools and data collected from different universities to address the shortcomings from literature. Precisely, we use a series of key matrices to gather data from multiple sources and use data triangulation to improve the validity of the research findings. It is against this background that we collect data from five different universities. We carried out experiments in universities in Uganda, US and Netherlands as LDC and Developed countries, as presented in the results in chapter 6.

We use both the quantitative and qualitative methods to supplement each other. The qualitative methods provide data that cannot be conveyed by figures. The quantitative methods investigate students’ perceptions of the MM instructional materials as compared to the traditional learning methods. The quantitative methods determine whether HOCS improved, and the instructional method that enhanced their achievement.

In the literature, data collection is carried out using one method. Bradley et al., (2007) recommends replication of the study with a larger sample size to improve validity and a longitudinal multi method study that involves a variety of data collection approaches to confirm that HOCS improve with MM instructional materials in analyzing and solving a problem. It is against this background that we use a large sample size and develop a method that measures actual HOCS improvement to supplement the perceived learning matrix.

We also carry out a survey using an online instrument to determine the impact of video recorded lectures on the learning process. We further assess the usage statistics of a Digital learning environment tool at a modern institution.

During analysis, a sample t test is employed for each of the constructs to compare the means of the pre and post achievement tests in order to analyze knowledge assessment and determine the change (delta) for the experimental and control groups. The t test assesses for statistically significant differences between the different variables.

During implementation, testing and validation are done. We collect student questionnaires along with written comments. The results from the case study are compared for the control group and the experimental group to test whether HOCS are attained using the MM method. The validity and reliability tests are adequate since the instruments were used for similar studies accepted and published in international conferences and journals. Validity of the qualitative data is established within the instruments, the method and by the use of a case study. We validate the method by administering a case study on undergraduate students from varied backgrounds and academic abilities, to test HOCS improvement. Throughout and after the duration of the research, the standardized series of assessment matrices and MM instructional materials are
re-visited in order to effect any necessary revisions. This helps maintain the quality of the assessment tools and instructional materials, a process, which is especially important for the rapid changes and developments in the CS and IT field. We discuss the research contributions in the next section and finalize this chapter with the thesis outline.

1.6 Conclusions and Research Contributions

We discuss the importance of HOCS improvement for academia, practitioners and industry. We carry out a thorough review of literature on the current state of art and practice of HOCS improvement methods, models and approaches, the learning theories, environments, instructional content design. Then we derive the HOCS improvement requirements using the relationship between theoretical background and the factors that determine HOCS improvement. The research contributions include a theory that determines the set of HOCS improvement requirements to guide content design. The theory provides the theoretical basis for developing an approach for introduction of an ICT education program in a LDC for HOCS improvement, building capacity and infrastructure. The theory also aids in developing content to improve HOCS. We evaluate the approach using case study experiments and validate the approach with the data from the experiments and proof of concept.

The thesis proposes an approach for HOCS improvement using MM that enhances the current MM instructional materials, content strategy and assesses HOCS improvement and the impact of technology on HOCS improvement for problem solving, critical thinking and decision making. The approach proposes that by administering personalized MM instructional content to students and using an actual HOCS improvement instrument; actual HOCS improvement is administered and tested. We develop the Learning by Construction approach for the introduction of an ICT education program to improve HOCS, build capacity and infrastructure.

In conclusion, we propose an approach using the HOCS improvement requirements. We derive and evaluate a theory that highlights metrics for HOCS improvement and use the theory to derive design choices that can be used to design content and products for HOCS improvement.

1.7 Thesis Outline

The seven chapters of this thesis are an account of an iterative research process. The structure is as follows. Chapter 2 presents an overview of the theoretical background, including current methods of HOCS improvement which is the main theoretical perspective for this research. We discuss the existing learning theories, learning environments, instructional Content Design and learning styles theories and instruments, to enable us determine the HOCS improvement elements for developing the approach. In Chapter 3 we describe Bloom’s Taxonomy as a general framework for learning and relate the taxonomy to ICT. We later describe the general concepts for learning for two process oriented and content oriented digital tools to derive requirements for an overall support for the learning process. In chapter 4 we use these requirements to introduce the Digital Learning Environments (DLE) for learning in the context of community-related knowledge management. We derive DLE characteristics for HOCS improvement. In chapter 5 we present the general approach for introduction of ICT education for HOCS improvement, building capacity and infrastructure for a LDC. We describe the case studies, methods and results from experiments carried out throughout the research at the different universities in chapter 6. We also present the results and some DLE usage statistics to validate the approach we propose. We also evaluate and compare two popular DLEs. The results presented in this chapter have been published in conference proceedings and journals.
In chapter 7 we give some conclusions, revisit the research questions and elaborate on contributions. We further give some recommendations for future research.
2. Theoretical Background

This chapter begins with a closer look at the state of art and practice of HOCS improvement. We give an overview of the current methods of HOCS improvement. We discuss learning theories, learning environments and instructional content design which are very important for learning and HOCS improvement in particular. We then review learning styles theories and inventories to justify the choice for the learning style inventory used in the research. We conclude this chapter with HOCS improvement requirements from the literature. The contents of this section are published in (Bagarukayo et al., 2007 and Bagarukayo & Mbarika, 2008).

2.1 Current Methods of HOCS Improvement

HOCS can be improved by (1) Problem Based Learning (PBL), (2) HOCS Promoting Teaching and Assessment Strategies, and (3) Multimedia methods. We elaborate the methods in the following subsections.

2.1.1 Problem-Based Learning

HOCS can be improved by PBL, a learning approach where a problem acts as the circumstance and driving force for learning. For the past 20 years, PBL has been used broadly with a major impact on thinking and practice in medical education (Mbarika et al., 2003, Bradley et al., 2007). PBL involves teaching students to apply knowledge they have acquired within their disciplines to solve authentic and practical situations. PBL encourages acquiring knowledge for problem solving and aspires at functioning towards understanding and finding a solution to the problem. The problem the students solve determines the skills attained. There are hardly any direct solutions to problems from the materials in text books.

The advantages of PBL include increased student motivation, deeper understanding of the subject area, encourages collaborative learning and HOCS improvement (Bradley et al., 2007, Bradley et al., 2005). Collaborative environments, typically computer-mediated, are used to help students explore potential solutions as they attempt to solve problems posed in the cases. Such environments provide interactive feedback that enhances the analysis of multiple perspectives. It is essential and suitable for science courses since it enables students to develop skills and confidence for formulating problems they have never seen before (Boud & Feletti, 1991).

PBL is based on constructivism and cognitive flexibility theories (Bradley et al., 2007). Constructivists assume that students engage in learning processes like self-reflection, hypothesis formulation, potential solutions generation, information gathering and ideas discussions in addition to learning of content. PBL requires engagement of students in the processes as they analyze and solve cases, and draws upon cognitive flexibility theory which highlights students viewing cases in an interconnected way as important. The instructional design theorists (Merrill, 2002) assert that when cases are compared, students analyze the fine and critical differences between situations. Students are therefore able to understand the complexity of a given situation and make conclusions on how to solve the problem, thereby transferring their learning from one context to another. Enhancing this ability to discriminate cases enables students to understand the complexity of a given topic and construct appropriate mental frameworks, making it more likely that they will transfer their learning from one context to another. PBL does not aim at finding the solution to a problem but in learning to think through a problem, in considering alternatives through dialogues with others, and in justifying decisions (Hmelo, 2002; Hmelo & Pfeffer, 2004; Bradley et al., 2007). As previously noted, the approach aims at improving HOCS by identifying and analyzing the different options through the synthesis of data and then selecting the best option that meets the desired outcome. It does not simply
find a single solution to a problem / completing an exercise but helps students infer by assessing all the options available in order to solve a particular problem. HOCS improvement enables students to analyse the different options and select a solution to the problem. Therefore because HOCS involve purposeful outcome-directed thinking, the outcome gives meaning to the task (Mbarika et al., 2001; Zoller, 2000; Zoller et al., 2002; Bradley et al., 2007; Mbarika et al., 2010).

2.1.2 HOCS Promoting Teaching and Assessment Strategies
HOCS can also be improved by the HOCS promoting teaching and assessment strategies created by Zoller. The paradigm shift from LOCS teaching to ‘HOCS learning’ is aimed at improving the quality of teaching, learning and assessment (Lubezki et al., 2004). Environmental issues are integrated to help bring real life problems into the classroom to interest students in the subject area. Assessment and exams constitute a critical part of Teaching - Learning process and should not only be in consonance with teaching and instructional goals, but also meaningfully contribute towards the attainment of these goals (Zoller, 2001). This approach cultivates students’ HOCS by HOCS promoting teaching strategies like self inquiry based study, homework assignments, and HOCS-requiring questions in examinations and assessment methodologies (Zoller, 2001; Zoller et al., 2002). The approach uses appropriately designed HOCS-oriented exams in science teaching in order to cultivate the students’ HOCS capabilities targeting ‘HOCS learning’ (Tsaparlis & Zoller, 2003). This approach has changed students’ assessment to HOCS promoting assessment by developing and implementing HOCS promoting environmental exam questions in traditional exams, teaching methods and environmental education courses.

In a study carried out, the basis for assessment of the entire pre and post exams was the distinction between HOCS and LOCS levels of learner responses (Lubezki et al., 2004). To determine whether and to what extent participants gained in their HOCS-performance and to what extent participants gained in their HOCS-performance, the grading of these questions, environment related type HOCS-promoting exam questions were developed and incorporated within traditional undergraduate courses. The test and examination questions were set on the different HOCS and LOCS levels. The questions testing HOCS improvement were interwoven in the test and exam. The distinction between HOCS and LOCS levels of learner responses served as a basis for the grading of the entire assessment. The results were discussed qualitatively, to complement the analysis of students’ answers and showed that the lower the ‘entry behavior’ score, the larger the ‘HOCS gain’ was, as measured by the higher score on the HOCS-promoting questions in the post-test. Some of the most indicative students’ answers were reported and analyzed. There was a noted improvement in ‘HOCS learning’ with respect to environment related issues for the students. The improvement in the ‘HOCS gain’ as evidenced from the better performance on the HOCS-promoting questions was noted.

The findings were that students were weak on both ‘making connections’ and system thinking with respect to environmental issues. It was recommended that persistence of this approach within which relevant environmental issues are integrated, have the potential of inducing ‘HOCS learning’. Students performed better in general questions compared to the environment-related questions in the exams and HOCS promoting teaching and assessment strategies may have constituted potential contributions to HOCS improvement. Further analysis of each learner’s response to each question noted that it was difficult for students to transfer science concepts to everyday complex situations, and this should be purposely and persistently fostered and cultivated by instructors (Zoller, 2001). The students’ challenge was HOCS improvement since the capability to connect between theoretical scientific concepts with everyday practical
environmental problems was evidently lacking, due to the students inability to solve real life problems.

2.1.3 Multimedia Instructional Materials

HOCS can be improved by the use of multimedia (MM) which involves technologies that support the interactive use of multiple media like graphics, text, animation, audio, still images, video, among others (Bradley et al., 2007). MM is the delivery of information in a computer-based presentation that integrates two or more media (Beckman, 1996). MM instruction captures attention, engages students and represents a natural form of representation with respect to the workings of the human mind. MM can be an effective, interesting and attractive way of teaching to supplement the traditional learning approach, offer a new quality of communication, due to interaction within teams, for problem solving and cooperative learning (Vernadakis et al., 2006). This therefore enhances students' motivation and interest, in the subject area and increases their retention. The insufficiency of PowerPoint presentations for communication also justifies the development of other tools, like MM to communicate complex technical and engineering problems to non-technical managers. HOCS are identical with deeper learning (understanding), since they lead to problem solving transfer, and are promoted by the use of MM in learning as compared to the traditional learning approach (Mayer, 1999; 2003; Mayer & Anderson, 1992). The assessment of MM learning is carried out through situations in which the learner uses the material to solve a problem. The impact of MM on learner performance has received different views by researchers.

Positive findings on the perceived impact of MM on student learning are documented. Collier, (1987) and Barrett, (1988) state that users can explore information in-depth on demand and interact with instructional materials at their pace with MM. Sankar & Raju, (2000) argue that non-linear access to vast amounts of information is facilitated by MM. Therefore this makes learning more interesting, increases student motivation and interest. With the use of MM, users can explore information in-depth on demand and interact with instructional materials at their pace. This encourages active students through the interaction and information exploration. MM instructional materials are argued to enhance HOCS improvement, and cater for students' different learning preferences and styles since material is presented in different forms. MM case studies have been used for many years in science courses as a form of instruction and have reportedly been successful in HOCS improvement. The MM methodology has been validated to demonstrate students' perception of HOCS improvement (Mbarika et al., 2010; Bagarukayo & Mbarika, 2008). However, “the impact of MM instructional materials on students’ actual HOCS improvement was not well established” (p. 226). Assessment of experiments using MM showed a significant improvement in perceived HOCS with an intervening variable included in the research questions. The students were able to make appropriate decisions in a given problem solving situation after using MM materials. Specific items in each category were developed based on identified learning questionnaire and assessment instruments which tap into two constructs. Since perceived HOCS improved after administering the MM materials, (Bradley et al., 2007) recommends that the main categories for each of the tools should incorporate constructs and items corresponding to learning-driven factors and HOCS.

Although positive effects have been reported, a number of studies have cast doubts on existing assessment approaches since studies were mostly based on “perceived” learning. Other researchers disagree that the use of multimedia guarantees students successful learning (Vernadakis et al., 2006). Dillon & Gabbard, (1999) conducted a meta-analysis of 35 experimental studies of hypermedia / MM using empirical quantitative methods to assess learning outcomes. Their findings indicate that the benefits of MM in education were limited to “perceived” learning tasks that relied on repeated manipulation and searching of information.
Past studies did not assess learning in terms of improving HOCS, a very essential element when training IT or Computer Science students who need to comprehend both the technology and management decision making aspects of technology (Sankar & Raju, 2000; Mbarika et al., 2003a, 2003b). Regardless of the many published reports on the topic of MM use, only 9 studies of human performance with this technology met minimally acceptable scientific criteria. Not one study had a comprehensive measure for HOCS and they also failed to measure improvements of actual HOCS. Most of the studies relied on a single assessment tool, did not use mix-methodology design and data triangulation to support findings, and qualitative research instruments were the preferred approaches used to collect self-reported attitudes toward the learning environment (Dillon & Gabbard, 1999). Moreover, many studies were based on just a single group of students at the same university, which made external validity of the findings questionable. Not only is there evidence that computerized MM instruction is important to cognition in terms of time, one study indicated a 88% reduction in learning time (90 minutes versus 745 minutes) (Kulik, et al., 1983), but also in terms of effective delivery of complex information. Mayer, (1993) carried out a study that MM instruction provided individuals with low prior domain knowledge ability to build cognitive models of systems.

2.1.4 Conclusion
The existing literature on HOCS improvement was examined to find the gaps in the existing models and methods used. We investigated the state of art and practice of HOCS improvement in order to identify the characteristics of the proposed approach. As noted, the methods for HOCS improvement i.e. PBL, HOCS promoting teaching & assessment strategies, and MM case studies are ineffective. The MM case study method is based on the students’ perceptions, and does not measure actual HOCS improvement. Unlike MM case studies, the other methods were not validated to reveal whether they led to HOCS improvement. Moreover, the methods did not consider the students’ personal needs and learning profile and did not monitor how students realistically carry out problem solving and decision making. Therefore, there was need for an improved approach that takes into consideration the students’ needs since the learners profile contributes to HOCS improvement. Since the results were based on perceived HOCS improvement and could not be used to infer actual HOCS improvement, it was necessary to understand and test for actual HOCS improvement.

In the next section we look at the existing learning theories than enable the learning process.

2.2 Learning Theories
Learning is a process that brings together cognitive, emotional, environmental influences and experiences for acquiring, enhancing, or making changes in one's knowledge, skills, values, and world views (Illeris, 2004). It is the way information is absorbed, processed, and retained. “Learning Theories” are elaborate hypotheses that describe how exactly learning occurs and therefore determine how HOCS can be improved. As previously noted, learning is a process where students interaction with learning materials, peers and lecturers’ results in change in behavior and thinking. Learning theories in educational design create the relationship between the information, learner and environment (Jones & Jo, 2004). There is a greater chance that the learner retains information within their own knowledge base when this relationship occurs. The learning theories control how learning occurs in human beings because they determine how knowledge is acquired, constructed, processed and stored for future reference. They have greatly impacted on the educational learning methods described in section 1.2. These theories include constructivism, cognitive, behaviorism, Bloom’s Taxonomy of learning objectives, situated learning theory, Gagne’s Theory of instruction. Mayer, (1996) describes the constructivism, cognitive and behaviorism learning theories as follows:
We expound on the constructivism, behaviorism, cognitivism, situated learning theories and Bloom’s Taxonomy of learning objectives below:-

Constructivism is a process in which students construct new ideas or concepts based upon their current and past knowledge (Bruner, 1960). It views learning as a process in which the learner actively constructs or builds new ideas from what they see, hear, read and perceive. Learner’s own knowledge is constructed individually and actively basing on their experience (Fosnot, 1996; Steffe & Gale, 1995). Constructivism promotes a student’s free exploration within a given framework or structure. Therefore learners are able to construct new ideas and concepts based upon current and past knowledge or experience. Schunk & Zimmerman, (1998) argue that teachers cannot supply knowledge but students must construct knowledge with the teachers’ help. The teacher acts as a facilitator, guide or mentor in the students’ knowledge construction process and encourages them to discover principles for themselves and construct knowledge by working to solve realistic problems. To construct knowledge, students should construct their own meaning out of the knowledge acquired from class and interpret it based upon their experiences. Aspects of constructivism can be found in self-directed learning, transformational learning, experiential learning, situated cognition, reflective practice and religious practice. The learner chooses and converts information, creates theories, and makes decisions by themselves. Constructivist learning is a very personal endeavor, whereby internalized concepts, rules, and general principles may consequently be applied in a practical real-world context i.e. social constructivism. Social constructivists posit that knowledge is constructed when individuals engage socially in talk and activity about shared problems or tasks. Not all knowledge constructions are equally viable during learning; therefore students must test their personal understanding against peers and teacher understanding (Rieser & Dempsy, 2002).

Behaviorism theory concentrates on the study of evident behaviors that can be observed and measured (Good & Brophy, 1990). Behaviorism is based on the underlying assumptions that the process of learning is manifested by a change in behaviour, the environment shapes behaviour and the principles of contiguity and reinforcement are central to explaining the learning process. For behaviorism, learning is the acquisition of new behavior through conditioning. Classical conditioning is where the behavior becomes a reflex response to stimulus and operant conditioning is where there is reinforcement of the behavior by a reward or a punishment i.e. the way in which behavior ‘operates on the environment’. A behavior may result either in reinforcement, which increases the likelihood of the behavior recurring, or punishment, which decreases the likelihood of the behavior recurring. Within this framework, behaviorists are particularly interested in measurable changes in behavior. Since behaviorists view the learning process as a change in behavior, educators arrange the environment to elicit desired responses through such devices as behavioral objectives, competency -based education, and skill development and training.

The cognitivism theory emphasizes the role of human beings in storing and processing information they receive (Good & Brophy, 1990). The focus of this theory is how individuals perceive, process, interpret, store, apply and retrieve information. This theory determines what needs to be learnt at a particular level depending on what has already been learnt or known to the learner. Therefore it emphasizes the consideration of prior knowledge brought to any problem solving situation in form of analyzing, interpreting, evaluating and synthesizing. The
assumptions that underlie this cognitive approach are that the memory system is an active organized processor of information and prior knowledge plays an important role in learning. Cognitive theories look beyond behavior to explain brain-based learning. Cognitivists consider how human memory works to promote learning. For example, the physiological processes of sorting and encoding information and events into short term memory and long term memory are important to educators working under the cognitive theory.

Brown et al., (1989) developed Situated Learning theory and emphasizes the idea of Cognitive apprentices which supports learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity. Learning, both outside and inside school, advances through collaborative social interaction and the social construction of knowledge. Situated Learning Theory posits that learning is usually not deliberate and normally occurs when embedded within authentic activity, context, and culture (Lave & Wenger, 1991). Social interaction and collaboration are important aspects of situated learning theory.

Bloom’s Taxonomy (BT) is an effective classification of learning objectives applied in many different learning environments and situations, which categorizes learning behaviour to assist in the design and assessment of educational learning (Bloom, 1956). The concept of HOCS is derived from this theory, therefore we discuss it in more detail in the next chapter, since it is the framework we choose for learning and HOCS improvement.

In conclusion, the constructivism learning theories enable learner centered, active learning approaches and the instructor helps in the knowledge construction process which are HOCS improvement attributes. The cognitive theory has prior knowledge, application and interpretation concepts which are HOCS improvement attributes. Therefore there is a relationship between HOCS improvement and the constructivism and cognitive learning theories, since they both acknowledge the importance of PK and HOCS attributes in learning. The situated theory emphasizes collaborative social interaction and the social construction of knowledge. Bloom’s Taxonomy on the other hand is the theory from where the concept of HOCS is derived.

In the next section we review learning environments that foster the learning process based on the learning theories above.

2.3 Learning Environments

A learning environment (LE) is an open, complex, adaptive system comprising elements that are dynamic and co-dependent (Antoniou et al., 2009). It is the virtual or physical setting where learning occurs. A physical LE generally integrates courses, resources (libraries), formal (boards) and informal communication, an administration, etc. Similarly, a virtual learning environment integrates a variety of tools supporting multiple functions: information, communication, collaboration, learning and management (Antoniou et al., 2009). The two general types of learning environments are Distributed Passive Learning (DPL) and Distributed Interactive Learning (DIL) (Khalifa & Lam, 2002). The learning material in the DPL environment is delivered by the web and is accessed at students convenience, however passive linear learning is encouraged because the material is non interactive and offered in a linear fashion. The only difference between the material on the DPL environments and the traditional learning approach is that the former is online. DPL may be seen as a typical Learning 1.0 methodology, where 1.0 refers to the corresponding Web 1.0 technology (Ebner, 2007). In a DIL environment, instructional materials are delivered by the internet thereby encouraging free information exploration. The instructional materials include text files, presentation files, linear MM material
like audio and video real player files and other modern communication technology. DIL is a typical Learning 2.0 methodology environment (Ebner, 2007), which emphasizes learner interaction with the material, teachers and other students because it utilizes hypertext and collaborative technologies. Information organization is mainly linear in DPL environment and hypertext based i.e. knowledge representation and interface modality, in the DIL environment.

The effectiveness of a LE is dependent on the way information is presented, the learning process, the learning methods, learning outcome and instructional strategies supported, and not on the information or the technology itself (Khalifa & Lam, 2002). Different LEs affect the students learning process and outcome differently; therefore instructors need to examine the instructional strategies supported to choose the best strategy that enables learning. The LE is responsible for facilitating the students’ ability to interpret the multiple perspective of the domain context, be guided to conduct and manage their personalized learning activities, and encourage collaborative and cooperative learning for critical thinking and problem solving (Liu & Sun, 2002; Sun et al., 2003). The cooperative and collaborative learning for critical thinking and problem solving are attributes for HOCS, therefore the instructional strategies supported on the LE can determine whether HOCS improve or not. The effectiveness of the environments in terms of information organization, learning process and learning outcome was examined (Khalifa & Lam, 2002). The students’ perceptions showed that the DIL environment offered a more active, interactive and explorative learning process. The DIL environment was enjoyable, more effective in supporting the learning methods and students achieved a higher level of learning. Therefore the DIL environment achieved the learning process and learning outcome as compared to the DPL. This is a result of the interaction, collaboration and cooperation of the environment, which improves HOCS.

The learning methods identified include objectivism, constructivism, collaborativism, cognitive information processing and socio culturism. Collaborativism, cognitive information processing and socio culturism are derivations of constructivism (Leidner & Jarvenpaa, 1995). With the objectivism method the learning process i.e. the learning pace and knowledge, is controlled by the instructor and can therefore be supported by DPL environment. The objectivism environment therefore creates passive students who only develop common understanding from instructors; however it does not facilitate any interaction with the material / other students. The disadvantage of objectivism method is that it transmits knowledge to students with little concern for their understanding / digestion of the material into their cognitive schema (Leidner & Fuller, 1997). As previously noted, the constructivism method emphasizes the learner-centered approach where the students realize and construct unique concepts based on their experiences and prior knowledge and the instructor participates in the students’ knowledge construction process. The DIL environment supports the constructivist learning method since it encourages free exploration and enables interactivity with the instructor and fellow students. Exploration is the main requirement for constructivism and the interaction capability enables the extension of constructivism to collaborative learning.

In the next section we discuss designing of instructional content that enables the learning environments to provide the knowledge, skills, attitudes and competences, for learning and HOCS improvement to take place.

2.4 Instructional Content Design
Fardanesh, (2000) defines instruction as ‘accumulation of decisions and activities that are made and carried out in order to procure the desired outcomes for students’. Some of these decisions and activities include examination of students’ prior knowledge, determining the structure and
combination of learning materials, use of incentives and feedback, determining the required learning conditions, identifying ways of measuring learning outcomes, determining presentation strategies, determining the time necessary for learning, informing students about the learning goals, communicating with the students, providing learning materials, setting appropriate standards for performance, evaluation and managing the learning processes, among others.

Gagne's theory of instruction is based on the concepts of learning outcomes, conditions of learning, nine events of instruction and influences the instructions that are incorporated in education (Abbamondi, 2004). Gagne asserts that specific learning conditions critically influence the learning outcomes. The nine events of instruction, also known as the external conditions, should be given special care during instruction. The events include gain attention, inform students of the objectives, build on prior knowledge, present the stimulus, provide guidance, elicit performance, provide feedback, assess performance and enhance retention and transfer. The use of Gagne's nine instructional events encourages keeping lecture time short and spending more time on problem solving by making the training active and relevant. Gagne's taxonomy consists of five categories of learning outcomes, which lead to a different class of human performance (Gagne et al., 1992). The categories include verbal information, intellectual skills, cognitive strategies, attitudes and motor skills. Since the different categories lead to different performance, learning in all these categories may improve HOCS since they address Bloom’s Taxonomy’s knowledge, skills and attitudes, which we discuss in chapter 3.

Many instructional designers have concentrated on designing content that does not develop HOCS. Therefore there is need to create instructional content for enhancing and assessing HOCS improvement for students to develop skills for problem solving and decision making. The instructional designer needs to know the students’ requirements, characteristics and preferences during content creation to design materials aimed at achieving the students’ learning outcomes. Gagnes instruction events also emphasize retention, prior knowledge, problem solving, therefore they also promote HOCS transfer.

In line with designing instructional content, the importance of the knowledge of the students’ profile, which includes the prior knowledge and preferred mode of learning, has been highlighted. It is against this background that we carried out a thorough literature review of learning styles theories and instruments, as a basis for choosing the instrument to adapt for the research. The next section therefore highlights our findings on learning styles from literature.

2.5 Learning Styles

2.5.1 Introduction

‘Learning Styles are distinctive and habitual manner of acquiring knowledge, skills and attitudes through study or experience and can be determined using a Learning Style Inventory (LSI)’ (Shaw & Marlow, 2000). Cognitive styles are people’s preferred ways of thinking and processing of information, also referred to as thinking styles. Learning styles therefore refer to how students tend to think and approach information in the learning contexts. The individual learners have a preferred mode of learning i.e. different learners input, process, store and output information differently. Learning styles indicate the success of the learning process by providing useful information about the individual’s preferred mode of learning (Smith & Ragan, 1999). Learning style knowledge is used to guide instructors in their selection of learning and assessment strategies and enables development of appropriate learning approaches and instructional materials to meet the required educational needs. Thus, determining the learning styles is
important to aid the instructional content design to enhance an effective and efficient learning process. The instructor’s role is to assess, teach knowledge, attitudes and skills to meet the students’ educational needs for effective learning. The instructor improves the learners' personalized teaching by determining their learning style.

Learning styles are increasingly being integrated into computer assisted learning with the advancement of technology. Learning styles research is important in order to address the challenge of individual differences that instructional designers face. In order to improve learning it is therefore important to provide content that appeal to students learning style. The motivation, achievement and performance of students improve when instruction adapts to learning styles, therefore instructors should determine the students’ learning styles and match them with the instructional style suitable. Instructional designers need to understand the different learner preferences to avoid designing material that is skewed to only one learning style. One way of determining an individual’s learning style is by thinking of the method they prefer to begin with when tackling a problem or theory e.g. reading, talking, doing, thinking quietly etc. There is no superior learning style and therefore learning styles are not related to intelligence, mental ability, or actual learning performance (Hoover & Marshall, 1989).

Learning and thinking styles make a difference in academic success (Zhang, 2002; Moallern, 2002) therefore several authors have encouraged teaching students in their learning styles. Tittel, (2004) shows that individuals who study in their preferred mode learn more easily, have better academic grades, improve learning, retain information better and longer, and enjoy the learning experience more than those who learn in different modes. Individuals who are taught in their learning style retain information longer, apply it more effectively, and have more positive attitudes towards the course than those with mismatching teaching / learning styles (Moallern, 2002; Dunn, 1995; 1999; Felder, 1993). Mitchell, (2000) argues that the learning process occurs better when the student is provided with content that matches their learning style. The learning style is an indicator of whether the instructional material is effective for different learners and if the learning process occurred successfully.

In a study carried out (Banner, 1989) students attained higher achievement scores when there was a match of student and instructor learning / cognitive styles. However, (Macneil, 1980) argues that providing content that matches the learning style does not necessarily improve the students’ learning process. Researchers agree on the importance of modeling and using leaning styles, however (Brusilovsky, 2001) argues there is little agreement on whether the aspects of learning style are worth modeling, and what can be done differently for users with different styles. The relationship between learning styles and possible interface settings is still an unclear area. In the next sections, we discuss the theoretical basis for identifying a learning style inventory and then conclude with implications for research and practice.

2.5.2 Learning Styles Theory

Learning Style Theory suggests that individuals learn in different ways and it is of extreme importance for an individual to know their learning style. There are numerous learning style models / inventories in literature. LSI’s are predicted upon information- processing models which aim at describing an individual’s preferred intellectual approach to assimilating information (Baykan & Nacar, 2007). Some learning style models are multidimensional, encompassing cognitive, affective, and psychological characteristics, while other models are limited to a single variable, most frequently from the cognitive or psychological domain (De Bello, 1990). Learning styles are based on a complex set of reactions to varied stimuli, feelings, and previously established behavioural patterns (Dunn, 1993). The patterns tend to be repeated when a
A student concentrates on new or difficult material. Several learning style theories have been applied in educational environments widely. They include the Theory into Practice database (TIP, 2003) which provides 50 major theories of learning and instruction, such as Kolb’s learning style theory (Kolb, 1984), Gardner’s Multiple Intelligences theory (Gardner, 1993), Felder-Silverman learning style theory (Felder & Silverman, 1988; Felder, 1993), Litzinger & Osif theory of learning styles (Litzinger & Osif, 1993), Myers-Briggs Type Indicator (Briggs & Myers, 1977; Myers & McCaulley, 1985). Other LSI’s include Dunn and Dunn Learning Styles model, (1978); Grasha-Reichmann Learning Style Scales, (1974); Gregorc Learning Styles, (1985); Hermann Brain Dominance Models, (1996). Some of the LSI’s used for classifying and determining the students’ learning style are elaborated below.

2.5.3 The Field Dependent and Field Independent Learning Styles

One of the most prominent affective learning style theories is the Wikin’s Bipolar Construct of Field Dependence and Field Independence. The Field Dependence (FD) or global learning style is ‘the degree to which a learner’s perception or comprehension of information is affected by the surrounding contextual field’ (Jonassen & Grabowski, 1993). The FD individuals accept given information without recognizing it (Hoover & Marshall, 1998; Dunn & Dunn, 1993). The Field Independent (FI) or analytical learning style individuals are more exploring and like to discover and reorganize information based on their own learning preferences (Jonassen & Grabowski, 1993; Hoover & Marshall, 1998).

2.5.4 The Kolb’s Learning Style Inventory

Kolb describes learning as ‘a process by which each individual acquires knowledge by linking new experiences and information to theory and application through a preferred approach’. In 1976, Kolb developed the Learning-Style Inventory (KLSI), an instrument that individuals complete by answering questions contained in the self-scoring inventory and interpretation booklet to determine their learning style (Kolb, 1985). Kolb revised the KLSI in 1985 after some researchers (Ruble & Stout, 1993) claimed that the instrument was an invalid tool for research. The KLSI is made up of two dimensions and four learning modes or processes which should be present in the learning cycle for learning to occur. Kolb, (1984) theorizes that the learning cycle is made up of four combinations of perceiving and processing that determine the four learning styles. The learning cycle and associated learning styles are described to provide instructional design guidelines that accommodate the different learner preferences in processing and presenting information. The two levels which include a four-stage learning cycle and four learning styles, on which Kolb’s model works are elaborated below. -

2.5.4.1 Kolb’s Learning Cycle

Kolb’s learning cycle, just like the KLSI, also measures learning style preferences. A tertiary bridging course for adult learners provides examples of learning activities for each stage of the learning cycle. However, students may change or adapt from one learning cycle to another as much as they may have one preference. Any individual’s actual process of growth advances through successive oscillations from one stage to another (Kolb et al., 1979).
The Abstract-Concrete dimension (AC-CE) and Active-Reflective (AE-RO) dimensions underlie the learning process (Marriott, 2002). AC-CE dimension relates to how the learner perceives new information and experiences while the AERO dimension pertains to how the learner's perceptions are processed.

- **Active Experimentation** (Activist) - doing or being results-driven influences learning (Kolb, 1985). The individuals welcome practical applications rather than reflective understanding, such as actively influencing others and situations rather than observing.

- **Reflective Observation** (Reflector) - watching, observing and listening rather than active participation influences learning (Kolb, 1985). Learners like time to think about the concepts or the problem at hand.

- **Abstract Conceptualization** (Theorist) - thinking (think more than feel) or analyzing problems in a systematic method influences learning (Kolb, 1985). Learners relate concepts to prior knowledge and experiences.

- **Concrete Experience** (Pragmatist) - feeling (feel more than think) or reactions to experience influence learning (Kolb, 1985). Learners want to know how they can apply concepts in practice.

### 2.5.4.2 Kolb’s Learning Styles

The four cycles are tied into four specific learning styles that depend on where a learner lies in each of these dimensions in the cycle (Kolb et al., 1979). Kolb identified four statistically prevalent learning styles as diverger, assimilator, converger and accommodator. Assimilation and accommodation ideas originate from Jean Piaget’s definition of intelligence as the balance between the process of adapting concepts to fit the external world (accommodation) and the process of fitting observations into the world of existing concepts (assimilation) (Kolb, 1985). J.P. Guilford’s structure-of-intellect model identified the convergence and divergence as the two essential creative processes. The learning styles are elaborated below:

- **Accommodator** (doing and feeling - CE/AE) – dominant learning strengths are Concrete Experience and Active Experimentation. Accommodators are intuitive, risk takers and tend to do well in situations that call for adaptation to specific immediate circumstances (Kolb et al., 1979).

- **Diverger** (feeling and watching - CE/RO) – dominant learning abilities are Concrete Experience and Reflective Observation. Kolb called it ‘Diverging’ since the persons excel in situations that require generating many ideas, like brainstorming, and in their ability of viewing concrete situations from a variety of perspectives to problem solve (Kolb et al., 1979).
• **Converger** (doing and thinking - AC/AE) – favors the learning cycles of Abstract Conceptualization and Active Experimentation, characterized by learning by doing and thinking. Convergers prefer to work with things, not people and use hypothetical-deductive reasoning to solve and focus on specific problems (Kolb et al., 1979).

• **Assimilator** (watching and thinking - AC/RO) – dominant learning abilities are Abstract Conceptualization and Reflective Observation. The Assimilator uses inductive reasoning and creates theoretical models to solve problems (Kolb et al., 1979).

In conclusion, well balanced learners are individuals that have all the four learning styles; however the majority of the learners have one or two learning styles.

### 2.5.5 Honey and Mumford Learning Style Questionnaire (1986)

Honey and Mumford developed a Learning Style Questionnaire (LSQ) by modifying Kolb’s LSI. The LSQ classifies individuals in terms of strengths and weaknesses for each stage of the learning cycle (Honey & Mumford, 1986; 2008). The following are the different categories of learning styles.

- **Activists** are open minded, take direct action, enthusiastic about exciting and novel experiences, are bored with implementation, putting things into a broader perspective, past experiences and lose patience quickly.

- **Reflectors** reproduce different perspectives and take a thoughtful approach i.e. they think carefully about their actions before making inferences. They observe and listen to the views of others before offering their own.

- **Theorists** are logical and objectivist individuals who prefer a sequential approach to problems. They are analytical, pay great attention to detail, tend towards perfectionism and fit things into a rational scheme or overall pattern.

- **Pragmatists** like to see how things work in practice and are enthusiastic about trying things out. They like concepts that can be applied to their job.

### 2.5.6 The Myers-Briggs Type Indicator Learning Styles Instrument

The Myers-Briggs Type Indicator (MBTI) is a prominent instrument that affective learning style theories devised to represent Jung’s theory of psychological structure concerning the way people perceive information and make judgments (Brown, 1998). The MBTI instrument is used in assessing learning styles and assesses the relative strength of the processes of introversion versus extraversion, sensing versus intuition, thinking versus feeling and judging versus perception (McCauley et al., 1985). Form G of the indicator consists of 166 forced-choice items and categorizes the respondent on four dichotomous scales: extraversion / introversion (E / I), sensing / intuition (S / N), judgment / perception (J / P) and thinking / feeling (T / F) (Brown, 1998). The MBTI is expressed as a combination of the four scales, such as ISFJ or ENTP, and shows the respondents’ favoured style of perceiving and judging in all situations including the learning situation.

McCauley et al., (1985) defines the four MBTI preferences as follows:

- Orientation to life: extroversion (E) — introversion (I),
- Perception or becoming aware: sensing (S) — intuition (N),
- Decision making: thinking (T) — feeling (F), and
- Living in the world: judgment (J) — Perception (P)

The S or N perception functions relate to the learning setting and describe how information is internalized, either through the senses (S) or through intuition (N). The psychological theory behind the MBTI predicts that the sensing types (the “S’s”) rely on experience rather than theory and have a preference for moving from the known in a step-by-step manner. The Intuitive types
(the “I’s”) rely more on intuition and inspiration which enables ability to understand abstract, symbolic and theoretical relationships.

2.5.7 Felder Silverman / Soloman – Index of Learning Styles (1988)

The learning styles model developed by Richard Felder and Linda Silverman (Felder, 1993; Felder & Silverman, 1988) is based on a composite of several theories and incorporates five dimensions, two of which replicate aspects of the Myers-Briggs and Kolb’s models. The ILS is widely used because it is easily administered over the web (Felder & Soloman, 2003) and provides a convenient and practical approach to establish the learner’s preferred mode of learning. The ILS is most appropriate and feasible for implementation of hypermedia courseware and its results can be linked easily to adaptive environments (Carver & Howard, 1999). The ILS model strives for a balance of instructional methods so that students are not taught exclusively in their preferences. Soloman, (1992) ILS developed a typology of different ways in which students learn. The typology classifies learning types into four categories: input, processing, perception, and understanding. Input varies between using visual or verbal information and Processing involves the physical (active) or mental (reflective) manipulation of the information provided. Perception is driven by sensing (observation) or intuition (reasoning) and Understanding involves a sequential (linear step-based approach) or global (ultimate objective driven) approach.

The diversity of learning styles was exhaustively examined and (Soloman, 1992) found that majority of students are active processors, driven by sensing, prefer visual input, and find sequential learning to be more coherent. The ILS is a 44 item self-scoring instrument which assesses preferences on four dimensions of learning i.e. active / reflective, sensing / intuitive, visual / verbal and sequential / global. To be specific, the perception dimension (sensing / intuitive) is analogous to the perception of both Myers-Briggs and Kolb; the processing dimension (active / reflective) is found in Kolb’s model. In addition, Felder-Silverman posit three additional dimensions: Input (visual / verbal), Organization (inductive / deductive), and Understanding (sequential / global). The ILS model explores the different ways individuals take in information and process it:

- Sensory or Intuitive: what type of information does the student preferentially perceive?
- Visual or Verbal: through which modality is sensory information most effectively perceived?
- Actively or Reflectively: how does the student prefer to process information?
- Sequentially or globally: how does the student progress toward understanding?

Felder-Silverman developed the ILS which classifies learning styles according to the five learning dimension in Table 2.1.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Dimension</th>
<th>Dimension</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do it</td>
<td>Active</td>
<td>Reflective</td>
<td>Think about it</td>
</tr>
<tr>
<td>Learn facts</td>
<td>Sensing</td>
<td>Intuitive</td>
<td>Learning concepts</td>
</tr>
<tr>
<td>Require Pictures</td>
<td>Visual</td>
<td>Verbal</td>
<td>Require reading or lecture</td>
</tr>
<tr>
<td>Step by step</td>
<td>Sequential</td>
<td>Global</td>
<td>Big picture</td>
</tr>
<tr>
<td>Specific to general</td>
<td>Inductive</td>
<td>Deductive</td>
<td>General to specific</td>
</tr>
</tbody>
</table>

Table 2.1: Felder’s Learning Dimensions (Source: Carver et al., 1999)

The ILS questionnaire is developed from these dimension’s descriptions of learning styles (Felder & Soloman, 2003). The questions are classified to correspond to four pairs in the Felder and Silverman LS theory. The pair of categories represents a range of the learning styles and is
not discrete i.e. individuals do not necessarily belong to one learning style or the other. A learner being more visual than verbal doesn’t mean that their preference is completely visual and not at all verbal. The guiding principle is that learners have different preferred modes of learning (Tittel, 2004) and are categorized generally as follows:-

• Learners who are action, fact, or experience-oriented, developed by collecting lots of close-ups to develop a big picture are sensing, inductive, active, and sequential learners.
• Learners who understand principles, theories, and concepts, and start from the big picture to give structure to individual close-ups and details are intuitive, deductive, reflective, and global learners.
• Visual learners learn best with pictures, diagrams, flow charts; and verbal learners learn best with words or speech.

The ILS describes five learning styles elaborated below:-

• Active learners learn by trying things out and working with others and Reflective learners learn by thinking things through and working alone.
• Sensing learners are concrete, practical, oriented toward facts and procedures and Intuitive learners are conceptual, innovative, oriented toward theories and meanings.
• Visual learners prefer visual representations of learning material, while Verbal learners prefer written and spoken explanations.
• Sequential learners gain understanding in linear, orderly, small incremental steps leading to a broader understanding and following logical stepwise paths in finding solutions while Global learners prefer to work from conceptual frameworks and fill the gaps.
• Inductive learners prefer presentations that proceed from the specific to the general and Deductive learners prefer presentations that go from the general to the specific.

2.5.8 VARK Learning Styles Questionnaire (1987)

The Visual Auditory Read-Write Kinesthetic (VARK) questionnaire developed by Neil Flemming in 1987, is a 13-item, self-reported, multiple choice questionnaire that is completed in 10 –15 minutes. The newer version consists of 16 questions and can be accessed online (Flemming, 1992; 2008). It is most appropriately used as a catalyst for reflection and discussion. It raises awareness level of the preferred learning modality to give individuals common language for discussing learning, and empowering them to adjust their learning behaviors to take advantage of their strengths and preferences. The self-reported VARK results are used to provide knowledge of the distribution of information intake preferences to adjust the information delivery method to match their preferences. Therefore individuals should use the information to adjust study habits to correspond to their individual learning strengths. Baykan & Nacar, (2007) emphasize that VARK preferences enhance learners’ development of additional and effective study skills to intake information and hence improve their examination grades. The questionnaire identifies the sensory modality, one facet of the student learning styles, by which they prefer to take in information (Slater, 2007). The advantages of the questionnaire include question options being drawn from real-life situations and respondents affirming the face validity of the tool by identifying with the results they receive. For example, in a study carried out, 60% of respondents on the VARK website reported that their results match what they perceive to be their learning preferences. Fleming & Mills, (1992) defined four sensory modalities of learning: Visual, Auditory, Read-write and Kinesthetic as explained below.
2.5.8.1 Visual

These are individuals whose preferred mode of learning is by sight and prefer the use of diagrams and symbolic devices e.g. using visualization software. To take in the information, visual learners should use gestures and picturesque language, text books with diagrams, pictures, videos, posters, slides, hierarchies, models, flow charts, graphical representations, symbols, highlighters, reconstruct the images in different ways, try different spatial arrangements, redraw the pages from memory and arrows that represent printed information. To perform well in the examination individuals need to draw things, use diagrams, write exam answers, recall the pictures made by their pages and practice turning their visuals back into words.

2.5.8.2 Aural or Auditory

A learner with strong preference for learning by Aural methods (A = hearing) is one who learns best by listening. Auditory learners prefer "heard" information when acquiring new information. They should use the following techniques to take in the information: attend classes, lectures and tutorial discussions with teachers or fellow students, explain new ideas to other people, use a tape recorder, remember the interesting examples, stories, jokes, describe the overheads, pictures and other visuals to somebody who was not there, leave spaces in their notes for later recall and 'filling'. The individual’s notes may be poor because they prefer to listen. They may need to expand the notes by talking with others and collecting notes from the textbook, putting summarized notes onto tapes and listening to them, asking others to ‘hear’ their understanding of a topic, reading their summarized notes aloud, explaining their notes to another ‘aural’ person. To perform well in the examination, they should imagine they are talking with the examiner, listen to their voices and write them down, spend time in quiet places recalling the ideas, practice writing answers to old exam questions, speak answers aloud or inside their head.

2.5.8.3 Read-write

A learner with strong read-write preference for learning is one who learns best using written or printed word and text as a means of information intake. They should use the following techniques for information intake: lists, headings, dictionaries, lecture notes, glossaries, definitions, handouts, textbooks, references, readings – library, notes, teachers who use words well and have lots of information in sentences and notes, essays, manuals. To perform well in the examination the individuals should write exam answers, practice with multiple choice questions, write paragraphs, beginnings and endings, write their lists, arrange words into hierarchies and points. These individuals should write out the words repeatedly, read the notes (silently) repeatedly, rewrite the ideas and principles into other words and organize any diagrams and graphs into statements, turn reactions, actions, diagrams, and charts into words, imagine the lists arranged in multiple choice questions and distinguish each from the other.

2.5.8.4 Kinesthetic

A learner with strong kinesthetic preference for learning is one who learns best by doing i.e. ‘hands on’. Kinesthetic learning is a multimodal measurement employing a combination of sensory functions. Kinesthetic learners acquire new knowledge by feeling or living the experience. They should use some or all of the following techniques for information intake:
• All the senses - sight, touch, taste, smell, hearing laboratories, field trips, examples of principles, lecturers who give real-life examples, applications, hands-on approaches (computing), trial and error, collections of rock types, plants, shells, grass, exhibits, samples, photographs, recipes, solutions to problems, previous exam papers, simulations of real practices and experience, case studies, “real-life situations,” role-plays and applications to help them understand principles and advanced concepts.

• To perform well in the examination these individuals should write practice answers, paragraphs and role play the exam situation in their own room. The lecture notes may be poor because the topics were not ‘concrete’ or ‘relevant’. Individuals will remember the “real” things that happened; therefore they should put plenty of examples into their summary.

• They should use case studies and applications to help with principles and abstract concepts, talk about their notes with another “K” person, use pictures and photographs that illustrate an idea, go back to the laboratory manual, recall the experiments and field trips.

2.5.8.5 Multimodal Study Strategies

Multimodal learners have a learning preference for a combination of more than one learning style i.e. two or more of the modalities. They do not have a strong preference for any of the learning styles. If an individual has multiple preferences they are even for all four modes. For example, if one person has scores of V=6, A=6, R=6, and K=6 in the majority, as approximately 60% of any population fits that category. Multiple preferences are interestingly varied. For example one may have two strong preferences V and A or R and K, or may have three strong preferences such as VAR or ARK. Some people have no particular strong preference and their scores adapt to the mode being used or requested. If the teacher or supervisor prefers a written mode they switch into that mode for their responses and learning. An individual is given a choice of two, three or four modes to use for interaction with others if they have multiple preferences. Positive reactions mean that those with multimodal preferences choose to match or align their mode to the significant others around them. Some individuals stay in a different mode from the one of the person they are working with to annoy them. If an individual has two almost equal preferences they should read the study strategies that apply to the two choices. Multimodal preference individuals say that it is necessary for them to use more than one strategy for learning and communicating, because they feel insecure with only one.

2.5.9 Dunn and Dunn Learning Style Assessment Instrument

The Dunn and Dunn LS instrument was developed in 1976. Dunn, (1990) describes learning style as “… the way each learner begins to concentrate, process, and retain new and difficult information”. To identify and assess a person’s learning style it is important to examine each individual’s multidimensional characteristics in order to determine what will most likely trigger each students concentration, maintain it, respond to his or her natural processing style and cause long-term memory (Dunn, 1990, p. 224). Dunn, (1982) compares the uniqueness of an individual’s learning style to the fingerprint. A person’s learning style is dynamic as a result of maturation, and preferences tend to be overcome only by high levels of personal motivation (Dunn, 1986). Determining the students preferred mode of learning is vital to the teaching and learning process. Dunn, Dunn and Price developed the Productivity Environmental Preference Survey (PEPS) learning style assessment instrument from the Dunn and Dunn LS Model. This instrument is comprehensive in nature, relatively easy to use for assessing students and interpreting the results.
The LS assessments are designed to respond to selected characteristics of global learners by including the use of stories, fantasy, holistic writing, imagery, humor and pictures (Dunn, 1986). The assessments measure the patterns through which learning occurs and summarize the environmental, emotional, sociological, physiological, and global / analytic processing preferences a student has for learning. The major components of the model include the model principles, the learning style elements, the identification of the learning styles and the model’s impact on the dimensions of the instructional situation. The model is grouped across five “stimuli” categories, which are made up of the 21 elements, environmental, emotional, sociological, physiological, and psychological (cognitive processing) preferences. The five categories or LS elements of Stimuli Preferences include:

- Environmental - Sound, Temperature, Light, Design Preference
- Emotional - Motivation, Persistence, Responsibility conformity and internal or external structure Preference
- Sociological - Self, Pair, Peers / Team, Adult and Varied Preference i.e. learning alone, with a partner, as part of a small group or team, with peers, with an authoritative or collegial adult, and / or in a combination of ways.
- Physiological - Perceptual, Intake, Time, Mobility Preference i.e. auditory, visual, tactile and / or kinesthetic perceptual preferences; food or liquid intake, chronobiological energy levels, mobility needs.
- Psychological - Global / Analytic, Hemisphericity (left or right brain dominance), Impulsive / Reflective Preferences i.e. Indication of global or analytic cognitive / psychological processing inclinations and impulsive versus reflective inclinations.

2.5.10 Gregorc Style Delineator Learning Styles Instrument

The Gregorc Style Delineator (GSD) is a research-based self-assessment instrument used to identify and quantify learning styles of adults, whose results are easy to understand (Gregorc, 1985). This instrument consists of ten sets of four words that an individual rank orders and identifies their learning style using a word matrix. The instrument contains key ideas about learning styles, the purpose of the style delineator, and characteristics of the four mediation channels. The four basic learning styles include Concrete Sequential (CS), Abstract Sequential (AS), Abstract Random (AR), Concrete Random (CR) are elaborated below:

2.5.10.1 Concrete Sequential (CS)

According to Gregorc, (1984, 1988), learners with high CS scores are methodical, deliberate and instinctive in their thinking by nature. They are pragmatic, have a tendency for perfection and finely tuned into their physical senses, prefer step-by-step conventionality when learning. They learn best in situations where information is presented in an orderly and efficient manner, look for directions and follow them, like clearly organized but lean presentations (i.e. lectures) and a quiet atmosphere in which to work, relate best to the physical, hands-on activities and think in ways that are methodical, ordered and predictable (Gregorc, 1982a).

2.5.10.2 Abstract Sequential (AS)

According to Gregorc, (1984, 1988), learners with high AS scores are sequential learners, who refer to the world of abstractions, thoughts and symbols that correspond to the concrete, reality-based world. They possess the ability to analyze and separate relevant from irrelevant information in order to grasp key ideas. They are highly verbal and prefer stimulating orderly and quiet learning situations. They mentally outline, correlate, compare and categorize data in a manner unsurpassed by other styles using their analytical abilities. They prefer guided assignments and detailed plans, as well as non restricted environments (Gregorc, 1982a).
2.5.10.3 Abstract Random (AR)
According to Gregorc, (1984, 1988), learners with high AR scores, experience the world of reality through their emotions, imagination and feelings. They are highly subjective learners and base many of their perceptions on their intuition and the five senses. They grab the essence of ideas and build themes as they work through information in a random fashion. They learn best by receiving information in an unstructured manner; prefer group discussions and vibrant sensitive-rich environments. They prefer order that is nonlinear, harmonious and non-traditional, have the natural ability to work well with people and work best when allowed to be creative and to display their emotions (Gregorc, 1982a; Gregorc & Butler, 1984).

2.5.10.4 Concrete Random (CR)
According to Gregorc, (1984, 1988), learners with high CR scores use the physical world as a laboratory to investigate ideas. They are very capable of examining, disassembling and changing the information presented to them. They make intuitive leaps in structured situations without being able to explain the steps used in reaching their conclusions. They learn best in a situation that is stimulus-rich where they can explore ideas, express opinions and work well independently or with small groups. They are intuitive, insightful and easily make transitions from fact to theory, may be risk takers, investigative, experimental, prefer a busy environment, being around many types of people and enjoy the role of a mentor (Gregorc, 1982a; Butler, 1987).

Individuals may be strong in one or two learning styles. Bimodal individuals operate effectively in more than one channel; have varied learning preferences therefore they increase their ability to relate to different students and classroom environments. In the next section we discuss the relevance of learning styles in the learning process.

2.6 Learning Styles Relevance
Federico, (2000) argues that understanding the effects of learning styles and learners’ perceptions of engagement is vital to improve planning, producing, and implementing of educational experiences, because learning styles are used to enhance students’ learning, retention, and retrieval. The adaptation of learning styles may also help increase the diversity in male-dominated fields by increasing understanding and competency and lessening some of the limitations of text-based learning materials that one group may encounter over another. Teachers should take the initiative to meet students’ learning needs. They can administer an instrument like the Critical Incident Questionnaire (Brookfield, 1990) midway through the semester for students to report if their learning needs are being met. This enables the instructor to provide variety of instructional methods to address students’ needs.

Dunn, (1982) shows that taking a learning style assessment benefits students in the following ways:
- Identification of preferred mode of learning.
- Provides the individual learning styles profile.
- Provides a foundation on which the students’ study environment can be altered for a better learning process.
- Shows the best methods each student can use when studying for optimal learning of new and difficult material, and methods through which students can excel.
- Provides instructional methods that are compliant with the students’ preferred learning styles.
- Provides proposition for the students’ best learning environment.
In the next section, we give some recommendations for successful learning for HOCS improvement using learning styles.

2.7 Recommendations

Learning styles research is vital for providing information about how learners interact and acquire knowledge from instruction. This information is vital for instructional developers to improve design of instructional materials and for teachers to provide more flexible teaching strategies. In this section, we highlight the importance of LS knowledge and provide recommendations for researchers, teachers and instructional designers to provide instruction in the most effective way. We also recommend teaching strategies for enhancing the learning process and outcome, in particular HOCS improvement, with learning styles knowledge. From the thorough literature review done about LS theories and inventories we make the following recommendations.

2.7.1 Learning Styles Knowledge

The knowledge of individuals’ learning style is an important consideration when developing a learning environment (Fahri et al., 2001). The use of learning styles in education improves retention, academic achievement, makes the learning experience fun and the learning environment less stressful. Students understand how they learn (learning to learn) by identifying their learning style and therefore incorporating learning styles into course design is an added benefit (Mumford, 1992). Instructors identify and solve learning problems using learning styles knowledge to produce more effective learners (Baykan & Nacar, 2007). It is important for educators to make sure tasks or activities are presented in the students’ modality preference. Appreciating that students have different learning styles enhances the development of appropriate learning approaches and explores opportunities for making the educational experience more productive. Hein & Budny, (1999) encourage using formal learning style assessments because they provide useful information for student and instructor benefits. However, (Brusilovsky, 2001) emphasizes that getting a student’s learning style is a psychological test process that should be specially designed. As noted previously, there are several ways of determining the student’s learning styles like interviews, questionnaires and monitoring their behavior. Individuals can take assessments to determine their learning styles using several questionnaires or psychometric tests. Some of these instruments are available online for free e.g. Kolb, VARK ILS etc. Individuals should be assessed using more than one questionnaire for validity. Research suggests that teaching students in their learning styles improves learning outcomes; therefore learning styles knowledge is important.

2.7.2 Matching Teaching Style and Students’ Learning style

Felder & Silverman, (1988) define teaching style in terms of the answers to five questions:

- What type of information is emphasized by the instructor: concrete (factual) or abstract (conceptual, theoretical)?
- What mode of presentation is stressed: visual (pictures, diagrams, films, demonstrations etc) or verbal (lectures, readings, discussions etc)?
- How is the presentation organized: inductively (phenomena leading to principles) or deductively (principles leading to phenomena)?
- What mode of student participation is facilitated by the presentation: active (students talk, move, and reflect) or passive (students watch and listen)?
What type of perspective is provided on the information presented: sequential (step-by-step progression, “the trees”) or global (context and relevance, “the forest”)? Therefore the teaching style is based on the terms above and we encourage teachers to balance the mode of presentation, student participation, the presentation organisation, the type of perspective and the information presented. There is a critical need for an appropriate match between student type and teaching style for students below average intelligence (Eggins, 1979).

Price et al. (1990) argue that ‘productivity style theorizes that each individual has a biological and developmental set of learning characteristics that are unique’. Improvements in productivity and learning are attained if instruction emphasizes the individual’s learning strengths. “Learning in matched conditions, in which instructional strategy is matched with students’ learning styles, may in certain contexts be significantly more effective than learning in mismatched conditions” (Chen & Ford, 2001 p.7). Butler, (1987) shows that students attain better grades, higher achievement attitude and have a less stressful environment when the teaching style is matched to the learning style; therefore instructors should tailor their teaching methods to match the students’ learning styles. In a study carried out, it was observed that students used instructional materials and strategies that were more matched with their learning styles (Moallem, 2002).

Their findings show a higher standard deviation indicating an overall academic achievement of students whose learning styles were matched as compared to those whose learning styles were mismatched. Therefore when instruction is compatible with students’ learning style preferences the overall learning process is enhanced. Smith, (1982) shows that the relationship between instructors’ teaching style and their learning preference is that teachers use strategies they prefer when learning, during instruction. It is therefore important for instructors to know their learning styles and the students’ learning styles; in order to know how they perceive the world, their teaching environment and create teaching strategies that accommodate the different learning styles. Teachers can match individuals’ learning styles with the method most responsive to that style, if they learn how their students learn best (Dunn, 1999). Dunn agrees that matching a student’s learning style and the teaching style leads to improved student attitudes and higher academic achievement.

2.7.3 Case Studies

Case studies provide theory in the form of concepts, tools and ideas, that enable learners to understand, interpret and solve problems better because they see how concepts interrelate. Currie, (1995) recommends that learning elements of the four learning styles, such as case study and role playing, that match learning styles should be incorporated in courses developed. This may enhance HOCS improvement because the learners preferred modes of learning are accommodated for. MM case studies encourage team work which enhances cooperative and interactive learning hence benefitting students with different learning styles from the instructional material presented. Bradley et al., (2007) showed that the use of MM case studies enhances perceived HOCS improvement. Therefore, instructors should move from theoretical models to practical applications and solving real life problems in a predictable rhythm. To overcome the historical disadvantage for the sensors and global learners, instructors can use an inductive teaching approach where topics are introduced by presenting specific observations, case studies or problems in the classroom. Theories can be taught or students helped to discover theories only after the need to know them has been established (Felder & Silverman, 1988). We recommend teaching theory by use of case studies to bring real life problems in the classroom and bring theory into practice, since the method is validated for perceived HOCS improvement.
2.7.4 Multimedia

As previously noted, MM involves technologies that support the interactive use of multiple media like graphics, text, animation, audio, still images, video etc. MM instruction provides individuals with low prior domain knowledge ability to build cognitive models of systems (Mayer, 1993). These findings suggest important ramifications for use and development of MM-based instructional materials as an aid in HOCS improvement. Felder & Silverman, (1988) argue that there exists little pedagogical support that addresses the diversity, calling for newer and more effective tools and techniques to enhance the learning process across the diverse styles. In that aspect, MM seems to emerge as a potential candidate of choice to help students with different learning styles. The rich interaction and adaptability that is imperative for learning technical subjects might be satisfied through the use of MM. MM provides dynamic didactic content delivery and therefore teachers of technical subjects can concentrate on exploring new and relevant content pointing to the learner’s needs. Therefore we recommend the use of MM instructional materials or visualization software as a supplement to lectures. This provides different media for presenting information thereby addressing different learning styles. MM-based learning and decision-making tools were found to help in perceived HOCS improvement, which is synonymous with an effective learning process (Mbarika et al., 2010; Bradley et al., 2007). For the learning process to be effective, the learners need to be challenged and provided with opportunities for learning in their preferred mode. One of the best ways to teach individual students’ strengths is to use a variety of instructional styles and modes of delivery (Price et al., 1990). This method of teaching is highly supported by MM.

By adapting to the learning style, MM instructional materials may motivate and encourage students to enter science fields, by increasing understanding, competency and lessening some of the limitations of text-based learning materials that one group may encounter over another. This may attract, motivate and retain individuals who find technical fields boring, difficult to learn or where they may feel pressures from stereotypical feelings of inferiority. E.g. females and other under-represented groups in science fields will be encouraged to pursue these fields if different instructional materials more amenable to their learning styles are used for mastery of the subject matter. In a study carried out (Moallem, 2002) found out that students take advantage of the different instructional methods and use them to enhance their own learning. As noted previously, learning elements of all the four learning styles should be incorporated in courses developed (Currie, 1995). The elements can be added using case studies, role playing, MM like sight, sounds, visual, images, aural etc. This is reinforced by the findings from (Bradley et al., 2007) where IT managers or students, business or engineering students, males or females responded favorably to MM materials even though it was implemented in different classrooms by multiple instructors. The effectiveness of MM materials in conveying technical issues to students with various backgrounds and learning styles by bringing real life situations into the classroom is highlighted.

2.7.5 Active Learning Strategies

Active learning strategies are highly plausible because they promote thinking through reasoning, improving problem solving, critical thinking and decision-making skills, which are attributes of HOCS. Active learning strategies to enhance teamwork, cooperative learning, collaborative learning and hands-on learning are effective for students especially the “non-traditional” (Kramer et al., 1995). Therefore strategies like class discussions, cooperative learning exercises, role play, simulations, models, debates, case studies and game classes are recommended. These activities encourage team work and generate high levels of motivation, interest and enthusiasm. Passive learning aims at learning with the auditory and read-write learning styles, hence making
the learning process for the learners with the other preferences unexciting. There has been extensive research base supporting active, cooperative, and inductive teaching methods (Palou, 2006). Felder & Silverman, (1988) recommend that the instructional approach emphasizes active and cooperative learning techniques as a solution to overcome the active learners’ and global learners’ historical disadvantage. Students with different learning styles, preferences and skills may have a better opportunity in discovering what best fits their own strengths, needs and weaknesses when offered variety of classroom and learning environments. Students learn better using active learning strategies because they target different learning styles, increase learning interest and motivation (Baykan & Nacar, 2007). Therefore we propose supplementing passive learning strategies with active learning strategies like problem based learning, HOCS promoting teaching and assessment strategies, MM instructional materials and case studies to address problem solving and decision making situations in real life, thereby improving HOCS.

### 2.7.6 Instructional Designers

Instructional designers should develop courses for the learner with their learning styles in mind and avoid making courses that reflect the course designers’ learning styles (Fatt, 1993). The individual dispositions usually affect and influence learners' readiness to gain from the instruction offered, hence the academic progress. For instruction to be effective, the course design should be related to the learner characteristics, styles and preferences (Akdemir, 2007). Instructional designers are encouraged to use the learning styles literature and individual differences for a greater understanding of learners' approaches, to study greater awareness of individual differences in learning and improve content design to cater for diversity (Mcloughlin, 1999). The literature can enhance improvement of instructional design when designing content for several individuals. Instructional designers should carry out a needs analysis or learner profile to determine the prior knowledge, motives, background interests, attitudes and learners’ experiences when designing instructional materials for various learners. This facilitates the design of learning resources tailored closely to learners’ needs. Instructional designers need to acknowledge the differences in preferred modes of learning and adapt instruction to the learners’ needs.

Mumford, (1992) recommends application of the learning style theory to course development for effective course design. The theory integrates the principles of learning cycle, learning styles and encouragement of learning to learn. Therefore, more attention should be focused on integrating theory with content. Reiff, (1992) states that a short period of mismatching may result in new and varied experiences, and too much matching can lead to boredom and disengagement. An instructor who varies teaching approaches is more likely to meet student needs whether the use of multiple delivery styles is to match learning style preferences, or to offer a combination of preferred / mismatched styles to hold attention and stretch the student (Slater et al., 2007). Therefore instructional designers must develop flexible courses to meet each student’s preferred learning style. Instructional materials should have hands-on exercises, labs and problem-solving experience, try to balance the verbal and visuals to cater for all learners, the use of examples, case studies, illustrations, demonstrations, walk-throughs, include definitions, summaries, formulae, theories and other condensed forms of explanation and motivation (to cater for global learners’ understanding of the subject details and for sequential learners to develop the right picture so that they can develop the right steps) (Tittel, 2004). We therefore recommend that instructional designers design content like MM instructional materials as teaching strategy that provides students with a variety of delivery styles to match the different students’ learning styles.
2.7.7 Develop Systems that Incorporate Learning Styles

The educational hypermedia systems that have implemented learning styles can be adopted by instructional designers to enhance the learning process and outcome. The existing systems include a system developed by (Carver et al., 1999) which relates learning styles based on Felder-Silverman LS theory to course components e.g. slides, hypertext, media clips. The system presents a list of course components with links ordered according to learning style, which the student explores by clicking the links. The Arthur system (Gilbert & Han, 1999; Gilbert & Han, 1999a; Gilbert & Han, 2002) is based on Flemming’s VARK questionnaire which has course material for the four different learning styles. The system delivers course content to the student randomly after they log on, monitors the student’s learning process and updates the student’s learning styles based on the evaluation. The system thereafter provides suitable course content based on the student’s preferred mode of learning. The third system is the Adaptive Courseware Environment (ACE) which provides certain mechanisms to adapt to student’s learning styles (Specht & Oppermann, 1998). The students are asked for their learning strategies, such as learning by example, reading texts, or learning by doing when they start to use the new courseware. The presentation component selects appropriate learning units and generates individual hypermedia documents based on the learning model, domain model and pedagogical model. More research should be conducted on how LS theory can be applied to course development because it is insufficient. New systems can be developed to improve on existing ones basing on their strengths and weaknesses.

2.7.8 Culture Recommendation

Culture influences perceptual, organizational, processing and communication styles (De Vita, 2001). Wan, (2001) argues that current research centered on discovering how LS diversity affects educational needs has shifted attention from cultural diversity. These processes are core elements in LS theory, therefore the learning process and outcome is affected by the individual’s culture. Therefore it is important for researchers to discover the relationship between culture and learning style (Church, 2001). We therefore recommend carrying out a study to assess the relationship between LS’s and student cultures.

2.7.9 Conclusion

LS theory can be used to predict instructional strategies for effective learning. The contradictory findings therefore call for further investigation to find the relationship between learning styles and instructional strategies. Research needs to be done on the nature of the LS construct to determine whether it was more effective to match or mismatch the LS with instructional style. The findings from literature suggest the need to address the research gap.

In the next section we discuss the requirements for HOCS improvement.

2.8 HOCS Improvement Requirements

From the literature, we determined the relationship between the theoretical background and HOCS improvement in order to achieve the research objectives. The research design is based on three elements as identified from the theoretical background. They include Learning profile, MM Instructional Content Design, and HOCS Promoting Teaching and Assessment Strategies for actual HOCS improvement. We elaborate on each of these elements in the next subsections.
2.8.1 Learning Profile

The existing strategy used for PBL and MM did not incorporate initially the learner’s learning profile. This strategy also did not monitor how students realistically carry out problem-solving and decision making. We propose monitoring and using the students profile during the learning process to test for actual HOCS improvement.

We reviewed the existing learning style literature as a basis for determining the best LSI inventory to use during the experiment to determine the relationship between the LS and HOCS improvement. The VARK questionnaire was chosen because it has been widely used in literature, the questions options are drawn from real-life situations and the respondents affirm face validity of the tool by identifying with the results they receive as we noted earlier. We therefore determine the learning profile by use of the questionnaire to assess the students’ preferred learning style. We propose administering the VARK LSQ to measure the learner’s preferred modes of learning, their learning experience and strategies. The items from the questionnaire are used to measure the learning-style factor. We propose incorporating and testing LS theory into existing MM case study content to assess the relationship between LS and HOCS improvement.

2.8.2 HOCS Promoting Teaching and Assessment Strategies for Actual HOCS improvement

VarHagen and Zumbo, (1990) found positive learner perceptions but had no impact on HOCS improvement and did not attempt to measure “actual” learning since the results were based on “perceived” learning. The major limitations from literature were that the results, based on “perceived” learning, could not be used to infer whether actual HOCS improved. However it is necessary to understand if actual HOCS improved. Measures such as learner grades, an observation instrument, pre and post-tests as a measure of actual HOCS improvement were recommended (Bradley et al., 2007). To capture the impact of task difference on learning, we propose assessment of actual HOCS improvement. We developed a set of inter-related qualitative and quantitative matrices to assess students’ perceived and actual HOCS improvement during and after using the MM instructional material. The perceived HOCS improvement was measured by a set of items that were validated in earlier research. However the actual HOCS improvement was measured using an instrument we developed and validated, using Zoller’s concept of HOCS promoting teaching and assessment strategies. The instrument comprised of HOCS promoting exam-like questions about the material that was studied from the case studies. The students’ responses were analysed to determine if actual HOCS improved. The results are presented in chapter 6.

2.8.3 Multimedia Instructional Content Design

Landauer, (1995) notes that regardless of the many published reports on the topic of MM use, only 9 studies of human performance with this technology met minimally acceptable scientific criteria. As noted in Chapter 1, despite the successes of MM implementation, there were no clear assessment studies conducted on the effectiveness and impact of the materials on improving actual HOCS and the instructors’ creative teaching strategies. Much more research was needed, we therefore study MM case studies approach at the universities, develop and validate instruments to assess the effectiveness of instructional MM case studies in enhancing learning outcomes and work with the universities to complete the planned qualitative and quantitative research agenda to significantly contribute to the body of knowledge relative to how students learn. The current method of HOCS improvement through MM did not consider initially the learner’s profile, therefore the MM instructional content did not suit them, and hence the need to use the learner profile during the learning process.
Through the creation of instructional content for enhancing and assessing HOCS improvement, the students can attain skills required by the employment industry. This confirms that the instructional materials used for learning should aim at achieving the students’ learning outcomes and HOCS improvement, in particular. The students’ needs are analyzed to recognize their learning styles and prior knowledge to assist the instructors in developing appropriate content. It is essential for the instructional designer to know the students’ requirements and preferences during content creation. We determine the learning profile by use of pre-test questionnaires to determine the prior knowledge and the VARK LSQ to determine the preferred mode of learning. We propose developing MM content based on a real-life problem case to test well-established MM technologies. The enhancement of HOCS improvement is achieved through the instructional design of content that motivates students to solve, evaluate, synthesize, interpret and analyze problems (Bagarukayo et al., 2007). If the content that matches the LS is designed, we believe the student’s HOCS will improve. We recommend that the instructors and instructional designers provide content in various forms to cater for students with different LS’s. We discuss the results of the study in chapter 6.

In the next chapter we discuss Bloom’s Taxonomy as a general framework for learning for HOCS improvement and further relate learning to ICT using its digital extension.
3. Relating Learning to Information and Communication Technology

In the previous chapter we discussed methods of HOCS improvement, learning styles, environments and theories. In this chapter we focus on Bloom’s Taxonomy as a general framework for learning since the aspect of HOCS is derived from it. We discuss the effect of Information and Communication Technology (ICT) on the learning process in general. In particular we focus on the effect of ICT on Higher Order Cognitive Skills (HOCS) improvement. We discuss the extension of Bloom’s Taxonomy catering for new advances in ICT and look at the general idea and compare the basic concepts offered by state-of-the-art digital learning tools. We highlight (1) the concepts that promote learning and HOCS improvement and (2) how they are used in a learning environment, paying extra attention to the potential of multimedia (MM). From this comparison we derive the requirements for a Digital Learning Environment as it will be introduced in the next chapter.

3.1 Bloom’s Taxonomy as a General Framework for Learning

Bloom’s Taxonomy (BT) is an effective learning theory applied in many different learning environments and situations, which categorizes learning behaviour to assist in the design and assessment of educational learning (Bloom, 1956). The rationale behind using BT is the fact that it is an extensively accepted educational taxonomy, and used in education today for preparing learning objectives and analyzing learning outcomes at the different cognitive levels (Parham, 2009). Bloom, (1956) developed a taxonomy of Educational Objectives, which is a key tool in structuring and understanding the learning process. The taxonomy is a classification for different objectives and skills that have been identified as necessary for learners in various curricula (Bloom, 1956; Clark, 1999; Forehand, 2005). Bloom’s Taxonomy is easily understood and is probably the most widely applied today. Bloom identifies three overlapping domains (categories) referred to Cognitive, Psychomotor and Affective.

These domains address Knowledge, Skills, and Attitudes, referred to as KSA respectively.
- Cognitive domain: ‘what we know’ - is processing information, knowledge and mental skills (Knowledge);
- Psychomotor domain: ‘how we do’ - is manipulative, manual or physical skills (Skills);
- Affective domain: ‘how we feel’ - is attitudes and feelings (growth in feelings or emotional areas (Attitudes).

For each of these domains, the taxonomy identifies a hierarchical progression in which to categorize lower to higher order levels of mastering / cognitive processing. The concept of HOCS is derived from the higher levels of the cognitive domain in Bloom’s Taxonomy (Ball & Garton, 2005).

In terms of the taxonomy, the main objective of the learning process is to create a holistic learner by addressing all the three domains; more specifically to acquire new KSA. The KSA are positioned in the competency development program as described in the architectural model of competence by (Roe, 1999) which we discuss in the next chapter.

The taxonomy divides the objectives of these three domains into subdivisions ranging from the simplest to the most complex. Verbs are used to describe the typical behavior that is expected at each level of competency. For example, it looks at the cognitive domain which categorizes
and orders thinking skills and objectives. It classifies learning behaviors and provides concrete measures for identifying different measures of learning and follows the thinking process.

The learning taxonomy outlines the levels of creative and cognitive thinking that should be nurtured while creating a lesson plan and defining objectives (Bloom, 1956). This taxonomy of learning behaviors is also thought of as “the goals” of the training process. The role of the teacher is to help students move from the lowest to the highest level of thinking and inquiry. Teachers should aim at preparing students to think critically and not only to pass exams; however the main challenges are time and resources. Another challenge is the teacher’s ability to develop questions to address all levels of the taxonomy in the same lesson.

The taxonomy can be used in education to offer the instructional designer a set of meaningful words which can be used for writing objectives. The verbs in each level of the hierarchy offer concrete, measurable actions that can be combined with the audience, behavior, condition, and degree of the objective. The terms assist the learner to understand specific levels of proficiency with skills and / or knowledge (Hobgood et al., 2011).

The hierarchy helps the learner reach higher and higher levels of cognitive thinking by clarifying existing states of understanding and offering a clear set of steps to improve performance. The verbs in the taxonomy can be used in education to offer the instructional designer a set of meaningful requirements to be implemented for each level. The taxonomy describes for each level typical verbs that operationalize what the learner is supposed to learn for mastering that level. Figure 3.1 shows the hierarchical structure of Bloom’s Taxonomy with the levels associated with each domain.

![Bloom's Taxonomy of Learning Domains and their Levels](image)

Bloom, (1956) compiled the cognitive and affective domains. The psychomotor domain was later developed by Simpson, Harrow and Dave (Anderson, 2006). We discuss the three domains and their levels in the next subsections.
3.1.1 The Affective Domain

The affective domain consists of behaviors corresponding to attitudes of awareness, interest, attention, concern and responsibility, and the ability to learn and respond in interactions with others. Furthermore, it consists of the ability to demonstrate those attitudinal characteristics or values which are appropriate to the test situation and field of study (Krathwohl et al., 1973). The affective domain relates to emotions, attitudes, appreciations and values such as enjoying, conserving, respecting and supporting. The skills developed describe the way people react emotionally and their ability to feel another living thing's pain or joy. Affective objectives typically target the awareness and growth in attitudes, emotions, and feelings. The affective domain addresses the emotional side of an individual and has 5 levels that progress from the lowest to the highest order processing of skills (Bloom, 1956; Rothwell & Kazana, 1994):

1. Receiving is the lowest level where students passively pay attention and listen to others with respect. Without this level learning cannot occur. This level is important since students need to listen to the teacher for learning to take place. E.g. students listening attentively to the teacher in class to develop awareness of a topic.

2. Responding involves showing active interest in something. Students are active participants in the learning process, attending to stimulus, hence leading to some type of reaction from the student. E.g. students can actively participate in the learning process by asking and answering questions, doing tests, assignments, class discussions, presentations, or group work.

3. Valuing involves accepting values / beliefs committing one to taking up an attitudinal position. The student shows the ability to solve problems by assigning some value to an object or piece of information. E.g. informing management about issues they feel strongly about.

4. Organization involves developing or acquiring a new value system, making adjustments or decisions from among several alternatives. This therefore is similar to problem solving and decision making where alternatives are prioritized by contrasting different values, and resolving conflicts between them. The emphasis is on comparing, relating, and synthesizing values. This is the ability to put different information to use. Students put together different values, information, ideas and accommodate them with their own schema by comparing, relating and elaborating on what has been learned. E.g. to discuss, to theorize, to formulate, to balance, to examine.

5. Characterization is the highest level where students have a particular value or belief that now influences their behavior so that it becomes one of their own characteristics. This involves adopting a new way of life or outlook, integrating one’s beliefs, ideas and attitudes into a total, all embracing philosophy. E.g. to revise, to require, to be rated high in the value, to avoid, to resist, to manage, to resolve.

3.1.2 The Psychomotor Domain

The psychomotor domain describes the ability to manipulate an instrument or a tool. This domain is characterized by progressive levels of behaviors from observation to mastery of a physical skill. Bloom never created subcategories for the skills of this domain but since then other educators (Simpson, 1972; Harrow, 1972; Dave, 1975) have created their own psychomotor taxonomies. Simpson’s (1972) domain has the perception, set, guided response, complex overt response, adaptation and origination levels. Harrow’s (1972) domain on the other hand has the reflex movements, basic fundamental movement, perceptual, physical activities, skilled movements, non-discursive communication. We elaborate Dave’s (1970) domain because it was the earliest, and therefore the others are its improvements and it takes into
account the aspect of assessment in the naturalization level, which is important for learning. However we highlight the verbs of the three different domains in the last part of this section.

Anderson, (2006) states that Dave developed his version of the taxonomy as follows:

- **Imitation** is observing and patterning behavior after someone else or copying someone else. The performance may be of low quality e.g. copying a work of art.
- **Manipulation** is being able to perform certain actions by following instructions and practicing. It is guided via instruction to perform a skill e.g. creating work on one's own after taking lessons, or reading about it.
- **Precision** is when accuracy, proportion and exactness exist in the skill performance without the presence of the original source. It is refining, becoming more exact and few errors are apparent e.g. working and reworking something so it will be “just right.”
- **Articulation** is two or more skills combined, sequenced and performed consistently. It is coordinating a series of actions, achieving harmony and internal consistency. E.g. producing a video that involves music, drama, colour, sound, etc.
- **Naturalization** is when two or more skills are combined, sequenced and performed consistently and with ease. The performance is automatic with little physical or mental exertion. Having high level performance becomes natural without needing to think much about it.

Table 3.1 below highlights the psychical behavior descriptions for each stage, examples of activities, demonstrations, and evidence of learning.

Based on Dave's taxonomy, (Harrow, 1972) developed the domain organized according to the degree of coordination including involuntary responses and learned capabilities (Armstrong, 1970; Anderson, 2006). The following is a combination of the three different psychomotor domains:

- **Observing** is active mental attending of a physical event. E.g. the learner watching a more experienced person. Another mental activity, such as reading may be a part of the observation process.
- **Imitating** is attempted copying of a physical behavior. E.g. the first steps in learning a skill. The learner is observed, given direction and feedback on performance. Movement is not automatic or smooth.
- **Practicing** is trying a specific physical activity over and over. E.g. repeating a skill over and over. The entire sequence is performed repeatedly. Movement is moving towards becoming automatic and smooth.
- **Adapting** is fine tuning to perfect the skill. E.g. making minor adjustments in the physical activity in order to perfect it. A mentor or a coach is often needed to provide an outside perspective on how to improve or adjust as needed for the situation.

Behavioral verbs appropriate for psychomotor domain are: bend, calibrates, constructs, differentiate (by touch), dismantles, displays, fastens, fixes, grasp, grinds, handle, heats, manipulates, measures, mends, mixes, operate, organizes, perform (skillfully), reach, relax, shorten, sketches, stretch, write, chooses, describes, detects, distinguishes, identifies, isolates, relates, selects, begins, explains, moves, proceeds, reacts, shows, states, volunteers, copies, traces, follows, reproduce, responds, assembles, builds, adapts, alters, changes, rearranges, reorganizes, revises, varies, arranges, combines, composes, creates, designs, initiates, makes and originates.
<table>
<thead>
<tr>
<th>Steps</th>
<th>Instructor</th>
<th>Student</th>
<th>Instruction Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imitation</td>
<td>Impart content knowledge listens to instructor</td>
<td>attempts to imitate instructor</td>
<td>Explanation</td>
</tr>
<tr>
<td></td>
<td>Demonstrate the entire skill without interruptions e.g. demonstrate basic</td>
<td>observes the instructor</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>jumping rope skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provide student opportunity to &quot;imitate&quot;</td>
<td></td>
<td>Guided practice</td>
</tr>
<tr>
<td>Manipulation</td>
<td>Break skill into step-by-step actions, explain each step e.g. start in</td>
<td>tries specific steps over and over</td>
<td>Guided practice</td>
</tr>
<tr>
<td></td>
<td>position - Swing rope - Jump over rope</td>
<td></td>
<td>Feedback</td>
</tr>
<tr>
<td></td>
<td>Provide student opportunity to &quot;imitate&quot; each step</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provide student opportunity to &quot;imitate&quot; entire skill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precision</td>
<td>Provide student time to practice alone</td>
<td>practices until able to perform with no mistakes</td>
<td>Practice alone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>practices skill over and over</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>spends up performance</td>
<td></td>
</tr>
<tr>
<td>Articulation</td>
<td>Provide student time to practice</td>
<td>creates jump rope routine to music</td>
<td>Practice alone</td>
</tr>
<tr>
<td></td>
<td>alone</td>
<td>fine tunes performance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naturalization</td>
<td>Assess student’s entire performance</td>
<td>creates own routine to music e.g. Student can perform jumping rope</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>upon demand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>goes from being a novice to an expert</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1: Psychomotor Domain (source: wikiversity)

3.1.3 The Cognitive Domain
Bloom, (1956) and Anderson, (2006) describe skills relative to knowledge, comprehension and thinking about a particular subject. The cognitive domain involves knowledge and development of intellectual skills. This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. The six levels of the cognitive domain are associated with degrees of difficulty from the simplest to the most complex behavior i.e. the first one must be mastered before the next one can take place. This leads to a categorization and ordering of thinking skills and related objectives. They include knowledge, comprehension, application, analysis, synthesis and evaluation. A concept cannot
be understood if it is not remembered and knowledge concepts cannot be applied if they are not understood. It is a range from Lower Order Thinking Skills (LOTS) to Higher Order Thinking Skills (HOTS). LOTS and HOTS are synonymous with LOCS and HOCS respectively; they are used interchangeably in this thesis. The knowledge, comprehension and application levels form LOCS and analysis, synthesis and evaluation levels form HOCS. Educators are therefore faced with the challenge of emphasizing application, analysis, synthesis and evaluation of knowledge to promote students HOCS which are important for industry and society as noted in section 1.4.

Anderson & Krathwohl, (2001) created and published Bloom’s Revised Taxonomy (BRT) by changing the category names from noun to verb forms, and slightly rearranging them by interchanging the order between the Evaluation and Synthesis categories. The new levels of the BRT are remembering, understanding, applying, analyzing, evaluating and creating. The revised taxonomy reflects the enlarged understanding of the teaching and learning process, a more active form of thinking and perhaps more accurate. The six levels of the cognitive domain of BRT are elaborated in figure 3.2 below:

![Figure 3.2: Levels of the Cognitive Domain](image)

The levels are explained below in increasing order from lower order to higher order skills (Anderson, 2006; Huitt, 2009).

- Remembering describes ability to exhibit prior learned facts by recalling information such as facts, terms or answers. It is a basic recall of ideas and often requires a student to relay the basic who, what, when, where, and why of any given situation. It involves memorizing information precisely and being able to remember but not fully understand. The dimension is - can the student recall or remember the information? The objectives include arrange, define, duplicate, label, list, memorize, name, order, recognize, reproduce, repeat, recall and state.

- Understanding demonstrates the ability to understand facts and ideas by comparing, organizing, translating, interpreting, describing and stating focus points. Students need to understand information about a subject on a deeper level and read between the lines. It involves restating in one’s own words, paraphrasing, summarizing and translating. This is the ability to know what a message means. The dimension is - can the student explain the ideas or concepts? The objectives include classify, describe, discuss, explain,
express, identify, indicate, locate, recognize, report, restate, review, select, paraphrase and translate.

- Applying is the ability to use new knowledge to create a tangible result in new situations and involves using what has been previously learned. It involves using information to solve problems, translating theoretical ideas to practical situations, identifying connections and relationships and how they apply. Demonstration of this ability is by using theorems, facts, and technologies in a different manner from the method presented. The dimension is - can the student use the information in a new way? The objectives include apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use and write.

- Analysing is examination and isolation of information in parts by identifying motives and causes. It involves identifying components, determining arrangement, logic and semantics. The student is able to make inferences and provide generalizations by disassembling a whole into parts. The dimension is - can the student distinguish between the different parts? The objectives include analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question and test.

- Evaluating is presenting and defending judgments by presenting supporting data and involves assessing the value of ideas, things etc. It involves making decisions and supporting views, and requires understanding of values. The dimension is - can the student justify a stand or decision? The objectives include appraise, argue, assess, attach, choose, compare, defend, estimate, judge, predict, rate, core, select, support, value and evaluate.

- Creating is the ability to compile information in a different way by combining facts or elements into a new pattern or providing alternative solutions. It is combining information to form a unique product, and requires creativity and originality. The student being able to assemble a whole from parts. The dimension is - can the student create a new product or point of view? The objectives include arrange, assemble, collect, compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up and write.

In the Bloom’s Revised Taxonomy (BRT), knowledge is at the basis of these six cognitive processes; however a separate taxonomy of the knowledge types used in cognition was created (Armstrong, 1970). It identifies four general types of knowledge: factual, conceptual, procedural and metacognitive which make up the knowledge dimension.

- Factual Knowledge is knowledge of terminology and knowledge of specific details and elements.
- Conceptual Knowledge includes knowledge of classifications and categories, knowledge of principles and generalizations and knowledge of theories, models, and structures.
- Procedural Knowledge includes knowledge of subject-specific skills and algorithms, knowledge of subject-specific techniques and methods and knowledge of criteria for determining when to use appropriate procedures.
- Metacognitive Knowledge includes strategic knowledge, knowledge about cognitive tasks, including appropriate contextual and conditional knowledge and self-knowledge

Mastering the affective domain and the cognitive domain are related. The following table shows how the levels of the cognitive domain are related to the levels of the affective domain:
3.1.3.1 Typical Activities Related to Cognitive Domain
BT is a model of the stages and progression of critical thinking (Marzano & Kendall, 2007). The higher the level of learning one gets to, the higher the order of thinking or cognitive skills demanded. Student’s expected achievement at each level and how teachers can practically scaffold their understanding in order to reach the peak of critical thinking or HOCS, focusing on practical application, is elaborated below:

- **S0 - preparing**: identify the steps associated with the critical thinking process, that is, knowledge, comprehension, application, analysis, synthesis, and evaluation. As noted in section 3.1, each step requires a higher level of thinking and should be used to meet maximum potential for retention.
- **S1 – Remembering**: begin with a knowledge base. In order to access a student’s knowledge a teacher can ask students to make lists of events, create time-lines, chart facts, list action sequences, describe details, or recite information. Knowledge retention is the foundation for HOTS or HOCS.
- **S2 - Understanding**: test comprehension. Teachers may ask students to explain, interpret, discuss, predict, or compare ideas. In order to test comprehension of a subject, teachers should ask students to create illustrations to represent facts in their own words, discuss the main idea or theme, or compare concepts.
- **S3 - Applying**: apply knowledge and comprehension. To apply a concept, a student should be able to solve, show, use, construct, examine, or classify knowledge and understanding. Some application of ideas can be illustrated through model building, diagrams, scrapbooks, puzzle and / or game design. The activities should encourage a student to present their ideas in a non-traditional application e.g. the student should create a tangible object based on the knowledge and explain its significance.
- **S4 - Analyzing**: analyze topic or text is breaking things down, that is, critical thinking, which is the beginning of HOTS / HOCS. Many students will struggle to make rational sense of their understanding. Therefore, it is essential that analysis be teacher-guided and modeled initially. In order to analyze, a student should distinguish, examine, compare, contrast, investigate, connect, and explain the rationale. A teacher can assign activities that naturally ask for analysis of a subject e.g. students can create questionnaires, conduct interviews, investigate or research information to support a view or opinion, write a biography, or prepare a report on a chosen topic.
- **S5 - Evaluating**: understanding is at the top level of reasoning and refers to judgment. It is an important step in critical thinking and the most important factor in material retention which allows students to reflect on their processes i.e. meta-cognition. Evaluating one’s
understanding requires a person to look outside themselves and involve others in defense of their ideas. Students should be able to judge, select, choose, justify, debate, verify, argue, recommend, or rate their subject matter and their own understanding of it. For a student to reach evaluation, a teacher should encourage them to ask questions about the position, solution, belief, and what should be changed and differed. Based on these questions, teachers could ask students to stage a debate, write an evaluation, hold a panel discussion, or write a letter inciting change to see where they go from there.

- **S6 - Creating: synthesize ideas** is similar to application, on a much more sophisticated level. It requires a complete understanding of a topic to create a viable and thought-provoking project. To synthesize, one must first invent, compose, plan, construct, imagine, propose, devise, or formulate. Synthesizing requires putting things together i.e. creative thinking. For teachers, this is an in-depth project assignment that may require significant time for students to adequately prepare e.g. design a project or product to visually capture the subject matter related to the topic.

In summary therefore, when planning lessons, teachers should use the levels of BT to create activities for students to perform. Teachers should start at the beginning of the taxonomy and work their way up. Having students work through levels of the taxonomy helps them to familiarize themselves with material presented in the instructional units, going from basic activities to more advanced ones. For example, the base of BT is the knowledge level, where students learn basic information and are able to memorize and remember it. At this level the teacher should plan activities in which students try to memorize facts and recall them, possibly using flash cards or other memory devices. The application level, at the center of the taxonomy is where students employ problem-solving and the use of facts. Students might explore the significance behind the information they have learned so far. At the top of the taxonomy is the creating level, where students resolve conflicts and develop opinions. Students might write a position paper using the information they have learned in the unit at this level.

### 3.1.4 Direct Questioning and Assessments

BT can be used across several lessons in a unit, a single lesson or class period. Teachers should use the taxonomy to guide their questions to review student information by starting with knowledge-level questions and moving to evaluation-level questions, or mixing them up as they teach. Asking students questions on a variety of levels helps the teacher understand how well the students know the material. This enables the teacher to differentiate the students' instruction after determining the level they are at in the taxonomy. BT can be used as a rubric to judge student assessments using the list of taxonomy levels with verbs explaining what students can do or understand on each level and a list of ways to evaluate understanding of a topic. When the teacher assigns an essay or project at the end of a unit, they should determine whether students have made it to the evaluation level, if they can create a new product. However, if they fail to make the product then they fall at the lower levels of the domain.

### 3.1.5 Applying Bloom’s Taxonomy

Students having knowledge and skills about a particular subject, without the ability to know how, when, and where to apply it is not enough. As noted, there has been a concern by the academia and industry that students are not prepared to be critical thinkers (Bradley et al., 2007). Therefore educators need to raise the level of learning effectiveness based on BT. The objectives and activities for each level of BT with regard to the lesson should be outlined in the lesson plan, to give students clear expectations, and the teacher a method of work evaluation. This enables the teacher to differentiate for student needs, e.g. if a student is a low-performer in artwork, they might want to skip the level with artwork as the activity. As noted, BT can be used
to analyze the learning outcomes classification of the various knowledge levels that may be achieved by a learner (Bloom, 1956). Learning outcomes are very important and should be aligned with the learning levels of BT. The teacher should ensure that students learn a topic at all the levels in BT. For example, a student should not only recite or comprehend a concept but also implement and apply it. Yuan & Zhong, (2010) used BT to specify assessable learning objectives in measurable terms, to bridge the course description with specific topics covered in the classroom. The aim was to help instructors design exam questions targeted at the course objectives. They also used the learning outcomes in the curricular as a basis for setting up labs to cover the learning outcomes. They had to determine whether the learning outcomes could be implemented in the labs and if the lab was relevant for the lecture to meet the course objectives. They used BT to map the objectives to the application level that could be implemented into the labs. Based on the learning outcomes at the application level of BT, labs were designed to cover topics that would develop students’ practical and application skills to solve real life problems in the industry. The students were then given assignments to create products by the end of the semester to test the skills acquired.

The Bloom’s mastery learning model suggests mechanisms by which the effects of technology can be beneficially multiplied as it is applied to a wide array of developmental courses (Bloom, 1956). The model breaks learning into incremental units of instruction infused with frequent testing, gives students an active role in responding and self pacing. The five criteria for successful use of this model include having an aptitude for particular kinds of learning, instruction quality, ability to understand instruction, perseverance, and time allowed for learning (Winn, 2004). Pintrich et al., (1991) recognize five scales as indicators of cognitive regulation that provide measures of monitoring and controlling cognitive activities by students. The scales include rehearsal, elaboration, organization, metacognition and critical thinking. The rehearsal, elaboration and organization scales reflect the use of basic cognitive and learning strategies to understand the material in the course. The critical thinking scale assesses the extent to which students apply prior knowledge to new situations to problem solve, analyze and evaluate information in a thoughtful manner. The metacognition scale represents activities to aid students plan, monitor and regulate or change their learning. Metacognition is ones knowledge concerning their cognitive processes (Flavell, 1976). It is the procedure of thinking about thinking. In summary these five scales aim at improving HOCS. We discuss the Bloom’s Digital domain in the next section.

3.2 Relating Bloom’s Taxonomy to ICT

The digital native learners are accustomed to modern digital technology, including Internet, cell phones, iPods, etc. There is an increase in demand and desire for technology skills for future careers. Instructional designers can create lesson plans by integrating modern technology with BT using the available tools (Hobgood et al., 2011). ICT provides better options for presenting learning material and enables effective communication between those involved in the learning process, thereby promoting collaborative learning. As noted in chapter 1, the need to create active customized LEs for learner motivation and continuous learning desire for different ICT tools is acknowledged. Moreover, MM instructional materials have been recognized for enabling understanding of complex science and ICT decision making situations that require HOCS. In this section, we discuss how ICT can be applied in the learning process to attain learning at the different levels of BT domains. The contents of this section are published in (Bagarukayo et al., 2011a)
3.2.1 Affective Domain in a Digital Context

Since the affective domain (section 3.1.1) consists of (1) behaviors corresponding to attitudes of awareness, interest, attention, concern and responsibility, (2) the ability to learn and respond in interactions with others and (3) the ability to demonstrate those attitudinal characteristics or values appropriate for the actual situation, interaction and reflection, supporting tools will be most relevant to support the learning process of the affective domain. How the various skill levels of the affective domain can benefit from modern ICTs is summarized in table 3.3:

<table>
<thead>
<tr>
<th>Affective Domain</th>
<th>Level</th>
<th>Definition</th>
<th>Digital Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiving</td>
<td>The lowest level where students passively pay attention.</td>
<td>presentation tools, Notice boards, Discussion boards</td>
<td></td>
</tr>
<tr>
<td>Responding</td>
<td>Students are active participants in the learning process, attending to stimulus, hence leading to some type of reaction from them.</td>
<td>Interactive communication tools- email and chat rooms</td>
<td></td>
</tr>
<tr>
<td>Valuing</td>
<td>Students assign some value to an object, phenomenon or piece of information.</td>
<td>White boards, editing tools</td>
<td></td>
</tr>
<tr>
<td>Organizing</td>
<td>Students put together different values, information, ideas and accommodate them with their own schema by comparing, relating and elaborating on what has been learned.</td>
<td>Graphical tools / figures, calendars</td>
<td></td>
</tr>
<tr>
<td>Characterizing</td>
<td>The highest level where the students have a particular value or belief that now influences their behavior so that it becomes one of their own characteristics.</td>
<td>Personalized content presentation tools, Mind maps</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.3: Affective Domain in a Digital Context

The table illustrates the different levels of the affective domain and gives examples of tools currently available with web 2.0 technologies e.g. at the level of receiving, power point presentations can be used for students to receive knowledge in class.

3.2.2 Psychomotor Domain in a Digital Context

The psychomotor domain focuses on the ability to manipulate an instrument or a tool. By using ICT, advanced instrument or tool simulators can be devised. Besides, the digital techniques provide options for better monitoring the acquisition of skills in the psychomotor domain. In this case information and communication techniques are less prominent, since skill development requires specialized techniques to support the training of the skill under consideration. We elaborate the levels in the combination of the three psychomotor domains, and ICT tools that can be used in table 3.4. The table illustrates the different levels of the psychomotor domain and gives examples of the tools currently available with web 2.0 technologies. For example, at the level of practicing, wikis and glossaries can be used for discussions. MM techniques help to make more realistic simulations as video games to practice a skill to be learned.
3.2.3 Cognitive Domain in a Digital Context: Bloom’s Digital Taxonomy

As noted in section 3.1, the cognitive domain describes learning of skills relative to knowledge, comprehension and thinking about a particular subject. The elements of the cognitive domain cover many classroom activities and objectives; however they do not make use of the new objectives presented by the emergence and integration of ICTs into the classroom and the students’ lives. Bloom’s Revised Taxonomy (BRT) doesn’t account for the increasing ubiquitous facilities of personal and cloud computing and Web 2.0 technologies. Bloom’s Digital Taxonomy (BDT) is an update to BRT to account for the new behaviors, actions and learning opportunities emerging as technology advances and becomes more ubiquitous (Anderson and Krathwohl, 2001). BDT aims at addressing the advances in technology and insights; and their applications in the field of academia. In order to let the learning process benefit from modern technology and new insights, BDT uses tools to facilitate learning. BDT includes digital technologies and digital cognitive objectives and is summarized in table 3.5 from lowest to highest levels of cognition.

The table gives a detailed illustration of the different levels of the cognitive domain of BDT and examples of the tools currently available with web 2.0 technologies e.g. at the level of understanding, discussion forums are tools that aid in comprehension of topics taught in class. To remember students can use power point presentations, youtube, yahoo, google, blogs, wikis, lesson (flash card) and quiz functionalities among others.
### Cognitive Domain in a Digital Context

<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
<th>Digital Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Recognizing, listing, describing, identifying, retrieving, naming, locating, finding, Bullet pointing, highlighting, bookmarking, social networking, Social bookmarking, favorite-ing/local bookmarking, Searching, Googling</td>
<td>YouTube, yahoo, Google, blogs, wikis, quizzes, Advanced searching, Boolean searching, blog journaling, twittering, categorizing and tagging, commenting, annotating, subscribing</td>
</tr>
<tr>
<td>Understanding</td>
<td>Interpreting, Summarizing, inferring, paraphrasing, classifying, comparing, explaining, exemplifying Advanced searching, Boolean searching, blog journaling, twittering, categorizing and tagging, commenting, annotating, subscribing</td>
<td>TED, Skype, twitter, journal, Advanced searching, Boolean searching, blog journaling, twittering, categorizing and tagging, commenting, annotating, subscribing</td>
</tr>
<tr>
<td>Application</td>
<td>Implementing, carrying out, using, executing, running, loading, playing, operating, hacking, uploading, sharing, editing.</td>
<td>go2web2.0, voki, picasa, SCORM, video podcasts, Flash games, assignment upload</td>
</tr>
<tr>
<td>Analyzing</td>
<td>Comparing, organizing, deconstructing, attributing, outline, finding, structuring, integrating, Mashing, linking, reverse-engineering, cracking, mind-mapping, validating, tagging</td>
<td>Google docs, CC mindomo, remix, blogs, glossary, Wikipedia, Google alerts, forums, chat rooms, blogs, journals, drop box</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Checking, hypothesizing, critiquing, experimenting, judging, testing, detecting, monitoring, (Blog/vlog) commenting, reviewing, posting, moderating, collaborating, networking, reflecting, (Alpha and beta) testing</td>
<td>Wikipedia, Google alerts, forums, chat rooms, blogs, journals, drop box</td>
</tr>
<tr>
<td>Creating</td>
<td>Designing, constructing, planning, producing, inventing, devising, making, programming, filming, animating, Blogging, Video blogging, mixing, remixing, wiki-ing, publishing, videocasting, podcasting, directing/producing, creating or building mash ups</td>
<td>voice thread, wiki spaces, blogs, mind maps, pod casts, lesson plan, assignment based uploads, face book</td>
</tr>
</tbody>
</table>

#### Table 3.5: Cognitive Domain in a Digital Context

The next section discusses the general concepts on which learning is based using two process and content oriented digital tools. We discuss the digital tools generally and discuss their effectiveness in the learning process. We discuss Moodle a very popular open source solution in comparison to Blackboard learning system a proprietary solution as specific examples of state of the art process oriented digital tools.

### 3.3 Process-Oriented Digital Learning Tools

The contents of this section are published in (Bagarukayo et al., 2011a). In this section we overview some state-of-the-art digital learning tools (DLTs) that have been developed to support the learning process. We first focus on process-oriented DLTs Moodle and Blackboard Learn because they are the most popular DLTs, in a more general way and in the next subsection we focus on tools supporting the learning process directly. We discuss the pedagogical principles, the functionalities and their effectiveness.
3.3.1 Moodle

Modular Object-Oriented Dynamic Learning Environment (Moodle) is an Open Source e-learning platform, using sound pedagogical principles to help educators create effective online learning communities with a focus on interaction and collaboration content construction (Dougiamas, 2004). As of December 2011, its user base had about 72,177 registered and verified sites serving 57,751,114 million users in 209 countries and 82 languages. Moodle is written in PHP and uses a cross-platform operating system. The current version 2.2 was released December 2011 under the general public license GPLV2+. The creator believes that a learning environment should be created by an educator. Moodle development continues as a free project supported by a team of programmers and an international community, based on contributions posted to the online community website that encourage debate and invite criticisms (Dougiamas & Taylor, 2002). Users can freely distribute and modify the software under the terms of the license or any later version. Moodle’s evolution led by its developers’ continuous updates has led to rapid development, bug fixes and major improvements on the display, flexibility and accessibility.

Moodle presents an excellent platform for resources and communication tools. Just like most e-learning platforms, it has basic features of a filtering system, tools for creating resources and activities, which provide various options for the tutor managing the course and the collaborative section. It contains tools and techniques extracted from the educators’ experiences to make the processes easy, flexible. It provides a variety of activity modules like forums, chat rooms, assignments, quizzes, surveys, workshops, lessons, glossary, database, choice, SCORM, and the wiki. The resources tabs include options for creating labels, text pages or web pages, links to files or web sites or pages directories.

Moodle’s design is based on the constructivist and social constructivist approach to education, described in chapter 2, emphasizing that pedagogically, for learning to be effective, it must be experienced (Dougiamas & Taylor, 2002). The tools within Moodle support this kind of learning because the social constructivist theory is an important factor to the Moodle developers. The theory emphasizes that we all are potential teachers and learners, learn well from expressing ourselves to others, through observing peer activity and by understanding learner context we can teach more effectively and a LE needs to be flexible and adaptable (Dougiamas, 2004).

The “social constructionist pedagogy” guides the design and development of Moodle. The pedagogy consists of four main related concepts of constructivism: (1) constructionism, (2) social constructivism, (3) connected behavior and (4) separate behavior. As noted in chapter 2, the constructivist theory emphasizes that people actively construct new knowledge as they interact with their environments. The information input by an individual is tested against prior knowledge and may form new knowledge, if it is viable within their mental world. The Constructionist theory emphasizes the effectiveness of learning when something is constructed for others to experience e.g. explaining an idea in one’s own words helps them understand it better (Dougiamas & Taylor, 2002). The Social constructivism theory extends constructivism into social settings, where groups construct knowledge for one another, collaboratively creating a small culture of shared artifacts with shared meanings. When one is immersed within a culture like this, one is learning all the time about how to be a part of that culture on many levels. The ‘Connected and separate’ idea looks deeper into the motivations of individuals within a discussion as elaborated below:

- Separate behavior is defending one’s ideas using logic to find holes in their opponent’s ideas. The learner is ‘objective’ and ‘factual’ and not open to new ideas.
• Connected behavior is a more empathic approach that accepts subjectivity, trying to listen and ask questions in an effort to understand the other point of view. The learner is more open minded and willing to give other ideas a chance.
• Constructed behavior is when a person is sensitive to the separate and connected approaches. They are able to choose either of them as appropriate to the given situation. Having some amount of connected behavior within a learning community is a very powerful stimulant for learning, brings people closer together, promotes deeper reflection and re-examination of their existing beliefs. Students and lecturers should be subjective and not too factual or objective. Teachers should focus on the experiences from the learner’s point of views rather than publishing and assessing information they think learners need to know. This will aid teachers realize that a participant can be a teacher or learner in the learning process, and therefore be open to discussions that may change their perceptions based on others’ views.

Moodle supports this theory with a wide range of ways people can create representations of their knowledge and share them. They include designing activities like forums, wikis, glossaries, databases, messaging that allow students to control common content, thereby encouraging students to add to the total course experience for others. The course structure supports forums which provide spaces for discussion and sharing of media and documents, wikis are collaboratively built pages useful for group work, glossaries are collaboratively-built lists of definitions that can appear throughout the course, and databases allow participants to enter structured media of any type.

Observing the activity of peers can be done using the recent activity block, online users block, and participants’ page where the tutor can find information about participants and how recently they have been there. Understanding the contexts of others is supported by the use of overall activity reports, survey module, user log reports, blogs, forum posts and user profiles, where information about people can be found.

The Moodle environment is flexible and adaptable because navigation is automatically generated, the grade book is automatically maintained, and the external systems are easily integrated to maintain authentication and enrolments. The creator basically emphasizes that the learner (not just teacher) can contribute to the learning experience. Moodle supports outcomes – oriented learning, not a constructivist teaching approach. Moodle is underpinned by a belief that people learn best when they are together, and the developers strive to improve the capability of the tool so that it satisfies educational requirements around the world. One of Moodle’s large adopters, Open University UK, emphasizes that the LE can equally be seen as relatively pedagogically – neutral (Neil, 2008). The ability of students to post thoughts, discuss, share ideas and the resources within a course creates a community of learners’ environment where even the teacher participates as a learner. This makes both the teacher and student learners, with the teacher as a guide and not the sole provider of knowledge, which is a true collaborative environment. In order to update teaching approaches, Moodle therefore allows control to be in the hands of the teacher and student where it should be as LEs demand today.

If we focus at the way of supporting aspect of Moodle, then we see that each skill level has an associated number of techniques to allow effective support for the activities typical for that level. The activities highly supported by Web 2.0 applications and available in Moodle are summarized in table 3.6.
Cognitive Domain | Moodle Support
---|---
Remembering | Moodle glossary, blogs, wikis, Moodle quizzes, Moodle lesson (flash card), complete search activity
Understanding | Moodle blogs, journal, collaborative Moodle wiki, Moodle glossary, Moodle database, Moodle RSS feeder (masgables e.g. voice threads)
Applying | Use of SCORM e.g. NLN, upload screen capture, upload slide share, audio / video podcasts, play embedded flash games, collaborative Moodle wikis (editing), assignment upload
Analyzing | Survey and choices within Moodle, Moodle database, Moodle glossary creation, Moodle wikis, blogs, assignment uploads (MS word, Excel)
Evaluating | Discussion forums, collaborative Moodle wikis, blogs, chat rooms, forum with peer evaluation, assignment based uploads, Moodle journal for reviewing own learning, assessment viewing
Creating | Create collaborative Moodle wikis, blogs, workshop, assignment based uploads, mind maps, upload video, pod casts, publish documents, plan a lesson

Table 3.6: Moodle and Bloom’s Digital Taxonomy Relationship (Dougiamas, 2004)

The teacher starts working with the LE at a low level skill, and then gradually will come at the higher levels. Finally, at the level of creation, the teacher will be able to develop new lessons effectively in the LE.

In conclusion, (Dougiamas, 2004) emphasizes that it is important to focus on experiences, which are best for learning from the learner’s point of view, rather than lecturers just publishing and assessing information they think students need to know. Teachers should realize that each participant in a course can be a teacher and a learner, and not dominate the learning experience by being the sole provider of knowledge. The teacher should become an influencer and role model of class culture, connecting with students in a personal way that addresses their own learning needs, and moderating discussions and activities in a way that collectively leads students towards the learning goals of the class. The designers of Moodle believe that it is the best for supporting this style of behavior, though it does not force it. In future, as the technical infrastructure of Moodle stabilizes, further improvements in pedagogical support will be a major direction for Moodle development.

In the next section we discuss the Bb Learning Content Management Solution (CMS) and how it impacts the learning process.

3.3.2 Blackboard Learning System

According to (Blackboard, 2012) the Blackboard Learning System™ is used to achieve the promise of the Networked Learning Environment (NLE) and to improve learning outcome by the following:
- Create powerful learning content, using a variety of different web-based tools.
- Bring world class publisher content into the e-Learning experience.
- Develop custom learning paths for individuals or groups.
- Facilitate student participation, communication and collaboration using tools that enable synchronous and asynchronous interaction.
- Evaluate students’ work using a rich set of assessment capabilities.
According to (Blackboard, 2012), NLE is an environment in which any student or teacher can view instructional content, collaborate with educators, evaluate academic performance and access any learning resource at any time in order to achieve their educational objectives.

Blackboard (Bb) is a popular Content Management System (CMS) developed by Blackboard Inc. that allows instructors to create, deliver, and manage web-based components for courses (Lacey & Liu, 2003). This software is used to add online elements to a traditional course, or to develop online courses completely with few or no face-to-face meetings. It is available for instructors and students who are enrolled in courses on Bb. The features of Bb include digital testing, discussion forums, advanced statistics tracking, wikis, chat rooms, online quizzes, surveys with automated grading and statistics capacity, course assignment and documents areas, course-related external links, online file sharing, timed release of quizzes, course materials, student rosters, e-mail, online grade book, group project areas, course announcements, personalized course calendars, asynchronous threaded discussion, synchronous group chat, group web browser and a course browser (Lacey & Liu, 2003).

Bb has login features for security and authenticity. Students have access to the courses for which they are enrolled and can check announcements posted by the instructor throughout the course. Students can also check for assignments posted to Bb by the instructor, which they can print and keep for future reference, or save. Bb has a Digital drop box feature which students can use to hand in assignments electronically and allows users to check grades for assignments and tests posted by the instructor. This feature allows the users and instructor to keep track of their performance in the course. Students can send emails to select users enrolled in the class by selecting the person in the communications section, or to all users enrolled in the course to the instructor. Bb also allows instructors to post questions in a discussion forum so that students can answer and respond to each other’s answers and opinions. This feature allows for a discussion to be held in asynchronous or synchronous manner whether face to face or online.

The Bb support for the Cognitive Domain in Bloom’s Digital Taxonomy is summarized in table 3.7:

<table>
<thead>
<tr>
<th>Cognitive Level</th>
<th>Blackboard Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Course announcements, blogs, wikis, quizzes, lesson, email, complete search activity, personalized course calendars</td>
</tr>
<tr>
<td>Understanding</td>
<td>Blogs, journal, collaborative wiki, chat rooms, database, RSS feeder, course assignment and documents areas</td>
</tr>
<tr>
<td>Applying</td>
<td>Digital testing, upload screen capture, slide share, audio / video podcasts, play embedded flash games, collaborative wikis (editing), assignment uploads, group project areas</td>
</tr>
<tr>
<td>Analysing</td>
<td>Synchronous group chat, glossary creation, wikis, blogs, Discussion forums, advanced statistics tracking, course-related external links, online file sharing, asynchronous threaded discussion, group web browser and course browser</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Course materials, student rosters, online grade book, collaborative wikis, blogs, chat rooms, Discussion forum with peer evaluation, assignment based uploads, assessment viewing, surveys with automated grading and statistics capacity</td>
</tr>
<tr>
<td>Creating</td>
<td>Create collaborative wikis, blogs, workshop, assignment based uploads, mind maps, upload video, pod casts, publish documents, plan a lesson</td>
</tr>
</tbody>
</table>

Table 3.7: Blackboard and BDT Relationship
We conclude that Bb is mainly a DLT that is not related to a particular educational approach.

In the next section, we discuss content oriented digital learning tools. The contents of this section are published in (Bagarukayo et al., 2011b)

### 3.4 Content-Oriented Digital Learning Tools

Digital learning may be used to support some particular learning activity. Many CDs / DVDs are specially devised for training children in specific topics like language and calculations. A major driving factor for these tools is the use of multimedia (MM) techniques. In this subsection we focus especially on the usage of MM as a common part of content-oriented digital learning tools. The contents of this section are published in (Bagarukayo et al., 2011b)

Digital media has become a part of students' daily life due to the dissemination of digital technology (Ficheman & Lopes, 2008). Due to the continuous emergence of new technology, more and more students want to use hi-tech electronic devices for learning. Digital media can be used to support learning activities in and out of school in both formal and informal situations (Ficheman & Lopes, 2008). The digital natives are accustomed to speed, multitasking, random access, graphics-first, active, hyperlinked, connected, interactive, fun, video games, television (MTV) and the internet. Typically students are interested in using new technology like mobile phones, tablet computers, game computers, iTunes, video recordings, iPhones, iPads and social media programs like Face book, Twitter, YouTube and Flicker. Therefore there is a demand for creation of tools that enable students to learn according to their current habits, at their own pace, place and time.

According to Ficheman & Lopes, (2008) it is believed that using new technology for learning may enhance the students' learning interest and motivation since it is easy to use and enables learning outside the classroom. Today's students engage in learning activities in different spaces, time and situations. These can therefore be supported by digital media, which also supports anywhere, anytime learning, whether they are alone or with other learners. Digital media is believed to motivate learners and engage them in the learning process. The use of digital technology may also make teachers work easier since teaching overcrowded classes is an uphill task (Ficheman & Lopes, 2008). As noted in chapter 2, students have different learning levels, learning preferences and styles, which may be addressed on an individual basis by digital technologies, thereby enhancing learning. The technology uses different types of (multi) media; text, videos, audios, among others and therefore addresses the different learners interests, needs, goals, preferences, styles and motivation. Blomkvist, (2002) highlights the importance of the persona, defined as the user description and their goals. It is therefore important to cater for the individual’s learning goal during content design. The personalization concept is very important for students to attain the knowledge, skills, attitudes and competencies required for the work environment. The acquisition of knowledge, skills and attitudes also ties in well with Bloom’s Taxonomy of learning as we mentioned previously.

In the next subsection we discuss the Video recorded lectures in general.

#### 3.4.1 Video Recorded Lectures

There are a growing number of universities worldwide recording lectures on video for students to access at their convenience. There is a great increase in the amount of audiovisual teaching resources freely available on the Internet which is usually very interesting, allowing students to attend a class regardless of time, pace and place (Arias et al., 2011). Lecture recording before a live audience and providing the recorded audio stream, video stream and slides over the web is
becoming more and more popular, because it provides for time independent learning (Zupancic & Horz, 2002). Research highlights several video recording techniques like the virtual videography. Authoring on the Fly system (AOF), among others. The AOF allows automatic production of a MM document with an HTML overview, by automatically recording courses and transmitting live to other universities while holding the lectures in front of a live audience (Zupancic & Horz, 2002). The presentation is automatically recorded in the background as the teacher explains using the traditional learning approach on an electronic Bb. There is no need for manual recording and post processing; therefore the recorded lectures are available on the local intranet in about an hour after the live presentation. Thus the students can use the recordings immediately for homework or exams preparation. The students can also use the content to comprehend and discuss the difficult concepts and carry out problem solving in their free time.

The Virtual Videography approach uses computer vision and signal processing methods to gather information about the lecture, a planning algorithm to choose appropriate shots, and image synthesis methods to generate new images from the original source footage (Heck et al., 2006). The approach offers several advantages of providing effective, inexpensive, archiving of traditional lectures with an unobtrusive process which does not require the instructor to alter their lecture style for the camera; requires no special equipment for setup, works without calibration in a wide variety of classrooms; and editing requires little to no human input. The system can produce multiple videos of the same lecture, each tailored to a specific need or viewer preference. Berkeley, Stanford and Michigan are some of the universities that have made videos available to the students through podcasts on iTunes (Dijk et al., 2010). Therefore, students are able to access the lectures anytime, anywhere and can study at their own pace.

Massachusetts Institute of Technology (MIT) is leading the trend in distribution of Open Courseware (Ficheman & Lopes, 2008). The university creates and avails course materials freely on the internet in a virtual learning environment. Video recorded lectures offer a self learning alternative to traditional classes and provide a convenient and effective way to archive lectures for future reference (Arias et al., 2011; Heck et al., 2006). The videos are a permanent resource for students who enroll for the courses even after several years. In a study carried out (Arias et al., 2011) students were required to learn theory on their own by watching videos to solve exercises assigned in advance. The students explained their solutions on the Bb as part of the evaluation method in the classroom. The lecturer only intervened to complete explanations, correct mistakes and give insights into the previously digested material. The method also benefitted the teachers because they got feedback from students, which helped them detect common difficulties in the subject. The results from the study showed that students using the video approach performed better than those using the face to face, and that the video approach influenced the students’ learning process more positively. We carried out a survey to determine the impact of video recorded lectures on the learning process; we discuss the results in chapter 6.

3.4.2 Multimedia Instructional Materials
Multimedia materials, in particular case studies have been created that fit within topics covered in the introductory engineering, computer science and IT classes and developed assessment tools for. The multimedia studies for use in science courses include POWERTEL, AUCNET, Chick-fil-A and Crist, some of which were used in this research to assess the impact of MM on HOCS improvement. All the case studies are packaged on CD-ROM with a mix of multimedia elements such as video, audio, animations, graphics, and various interactive simulations. They are also available on the Litee organization website. We present the results of the impact of text
versus MM on HOCS improvement in chapter 6. In the next section, we highlight the digital tool requirements.

### 3.5 Digital Tool Requirements

From the Digital Learning Tools (DLTs) we discussed in the previous sections, we can derive requirements for an overall support for the learning process. DLTs support a learning environment with learning materials that go beyond the possibilities of traditional pen, paper and books. They offer features like chat rooms, discussion boards or forums, digital testing, online grading, virtual classrooms, feedback, authentication, collaboration tools and content areas. DLTs offer a multi-featured way for teachers and students to communicate, interact and collaborate both in and out of class. DLTs are interactive, engaging, stimulating, assessing students in courses and should impact on teaching and learning through technology.

DLTs offer two advantages over traditional approach: (1) the richness and diversity of the learning materials that may be accessed from both local and networked sources and (2) the emerging availability of Web technologies for integrating such materials at the level of scientific concepts (Dhanasegaran, 2006).

Therefore, DLTs should have the following requirements:

- Delivery of the learning content (reading materials, assignments, tests, lecture slides) that is diverse to cater for various learner preferences and styles,
- Personalization to create customized environments for learner motivation and learning desire.
- Communication between students and teacher, and among students (e-mail, chat, discussion board, digital drop box),
- Module administration.

They should be characterized by the digitization of the course material, place independence, pace independence, web-based, asynchronous, interactivity, collaboration orientation (Antoniou et al., 2009).

In order to be effective, the DLT should support the educational process of the educational organization.

In the next chapter we will use these requirements to introduce Digital Learning Environments as a tool for learning in the context of community-related knowledge management.
4. The Digital Learning Environment

The contents of this chapter are published in (Bagarukayo & Weide, 2012a). In the previous chapters we discussed learning theories in general, and chose Bloom’s Taxonomy as the base learning theory for this thesis. Then we discussed how ICT can reinforce the learning process in general and HOCS improvement in particular. We overviewed some state-of-the-art digital learning tools, and made a distinction between features supporting administrative support (enablers) and those that support the learning process itself.

In this chapter we motivate the need for the Digital Learning Environment (DLE) in section 4.1 by discussing the current learning situation. Then we describe the typical users of a DLE, their goals and roles when using a DLE in section 4.2. We give a motivated definition of the DLE concept and how it is embedded in an education setting and the general architecture in section 4.3. We discuss the learning strategies of building competences and HOCS improvement using Bloom’s Digital Taxonomy and show how the DLE supports them in section 4.4. Then we argue that the DLE in its context is an effective means to acquire Higher Order Cognitive Skills (HOCS) and improve the learning process. Next we discuss how and why it should be integrated in the infrastructure of a learning institute; from the policy, system and beneficial side in section 4.5. This allows us to discuss criteria to measure the success of a DLE in section 4.6. We discuss the DLE as a tool by relating it to the methodological framework in section 4.7. We discuss the DLE implementation and relate it to the four in balance to evaluate its successful introduction in an institution in section 4.8. In section 4.9 we highlight the DLE characteristics for successful learning and HOCS improvement and conclude this chapter with recommendations based on experiences at several levels of education in several contexts, for successful implementation in an institution.

In the following chapter we propose an approach to effectively introduce the DLE in a low infrastructure context, showing how the DLE can play a central role in a community development. We evaluate whether DLEs have an impact on the students’ learning process and HOCS improvement, and present the results in chapter 6.

4.1 A Changing Landscape in Learning

Education has become more and more important in the 21st Century. Mastering knowledge, skills, and being informed are the most important preconditions for a successful business environment. The need for students to apply knowledge from class in novel situations for problem solving, critical thinking and decision making was acknowledged in chapter 1. Therefore it is important to provide education that encompasses HOCS for students to become productive and responsible members of society. The effectiveness of educational processes is an issue under discussion. We see that university programs suffer from high drop-out rates, students making risk-avoiding choices and students graduating without their HOCS improved. We first look at the different situations in which learning occurs by describing the long distance and short distance structure. Moreover, the number of learners is expected to continue growing. Therefore an effective way to handle this growth is imperative.

In literature a distinction is made between short and long distance learning. Short distance learning is where the students are assumed to be physically in the same place, at the same time in a common environment, such as a classroom. Short distance learning is used at schools, universities and other educational institutions. The institution offers the infrastructure to meet physically for common learning related activities. Long distance learning, or distance learning,
where the students are at various geographical locations worldwide, at different times. In traditional long distance learning systems, the student typically works isolated and only has a mail-contact with the institution. Long distance learning is useful when infrastructure and/or student requirements prohibit short distance learning. For example in Least Developed Countries (LDCs) a long distance solution may be the most effective solution to overcome infrastructural restrictions.

The traditional learning approach separates learning and application. During education, a learner is not involved in professional activities. After getting an education, the graduated student becomes a professional and generally stops active education. On the other hand, adult learners who study as they work have the strength of working experience, self motivation, and being autonomous. In lifelong learning approaches, learning and application are seen as a continuous interwoven process. It affects the professional career and leads to another style of learning for the students. In some cases especially the western countries, many students finance their education by having a job during their study. The best way to take advantage of this is when the study is seen as an education-oriented form of lifelong learning. Consequently, the student’s educational style is a mix between short and long distance learning. Such a student may spend the same time for study and work by choosing study times at their convenience. We will call this hybrid learning, a variant of distance learning. We will use the term hybrid learning when the short distance aspect is dominant and reserve the term distance learning when students and teacher are not assumed to meet at the same time and same place. In the next section we focus on the learning process of the learning actors.

4.2 The Actors

The actors of the DLE include the learners/ students, teachers and administrators. As we remarked, the traditional separation between learners and teachers becomes less prominent in a modern learning situation. Therefore we prefer to discuss the actors of the educational process in terms of the roles they can play. Each such role may be described as a persona, which is the user description and his goals. According to Blomkvist, (2002), a persona is a model of a user that focuses on the individual’s goals when using an artifact. The persona model is an archetypical representation of real or potential users and has a specific purpose as a tool for software and product design. The persona represents patterns of users' behavior, goals and motives, compiled in a fictional description of a single individual. It also contains made-up personal details, in order to make the persona more “tangible and alive” for the development team.

Actors can play one or more of the following roles: (1) learning, (2) teaching and (3) administrating (Knowles, 1975). Considering the learning role, we may distinguish this persona to be in the following states of mind:

1. Introducing: the person is considering the next educational step.
2. Learning: the person is actively involved in an educational task in a course.
3. Finalizing: the person is finishing the educational task.
4. Inactive: the person is not actively involved in any educational task.

We consider the introducing phase in some detail in section 4.3. Learning is extensively covered in section 4.4. During the finalizing phase, the learner has to prove that the educational task has been completed successfully. The inactive phase typically is the phase where the actor is still involved. During this phase the (former) learner can be a source of new knowledge, for example providing experiences related to the educational task. The teacher role is discussed in section.
4.9 when we consider the DLEs implementation. The other roles and phases are not further elaborated in this thesis.

During the phase of introducing, the actor is mostly interested in getting an overview. Typical questions of the actor are:

1. Where do I want to be, what competencies are required?
2. What is my position at the moment, what competencies do I have?
3. What are the next educational steps (compulsory, elective courses etc.)?

As described, the different types of students at the several institutions include the short distance, long distance, semi-available students, lifelong learners and adult learners. Malcolm Knowles theory of Adult learners (Knowles, 1975; Knowles et al., 1998) state that the characteristics important for learning are being autonomous, self-directed, self motivated to take special interest and therefore initiate the learning process (Lieb, 1991; CAEL, 2006). Students should be actively involved in the learning process and assume leadership, responsibility, be goal oriented, relevancy oriented, practical and be shown respect. Teachers, as facilitators, should get the students viewpoints on what should be studied by letting them work on projects where their interests lie. Therefore some of these aspects can be borrowed for students in general. In the long distance scenario, the students are available at their own time and leisure, instead of the institute specific time, therefore the time or place of study is not based on the institution defined criteria. The performance of the students is a signal to the teacher to take charge of what is going on in class. On the other hand, the short distance learning program relies on the presence of the students for approximately 40 contact hours a week. The students attend lectures conducted by a lecturer physically in a classroom and receive notes either by use of a text book or the modern way using the DLE. They sit for exams or tests in the classroom, or by use of the DLE in the case of the E-learning approach.

As discussed in section 1.2, the continuous search by educators for new approaches to capture students’ learning interest, motivation and enhance HOCS improvement has led to investment in learning environments to prepare students to be successful as they enter the work force (King, 2000; Bagarukayo & Mbarika, 2008). Therefore there is need to create active customized learning environments for learner motivation and continuous learning desire, using different ICT tools. ICT provides better options to present learning material, and enables effective communication, interaction and collaboration between those involved in the learning process. This therefore leads to more support for active, interactive and collaborative LEs to motivate students and increase their learning interest and HOCS improvement. We therefore look at DLEs as a method of teaching and learning to improve HOCS as a possible solution to this changing landscape. In the next section we discuss how the DLE is embedded in its environment.

4.3 The Digital Learning Environment in the Educational Setting

As previously noted a Learning Environment (LE) is the virtual or physical setting where learning occurs. LEs are based on core foundations, describing how knowledge is acquired and used, the underlying pedagogical philosophy, and the supported learning process, the role of technique and culture, and related pragmatics. Digital learning is the delivery of knowledge via digital means over the internet either to replace or supplement the traditional learning approach with a computer based Virtual Learning Environment (Antoniou et al., 2009). There are new advances in digital technology and science in the areas of Multimedia, Decision Support Systems (DSS), visualization software and expert systems, among others. In developed
countries special architectures have been developed and most of these solutions rely on the richly available infrastructure. In Least Developed Countries (LDCs), however such an infrastructure is not available, although the infrastructure is improving at some speed in some countries. Digital technology is seen as an extra opportunity for developing countries; especially in the promising area of e-learning. New technology is being developed at a fast pace and there are new promises of applications everywhere, yet there lacks a general top-down philosophy that guides the introduction. There are examples of good practices but in some cases there is no available theory describing how to best benefit. In chapter 5 we will discuss how the DLE as proposed in this thesis will support and improve this capacity and infrastructure building process in a LDC.

Digital Learning Environments (DLEs) are technical solutions for supporting learning, teaching and studying activities (Suhonen & Sutinen, 2006). DLEs can be educational software, a digital learning tool, an online study program or a learning resource. In this thesis we extend this definition as follows:

A digital learning environment (DLE) is a tool for maintaining, exchanging and acquiring knowledge, skills and attitudes, in particular supporting learning, teaching and studying activities.

A Digital Learning Environment Tool (DLT) is a (technical) realization supporting the way of working advocated by the DLE tool. This realization may consist of several DLTs. Following that tradition, a DLE may be seen as a virtual paradigm for a modern open school environment, taking advantage of modern Information Technology. Therefore, a DLE can be used to support the educational process.

The DLE has an associated way of working that requires the following functionalities:

- **F1**: delivery of the learning content,
- **F2**: personalization
- **F3**: communication between actors,
- **F4**: administration.

Given the changing landscape of the educational process and the fact that MM materials in the DLE enhance HOCS improvement as discussed in section 1.2, the mission of a modern educational institute is to offer an efficient, auditable, highly accessible training facility for a broader audience to support hybrid learning. Therefore if the right pedagogical philosophy, learning processes and core foundations are followed, the DLE can enhance HOCS improvement. The strategy should be a well equipped DLE tool supported by a sufficiently supporting DLT to play a central role as the main facilitator for distance education. The future for education is the use of DLEs because they enrich students learning experiences and change the way teachers engage their classes. Several authors indicate that using DLEs is the future for delivering education ubiquitously. F1 therefore enables students to access content uploaded by teachers. The students and tutors are able to access the LEs and undertake interactive learning at any place, any pace and anytime to enhance the learning process for HOCS improvement. The students have the freedom of learning at their own pace, time and space, which provides a flexible learning environment. Functionalities F2 and F3 improve interactivity and flexibility and thus the DLE makes learning dynamic and provide greater interaction and collaboration between the students and tutors. Also the DLE provides a conducive learning environment through their easy and adaptive functionalities hence making the learning process easy. F4 handles the teacher and student registration issues, course allocation, and financial issues among others.
Modern learning preferences require more and more decoupling of time and space and also to meet the growing demands of student numbers. An example is distance learning, where time and space are decoupled to a high extent. But also in traditional learning there is a gradual decoupling emerging. A special situation is the case of special needs children who require a personal learning approach due to physical restrictions. The hybrid learning method requires teachers to be flexible and in time the student-teacher meetings are made possible using the DLE. The reason is that student-teacher interaction should not suffer from a great delay in time. Since the student and teacher are not assumed to be at the same place, and the student’s working hours may vary, teachers should be available in a reasonable time frame. In summary, there is need for a learning solution that is independent of the number of students for course delivery, content management, and community engagement. A DLE is a platform where students and teachers can meet for educational purposes at their convenience.

The DLE enables instructors to develop online course material, interact with students and monitor their progress. It provides a platform to consult management and colleagues, and enables the student quick and easy access to online course material, interact with teachers, and educational management and to get feedback on their progress. If well founded on a learning methodology, the DLE will enhance the performance of both teachers and students. Measuring the DLEs performance is different from the traditional approaches and is discussed later in this chapter. In summary, a DLE embedded in an institutional environment is the perfect solution to meet the student demands of any time anywhere learning and lifelong learning. The environment takes care of all infrastructural and institutional requirements that are needed by the DLE. In the next section we describe architectural aspects of integrating a DLE in a learning environment.

4.3.1 General Architecture of the Digital Learning Environment

An educational architecture consists of embedding the DLE in its surrounding infrastructure, which is related to a clear educational philosophy that enables its users (students, teachers and administrators) to perform their processes efficiently and effectively. During the design and development of a DLE, the visions, goals, principles and objectives of the institution have to be clear. For a system to work effectively there is need for a vision, expertise, digital learning materials, and ICT infrastructure to be in balance (Kennisnet, 2010). There is also need for the cooperation and support of the staff, leadership and the pedagogical use of ICT for learning (Tondeur et al., 2010). Modern system architecture implements an information system as a set of cooperating independent modules. In a co-operational system there is no central definition of the business process. Each component describes an independent view on some part of the conceptual view. A single system provides a single point of failure; however, in a co-operational system a failing component will not prevent other components to be functional. A single system may lead to a single vendor which may lead to the vendor lock-in, proprietary lock-in or customer lock-in problem. Open standards are required, both for a central and a co-operational system. The separation of sub-systems makes the overall system less vulnerable to security attacks since they are connected via well-defined interfaces that provide only a well-chosen set of access functions. There are several disadvantages of building the information system as a single system. A DLE will work in the context of the other administrative systems of the educational institute. The typical administrative systems are student administration, teacher administration, course administration and financial administration. We will assume a general infrastructure as shown in figure 4.1
The policy should aim at linking the administration systems in the institutions with the DLE. The DLE helps to promote accessibility of education because it is space and time independent. This eases the process of auditing, monitoring and makes information accessible to a broader public to emphasize high quality. There should be easy exchange of information between the different systems in the university. The success of a DLE is affected by the lack of integration policies and depends on the integration with the other systems in the institution. The goal should be the scalability and flexibility of the DLE and not strictly improving the student results or performance, but educating masses with ICT.

We discuss the learning strategies of building competences and HOCS improvement using the DLE to support the learning process in the next section.

4.4 Learning Strategies using the Digital Learning Environment

The architectural model of competence (Bartram & Roe, 2008) sees the world as centered on competencies i.e. the way of thinking behind that architecture. Bloom’s Taxonomy makes more explicit the way to model the Knowledge-Skills-Attitude (KSA) part of this architecture, and also describes the general approach for a related way of working. In this section we focus on how the DLE can actually support the learning process by showing the relation between DLEs and gaining competencies. We start from a general model for competency building, since competencies are generally used to describe what education is supposed to achieve, then we refine this using Bloom’s Digital Taxonomy.

4.4.1 Building Competencies with the Digital Learning Environment

The educational approach is aimed at building competencies. Competences should be distinguished from KSA, which can be considered independently of the context in which they are applied. Competence is always relative to some setting or context, and defined in terms of the degree to which someone meets or fails to meet some externally defined standards. For the same reason, competence should also be differentiated from dispositions, i.e. abilities, personality traits and stable characteristics such as interests and values. Therefore the general idea is to identify the role the DLEs play in building students’ competencies. According to Bartram and Roe, (2008) competences are the ability to perform a task adequately and deliver the desired outcomes. Competencies provide a unique integration of KSA that matches requirements from the task and the setting in which it is to be performed.

The building of competencies generally relates to Bloom’s Taxonomy (BT) since it aims at developing KSA as we discussed in Chapter 3. Basically students cannot gain competencies
without gaining KSA by learning, studying and practicing. After students have attained KSA from class, they should put this knowledge into practice in a novel situation thereby gaining competences. The ability for students to put what they have learnt into practice enables them to gain sub competencies. As the students continue to practice what they have learnt i.e. learn by doing, they gain competences which are synonymous with HOCS and are the aim of the educational institution. As elaborated by BT, the three domains that categorize the cognitive processing levels of learning are the KSA which have to be built from a solid infrastructure. The KSA are positioned as shown in the competency development program as described in the architectural model of competence (Roe, 1999). In this architecture we see how personal qualities relate to competencies via KSA. As noted previously, for a student to gain competences, they have to gain KSA as illustrated in figure 4.2 below.

Since competences are developed after the KSA, the DLE can support HOCS improvement by providing tools and content that will develop these skills at the different levels of BT. The DLE supports the learning process by enabling students to manage their own learning (functionality F2). The DLE is believed to enhance the learning process by providing support for students to set their own learning goals, manage the content, learning process, and communicate with others thereby achieving the learning objectives. It therefore enables students to gain practical and hands on skills to use at the workplace for problem solving and decision making. By the content in the DLE addressing the learning styles, profiles, to promote HOCS improvement, this can promote learning. The content should address and assess students on all the levels of BT to promote learning. We discuss HOCS improvement using Bloom’s Digital Taxonomy with the DLE in the next section.

4.4.2 HOCS Improvement using Bloom’s Digital Taxonomy with the DLE

BT aids teachers to outline the learning objectives and the assessment for the learning process. As noted, the higher levels of BT address the development of synthesis, evaluation, critical thinking, information analysis, comprehension of new ideas, communication, collaboration, problem solving, and decision making skills. BT aims at the HOCS improvement by taking the students from the lowest to the highest levels of the taxonomy. It has been used by many researchers to evaluate students’ HOCS improvement required at the work environment. As
noted, Bloom’s Digital Taxonomy (BDT) incorporates the new advances in technology for learning purposes and therefore ties in very well with our research on the DLE integration and interaction.

As noted in chapter 3, Digital technology has become part of students’ life today, hence the term ‘Digital Natives’ in reference to today’s students. BDT examines the cognitive domain focusing on the description of the learning processes as actions. BDT describes the various thinking skills, ranging from low to high order thinking skills. BDT uses tools to facilitate learning to let the learning process benefit from modern technology and new insights, since technology is important for realizing learning skills in today’s knowledge economy. The research therefore aims at discovering how DLEs help students to reach higher-level thinking or HOCS of BT. With available tools; instructional designers can create lesson plans that integrate modern technology with BDT. For the creative teacher, a learning environment has the opportunity to encourage student inquiry from the knowledge to evaluation level of BDT. The teacher can outline both objectives and activities for each level of BDT with regard to the lesson to give the students clear expectations. It gives the teacher a method of student work evaluation that allows them to differentiate for student needs.

BT can help learners understand how to navigate towards subject mastery. Therefore the digital native learners will have learning objectives and outcomes for the DLE outlined using BDT. Therefore BDT is relevant for the DLE as a guide for the learning outcomes and assessment methods that the teachers will use. With all the recent advances in technology, assessment of understanding has become a necessary part of these trends in new learning environments. In particular, learners need to conduct self-assessment of their own learning to monitor their progress, in addition to instructor feedback. BDT offers a way for both learners and instructors to systematically analyze levels of understanding into a hierarchy of thinking levels that indicate progress towards content mastery.

The DLE should incorporate tools that emphasize HOCS attributes of problem solving, decision making and critical thinking in its design. The students should use collaborative, communication and interactive tools for them to achieve HOCS using the DLE and therefore promote learning. As noted above some of the features of the DLE include collaborative and interaction tools that encourage students to share knowledge, ideas and experiences thereby enhancing the improvement of critical thinking, problem solving and decision making skills which are HOCS attributes at the higher levels of BDT. With the DLE, the teacher only acts as a facilitator and the students take responsibility for the learning process thereby promoting active learners. The higher levels of BT emphasize the ability to apply skills in a novel situation, therefore with students taking charge of their learning they can attain HOCS. Table 4.1 describes the different levels of BDT, definitions, resources and examples.
<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
<th>Resources</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>finding, practicing, and memorizing information</td>
<td>sites that support knowledge-level questioning</td>
<td>Almanacs, encyclopedias, ready-reference sites, teaching tools, puzzle &amp; quiz generators, glossary, blogs, wikis, quizzes, lesson (flash card), complete search activity</td>
</tr>
<tr>
<td>Understanding</td>
<td>discussion, description, and translation</td>
<td>sites that support comprehension-level questioning</td>
<td>Tutorials, self-paced instructional materials, Blogs, journal, collaborative wiki, glossary, database, RSS feeder (massgables e.g. voice threads)</td>
</tr>
<tr>
<td>Applying</td>
<td>use the knowledge they have gained in a novel situation</td>
<td>sites that support application-level questioning</td>
<td>CNN Student News has weekly activities that encourage students to draw conclusions from a series of facts, TryScience.com can help students carry out experiments anytime, and can post and read responses from fellow students. Use of SCORM e.g. NLN, upload screen capture, upload slide share, audio/video podcasts, play embedded flash games, collaborative wikis (editing), assignment upload</td>
</tr>
<tr>
<td>Analyzing</td>
<td>Breaking down of knowledge into parts and the relation of those parts to the whole concept.</td>
<td>sites that dissect the subject matter, explain how the parts fit together, and then encourage students to seek more information</td>
<td>Sites with questions to develop scenarios and role-playing. Teachers can use posted lessons or create their own assignments to encourage student use and analysis of primary source documents. Survey and choices, database, glossary creation, wikis, blogs, assignment uploads (MS word, Excel)</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Judging, critiquing, comparing</td>
<td>Sites with primary-source information and provide opportunities to examine, evaluate, and assess</td>
<td>Sites like the National Constitution Center, Oral History etc, Discussion forums, collaborative wikis, blogs, chat rooms, forum with peer evaluation, assignment based uploads, journal for reviewing own learning, assessment viewing</td>
</tr>
<tr>
<td>Creating</td>
<td>Collecting information, and then creating a new insight.</td>
<td>sites that encourage cooperative learning activities that use a variety of materials to create new products</td>
<td>ThinkQuest is a site where students can work together to create interactive, content-rich Web sites, Web Quest is an inquiry-oriented activity designed to use learners’ time well, to focus on using information rather than looking for it, and support learners’ thinking at higher-level skills. Collaborative wikis, blogs, workshop, assignment based uploads, mind maps, upload video, pod casts, publish documents, lesson plan</td>
</tr>
</tbody>
</table>

Table 4.1: Bloom’s Digital Taxonomy & Digital Learning Tools (Hobgood et al., 2011)

4.4.3 DLE as a General Way of Supporting Learning
The DLE acts as the way of supporting for the learning method based on the methodology framework which we discuss in section 4.7. The role of the DLE is to help students achieve competencies, KSA as specified by BT and Roe’s model of competencies, by supporting the learning process. As noted in chapter 1, there has been a paradigm shift from the traditional to
electronic learning approach of the way students learn. Therefore institutions have to take care of the students' new demand of anywhere anytime learning. The teaching methods at the institutions should accommodate the new approach to learning by using technology to meet the demand of educating the masses and HOCS improvement. The ease of use, support, global standards, open systems, high scalability and implementation options are key selection criteria for any DLE. In the next section we discuss the DLE benefits.

4.5 Digital Learning Environment Benefits

According to the Four in Balance Monitor the major benefits of ICT usage are (Kennisnet, 2010, pp 6).

- ICT is very suited to offering subject matter in multiple ways, for example visually, with audio, and interactively. Providing subject matter via a variety of channels means that pupils learn more effectively.

- It is remarkable that weaker pupils in particular make progress when they learn with the aid of ICT. The condition for this, however, is that the ICT programs utilised are properly designed, are appropriate to the level of the pupil concerned, can direct the pupil's attention effectively, and take the pupil through the subject matter in a series of steps. If the digital learning material fails to meet these conditions, it will be ineffective (or at least much less effective).

- Most pupils like working with ICT. It is important, however, to alternate ICT with other learning methods. A second crucial success factor is that the pupil's attention must be focused on the learning task. It is therefore important that an ICT application should be assessed not only as regards whether it is fun to use but in relation to its pedagogical depth and efficiency.

However (Kennisnet, 2010) warns that these benefits are rarely the effect of ICT alone. In our opinion, the benefits of an educational institution lie in the quality of its supporting role for society. The basic question is: Are the right people trained in the right way according to the needs of society in the context of a broader view on society development? We restrict ourselves to flexibility and scalability of the institution, which are an important aspect in this question. The quality aspects can be distinguished into internal and external quality. The Internal quality addresses the question, how well does the educational institution perform? The Four in Balance Monitor (Kennisnet, 2010) is useful for this quality aspect. Since a research university should be seen as progressive enterprise, it should strive to adapt itself successfully to new management skills, principles, abilities and higher levels of competency (Ansari et al., 2009). At lower level educational institutes, most development activities are related to course development, where the course contents are clearly defined. The Four in Balance Monitor strongly focuses at this situation as a method to evaluate the success of the introduction of ICT in a scholarly environment. In an academic educational environment the method is useful to some extent to evaluate the success of ICT. The external quality addresses the question, how well does the DLE support the needs of society? The importance of HOCS for graduates for problem solving, decision making and critical thinking was discussed in chapter 1.

A DLE can play a crucial role for these aspects. The DLE may not necessarily improve teaching per student but improves teaching by making it more accessible to a far larger group of students. The benefits from DLEs in the context of “ICT is very suited to offering subject matter in multiple ways, for example visually, with audio, and interactively” (Kennisnet, 2010) include the following:
• DLEs are built to support different learning styles and preferences. Since it contains MM, the learning environment addresses the different learning styles and preferences of students. This is in line with the first benefit highlighted by (Kennisnet, 2010) since the DLE provides material in different forms.
• DLEs provide ubiquitous environments that enhance learning. The course content is stored in a central repository where it is linked to the appropriate course. DLEs are generally easy to use, reliable, resilient and are a good environment for providing blended learning opportunities.
• DLEs also make the teaching and learning process flexible for both the teachers and students, who can access the content and information at anytime from anywhere at any pace.
• DLEs are interactive, collaborative, simulative and adaptive. Users have the ability to work collaboratively without sending lots of emails. They can create content collection to a defined set of users, store, share and collaborate with core program materials. This is the best way of communicating and sharing digital content among people inside and outside the institution.
• DLEs can be utilized to train massively at any location thereby being efficient and effective. Students are able to access their personal and course information from one centralized location. They are able to communicate and collaborate through the use of groups. They also encourage individual responsibility for learning, thereby promoting self regulated learning.
• DLEs provide real time assessment of both formative and summative courses; therefore teachers can monitor students’ progress and help them to understand the content well. This kind of assessment supports the learning process because it does not assess the learning outcome only. The formative assessment can be done by students answering questions by sending text messages to the server. The system grades students’ responses, enters the grades into students’ grade books, and delivers immediate statistics to the class room, like real time quizzes.
• The DLE may not necessarily improve teaching per student but improves learning, by making the materials more accessible to a far larger group of students. One of the goals of DLE implementation is to meet the growing number of students' demands. The DLE therefore solves this problem, by students’ ability to access the learning material from different locations.

We discuss the DLEs success measures in the next section.

4.6 Digital Learning Environment Success Measures

In this section we discuss the characteristics of the educational institution and in what context they can be used as indicators to measure the DLE quality of that institution. The number of students using the DLE can be a measure of success since one of the DLE’s goals is to cater for the demand by the increasing number of students. The bigger the number of students in the class, the more the usage and therefore the more successful the DLE is, since it meets the increasing demand. The more the number of students, the more actively the teachers and students will use the DLE because they will realize how easy it makes their work. The students’ activeness is determined by the teacher’s activeness when using the DLE. If the teacher is really active so will the students because they will realize that using DLE is the only way to access information to pass the exam. The policies stipulated determine how active the students and teachers are. For example if the teacher indicates that discussions in the DLE will carry 20% of the total mark, then that will motivate students to participate. As noted from the four in balance monitor (Kennisnet, 2010) the role of leadership plays a very big role in achieving the
vision of the institution. The policy of the institution should encourage teachers to be active in the DLE to trigger students' motivation and interest e.g. the institution can enforce that teachers respond to student questions within a specified number of days to encourage students to use the DLE.

To measure the internal quality, the usage of DLEs involves the quality of the delivered product. The success on the adaptation of the system, improved student performance, learning habits, communication, interaction, are some of the indicators of a successful DLE. Surveys can be used to determine how students rate the success of the DLE. When a teacher uses a LE they should be able to see the added value. One of the ways to measure the success of a LE is noting the change in behavior of both teachers and students. By looking at the functionalities students and teachers use, the success of the DLE can be measured. When students transact from using easy to the hard functionality, then there is improvement in the interaction with the DLE. This can be watched over time by either asking the students what functionalities they used before a certain period and what they currently use. The difference can inform researchers that there is significant improvement in the interactivity with the DLE.

The success of the DLE can be measured by analyzing the questions teachers ask. If they are asking complex questions like creating assessments to compare different sections within the courses, creating e portfolios, incorporating web 2.0 applications etc and are no longer asking trivial questions about posts, that shows that they have mastered the environment. The users' ability to use more advanced features show that they have become experts at using the system.

The growth of DLE usage at the course level can be monitored by viewing how the depth and richness of content increases. This can be done by monitoring how many classes have content and how many times students access the content. DLE effectiveness in terms of HOCS improvement can be measured by the use of collaborative and interactive tools which enhance HOCS if the students are handling problem solving, decision making, critical thinking situations like assignments in the DLE.

The percentage of the number of active courses using the DLE for instruction is also a success indicator. However it should be noted that the measurement of success as per what is uploaded on the system is not necessarily an indicator because many of the uploaded courses may not be well developed and hence create no impact.

Looking at the level of activity within a course for both the student and lecturer each quarter of the year may also be used to measure the success of the DLE. The more activity going on in the course the more successful the environment is.

Students' engagement is another measure of a DLE’s success since it is believed that an engaged student is a successful student. The popularity and high adoption rates of the collaboration and communication tools within a DLE can be used to measure the success of a DLE because these tools may have a significant impact on students’ engagement on and off campus. The activities that the students engage in can be looked at, for example, how students create threads to a communication, how they respond to any communication and how they participate actively within a discussion.

An important measure is the availability of education with similar / less resources i.e. more efficiency. Therefore, measuring success should be wider availability of education (different hours), and higher efficiency in the number of students taught per teacher. The quality
assurance / control and information embedding is also an important measure for the success of a DLE.

In the next sections, we describe the methodological aspects of integrating a DLE in a learning environment. We study the learning process in relation to the DLE from the methodological point of view that brings together all relevant aspects of a methodology. We discuss the DLE as a support mechanism for this general learning process. We use the methodology framework to put together the concepts we have discussed so far. We position the approach at RU from the point of view of the methodology framework.

4.7 The Methodology Framework

In this section we consider the learning strategy described in section 4.5 in the context of the methodology framework. We relate the learning methodology to the various aspects of the methodology framework. We evaluate whether relevant aspects of the methodology have been addressed sufficiently well. In the next section we will go a step further, and discuss to what extent these aspects have been covered in the case considered. According to Land & Hannafin, (1997), “LEs, directed as well as constructivist, are rooted in five core foundations: psychological, pedagogical, technological, cultural and pragmatic”. We first introduce a methodology framework as systems of aspect for characterizing and comparing methodologies (Proper, 1994), based on a model of Seligmann (Figure 3.3). The aspects of this framework are:

1. The Way of thinking is how the methodology sees its universe of discourse.
2. The Way of modelling is a related system of concepts and their relations. The following sub-aspects are distinguished:
   (a) The Way of describing is the medium and notations used to represent the concepts as identified in a way of conceiving.
   (b) The Way of conceiving is a set of modeling concepts by which viewers observe domains and usually takes the form of a meta model.
3. The Way of working is the pragmatics of the way of modeling, leading to a concrete result (model) for a concrete case.
4. The Way of controlling is the managerial aspects of the methodology like human resource management, quality and progress control, and evaluation of plans, i.e. overall project management and governance.
5. The Way of learning is the process and measures that enable continuous improvement of the model.
6. The Way of supporting is the support to system development that is offered by (possibly automated) tools. In general it is supplied in the form of some computerized tool description of how the work is structured.

Figure 4.3: The Methodology Framework for Learning
4.7.1 The Digital Learning Environment as a Proposed Methodology

According to our definition, a digital learning environment (DLE) is a tool for maintaining, exchanging and acquiring knowledge, skills, attitudes and competences, in particular supporting learning, teaching and studying activities. In this section we show that the proposed DLE has all requirements for a methodology. For that purpose we use the methodology framework, based on a model of Seligmann (Seligmann et al., 1989), that has been presented as a mechanism for characterizing and comparing methodologies (Proper, 1994) to get a better understanding, and to compare different methodologies. We relate the DLE as a digital learning methodology to the various aspects of the methodology framework. Figure 4.4 summarizes this relation.

![Figure 4.4: Methodology Framework Matching Core Foundations to the Methodology Foundation](image)

**Figure 4.4: Methodology Framework Matching Core Foundations to the Methodology Foundation**

The way of thinking for a learning methodology is its general idea of knowledge and skill transfer in a broader context. For our purposes, the way of thinking may be related to psychological models. Different institutions may have been organized from a different way of thinking. The method described in the previous section is very generic, and may cover various ways of thinking, and is summarized as:

The essential part of knowledge and skill transfer is obtaining competencies, in the context of lifelong learning, where enhanced ICT’s enable the requested separation of time and place in the educational process.

The way of modeling is the formal model that makes it possible to formally reason about the associated application domain. The way of modeling is also the pedagogical description of what was intended by the way of thinking. The way of conceiving refers to the way the problem context is conceived.

For the way of describing, the learning environment is looked at from an educational perspective. The strict description rules are the framework to describe an actual situation.

The way of working describes how a concrete universe of discourse, seen through the eyes of the way of thinking, can be described in terms of the concepts and their relations as described by the way of modeling.
The way of learning is part of a continuous process of quality improvement and provides answers to questions on how the institution can continuously learn from past experiences.

The way of supporting is mostly supplied as the digital learning environment at the automated tool to make the learning process effective and efficient.

4.7.2 The Case of Radboud University

4.7.2.1 The Central Infrastructure System

Radboud University (RU) introduced Bb Learn as the DLE in 2000 and currently has about 20,000 students enrolled. The next section highlights RU’s central infrastructure and the methodological framework. RU has chosen the general infrastructure as displayed in the figure 4.1. There is no central system at RU; it has several sub systems interconnected for information sharing. The central administration is automated, and therefore management immediately recognizes the benefits by observing the way instructors and students use Bb, to determine if it is successful.

![Central Infrastructure System at RU](image)

Figure 4.5: Central Infrastructure System at RU

The systems in figure 4.5 are:

- **RBS** is the relationship management and administration system where new staff and students are created.
- **ISIS** contains all the course information and students enrolled for the courses. The information from RBS and ISIS is stored into Bb.
- **Bb Content System** stores all the content that can be accessed and used by the students in the system.
- **LDAP/IDM** contains the authentication protocols used to ensure that the right users access the system.
- The central infrastructure system is connected to the Bb server.

Bb is synchronized with the systems used to run administrative issues at the central level like course registration, examination registration, and programs registration. The Bb accounts and courses are automatically created for the new / continuing students who register for a new semester and staff who join the university. Teachers use Bb for communication since all students can access the information disseminated. The teachers are automatically enrolled on Bb for the courses they intend to teach. The teacher therefore does not worry about organization details like email addresses and information dissemination to students. All Bb courses have basic information about the students and often contain some announcements, posts, etc to the students. The university is trying to encourage the teachers to use modern methods such as digital testing especially for classes with big numbers.
4.7.2.2 The Methodology Framework for Radboud University

The methodology framework for Radboud University (RU) is as follows:

- The **way of thinking** describes how the methodology sees its universe of discourse. The university policy is a decentralized top-down approach trying to gradually define this view in a field of emerging philosophy and technology as a result of teachers’ experiments. The DLE was introduced to make the learning process easier.

- The **way of modeling** is not clearly communicated to the Bb participants. In our context, the implementation of the learning program into the DLE, leading to the composition of teaching material into the DLE, is described by the way of modeling which is BBT. Courses focus on getting hands-on experience and presenting best practices. An example is the handling of security aspects when applying the grade book functions of Bb. The way of describing includes what makes the students learn better, increase motivation and interest and how this can be improved in the educational sense.

- The **way of working** at RU is not a well-defined, which limits the application of Bb considerably. E.g. there are no courses introducing teachers in using Bb at the science faculty. Re-inventing the wheel is not always the most efficient approach.

- The **way of controlling** consequently basically is laissez-faire approach, using output controlled steering. This managerial style is typical for the management of complex and chaotic processes, but can also lead to output optimization (only). The management checks the quality by letting students evaluate the teacher. The teacher determines how they teach and management steers the process at a general level. If the students are not satisfied with the teacher, the management steps in to solve the problem. The evaluation of plans is done by determining the students’ growth and their future. However, there is not yet a systematic approach to measure the benefits of the DLE, as we discussed.

- The **way of learning** consists of special trainings derived from the way of modeling to empower the teachers to use the learning environment. At the moment learning focuses on the best way to use modern technology in a changing society, as has been described. The best practices and information sharing is how learning continuously takes place from past experiences at RU.

- The **way of supporting** is the most visible and dominant part of this phase and is offered by Bb. The educational process is left under the teacher’s control. The processes that are not educational related and not dependent on other people are handled by administration and automation. The entire process is automated and therefore teachers don’t have to request for courses or the administrative processes to be setup. The teacher only takes care of educational issues like teaching and posting notes on Bb. The teachers upload instructional materials and content onto Bb, that students access during the learning process.

We conclude that from a methodological point of view, a DLE per se should be seen as a way of working. Consequently, a DLE considered in isolation cannot be seen as a complete methodology. When the DLE is not related to the way of thinking, we expect a serious miscommunication between managerial levels and the working staff. When the way of working is not clear, either people are reluctant to use the DLE because they find it too difficult to use, or the investments may not be preservable. The way of learning is an important pre-condition for the acceptance of the teachers. In the next section we discuss DLE implementation in an institution.

4.8 Digital Learning Environment Implementation

Based on experiences in literature, during DLE implementation the following should be put into consideration. The cooperation and support of the management and staff are very important for
integrating ICT in an institution (Kennisnet, 2010). Therefore the teachers’ cooperation is very important for the efficiency of the DLE. Teachers should be able to cooperate at school national and international level to share their experiences and ideas with other universities in order to inspire one another (Tondeur et al., 2010).

The technical team should include features and services that students and teachers want to use. To make their courses more effective, the DLE should make the teachers’ work easier. The teachers are encouraged to incorporate tools to make their courses more effective and make their work easier, like developing building blocks to enhance the system. A feature and service that can interest teachers is the use of digital testing and automatic grading. If the system can grade tests and automatically insert them into a grade book, the teachers’ work is made easier and students will access the results and monitor their grades anytime. Such a feature may motivate the teachers to use the DLE.

Students are the main consumers of the DLE and therefore their requirements should be put into consideration. The students should be given the opportunity to request for services that make their study more effective and successful. They can give their recommendations for improvement on the current innovations which the administration can handle and provide feedback. The students can also exchange ideas with one another using polling functionalities, to rate the importance of the DLE and their feedback can be used to plan for the future of the institution. If the students feel they learn better from the DLE then the institution can use this information to make the use of the system compulsory. Another way to interest students is by letting them run the portal and give their opinion on their needs. This enables them to create and run an online community as an opportunity to change the institution through the system’s online polling capabilities. Therefore the students can use the system to ensure efficiency and effectiveness in running the institution processes.

Experience has shown that the use of collaborative tools, interactive tools and groups can enhance HOCS of problem solving, critical thinking and decision making skills (Mbarika et al., 2010). The discussion forums and chats are a creative way of engaging students and making them critically evaluate information. These collaborative tools enable students to improve their critical thinking skills through creating, reviewing and providing feedback, ability to assimilate knowledge and make recommendations for decision making and problem solving. Students are more motivated and enthusiastic about what they are studying during discussions, and this may increase their learning interest since they are more engaged in the learning process. The students enjoy communicating, collaborating, interacting with other students and the team work involved which enhances HOCS improvement.

Whatever technology is chosen, the institution has to make investments to learn to use and adapt the technology to their needs. In an educational environment, it will for example be necessary to develop teaching material to empower the technology. A well-known pitfall for this situation is referred to as vendor lock-in (Corrado, 2005), where all user investments are locked in the system, making it (almost) impossible to change from supplier without loss of all the investments. Vendor lock-in can be avoided by using open standards, such that (1) user investments can be exported from the DLE in this standard format and (2) specifications written in this format can be entered into the DLE. So this standard should be widely accepted and adopted. We present some data to give an impression of the usage of the DLE at RU in chapter 6. In the next section we relate the DLE to the four in balance monitor.
4.8.1 Relating DLE to Four in Balance

The original framework only distinguishes the following aspects of a methodology: the way of thinking, the way of modelling, the way of working, the way of controlling and the way of supporting. We relate the methodology framework to the four in balance. Requirements for a successful implementation of ICT have been formulated in the Four in Balance method (Kennisnet, 2010). We will discuss the introduction of the DLE in the context of this method.

The four pillars are used to measure the success prospect of ICT introduction in an organization on a more global level. The four pillars are the following (figure 4.6):

1. Vision
Successful usage of ICT requires a clear vision of the usage and deployment of ICT that is shared between managers and teachers.

2. Expertise
For teachers this relates to the skills necessary for using a computer as a pedagogical aid in designing and organizing learning processes. For learners this relates to the skills that are needed to learn with the aid of ICT outside the school environment.

3. Digital learning materials
The availability of dedicated digital learning materials is still below the minimum required level.

4. ICT infrastructure
This refers to the availability of computers, access to the Internet, and other computer facilities like interactive whiteboards and digital video applications.

Note that these pillars are not independent, as they have to be optimized in the context of a limited budget. Since the strength of a chain is determined by its weakest link, the least implemented pillar is an indicator for the total quality of the ICT usage.

![Figure 4.6: Basic Elements of the Four in Balance Method](image)

The way of thinking relates to the pillar Vision and the way of learning to the pillar Expertise of the Four in Balance method. The way of supporting relates to the pillar ICT infrastructure. The pillar Digital learning materials is mostly related to the way of working. The way of controlling is not directly covered in this four pillars model. The way of modelling can be seen as the basis for the pillars Expertise and Digital learning materials.
We present the characteristics of a DLE for HOCS improvement in the next section.

4.9 DLE Characteristics for HOCS Improvement

From literature (Snowden, 1992; Otto, 2000) and experiences from literature, the recommended characteristics for a DLE to be successful for learning and HOCS improvement in particular, include the following:

- The DLE should create visual material that improves teaching methodologies to improve the learning process on the basis of interaction, communication and allow students to network with peers and tutors. The emphasis is on ability to identify relevant information, generate a large number of ideas of different categories or approaches (Antoniou et al., 2009).
- The DLE should have communication and collaborative tools like discussion forums, groups, building blocks to promote a constructive learning environment to develop students’ creativity. This includes synchronous, asynchronous and indirect communication.
- The DLE materials should be user-friendly and support student interaction with the resources and other students. Interactivity enables student to student and student to teacher communication. A web portal for interactivity between students and the administration can be created. The DLE structure should be easily accessed from an interactive menu which is a visual feedback for the user.
- The DLE should integrate the curricula in the content, have digital course material and be place and pace independent. The delivery of content via Internet and digital forms of communication, digital tools of expression and social networking should keep the communication to improve learning.
- The DLE should offer a learner centered experience that addresses students’ unique and specific needs. The learners’ styles, preferences, cognitive styles and learning interests should be put into consideration, when content is being designed, to enhance HOCS improvement. DLEs should promote hands-on activities with different instructional materials and products to promote learning. As we discussed in chapter 2, learning occurs through senses and styles; hence they should all be explored.
• The DLE should give students competence in selecting and executing creative solutions to the individual skill or modified problems. The students should progress to the next lesson after they achieve the presumed objectives in the current module, from the lowest and highest BT levels.
• The DLE should offer activities that can build creative thinking skills to enable students to think creatively for problem solving and decision making situations that require the use of HOCS.
• The DLE should encourage active learning for the students, as emphasized by the constructivist approach discussed in chapter 2, where the teacher acts as a guide and facilitator in the learning process rather than giver of information.
• The DLE should encourage cooperative learning so that students can learn from each other, share ideas, and exchange information with their teachers. The DLE should encourage group efforts, asking prompting questions, offering suggestions in a positive manner. The DLE should give students the option to plan and evaluate activities and products to encourage self-motivation for learning.
• Digital testing and summative assessment are also important for the DLE, to make the teachers work easy and hence encourage them to use it.

4.10 Conclusions and Recommendations
We focused on the DLE within a higher level educational institution and used RU as an example. We reviewed the typical approaches to the students' interaction and communication with the DLE. We discussed the position of the DLE in a general architecture for an institution, and discussed its efficiency and effectiveness. Then we discussed the related generic educational approach in terms of the architectural model of competence and Bloom’s Digital Taxonomy when using a DLE. Based on the study and experience from other universities, we recommend the following for successful DLE implementation.

The Four in Balance monitor highlight that the four building blocks of vision, educational software and content, ICT infrastructure and Knowledge skills and attitudes (professionalization) need to be well balanced for the DLE to work efficiently and effectively (Kennisnet, 2010). There is also need for the cooperation, leadership and pedagogical use of ICT for learning, for the efficient DLE usage.

The students and tutors should be sensitized and encouraged to use the tools in the DLE. The importance of the collaborative, interactive and communication tools for HOCS improvement and student motivation need to be highlighted for the users. They should also use the content area, formulate groups, and participate in the group discussions, chat, and group email. The tutors and students need to realize the importance of the DLEs; the more they use them the more they will benefit from the learning process incorporated within. The learning environment affects learners in different ways, therefore the more they use it, the more they will adapt new characteristics from the environment (Lubega & Williams, 2007).

Instruments can be created for students to discuss difficult concepts in DLEs, which they can continue using during internships and / or job placements. The graduates can discuss and share experiences at the work place with students to put theory into practice and these discussions may help them recall the knowledge attained in class. This enables sharing of knowledge at different levels. With these instruments, students in class will have a feel of real life problem solving and decision making, which makes them learn from the experiences of their seniors. With these skills, the students HOCS are improved by the DLE.
The existing DLE solutions should be transformed into virtual LEs featuring course tool upgrades, personal file storage space, features like e-portfolios, blogs, wikis and a virtual one-stop shop that provides users with customized information. The email component that allows students to select messages sent to their email accounts as well should be integrated.

The institutions should take advantage of the ubiquity of the DLEs to deliver information to the students' mobile phones through text messages, especially in the case of emergency announcements. The ability to run the DLE on integrated PDAs, cell phones, tablets should be explored. As we noted in chapter 3, the digital natives are more interested and motivated if technology is used for learning. Students with web enabled phones can also receive a URL link embedded in the message which they can click to see the change. Instructors can also choose what type of course information they want to send on a regular basis.

The institutions should integrate assessment solutions and capabilities which enable assessment more broadly beyond the confines of a single course. Assessment data should be put from a variety of similar courses or multiple sections of the same course. This can be done to manage the problem of the increasing numbers.

Teaching, learning and assessment should be integrated in the DLEs. The DLEs is a redefining tool that enables creation of a very complex and rich environment. The DLE should promote more interaction and communication between the teachers and students.

We also recommend the introduction of podcasting building blocks so that students can click and drag an icon for the videos to iTunes and subscribe automatically to the podcast for a course. At RU, videos of recorded lectures are stored in Bb as discussed in chapter 3.

In the next chapter we discuss the learning by construction approach for introduction of an ICT education program for HOCS improvement, building capacity and infrastructure in a LDC.
5. Learning by Construction Approach

In the previous chapter we introduced the Digital Learning Environment (DLE) as a tool for maintaining, exchanging and acquiring knowledge, skills, attitudes and competences, in particular supporting learning, teaching and studying activities. In this chapter, we focus on the introduction of the DLE in a low infrastructure context. In particular we will show how the DLE can play a central role in community development. We will focus on an approach for introduction of an ICT education program for HOCS improvement, building capacity and infrastructure.

In this chapter we describe the proposed “Learning by construction” approach, as a mechanism for the effective integration of ICT in the educational process following Bloom’s Taxonomy as a general framework for learning using the DLE. We discuss how education itself also plays a role in the introduction of DLE. This research started with some experiments which led to the introduction of an overall learning system presented in chapter 4. The results of these experiments are presented in the next chapter.

This proposed system has not yet been validated by data since there is no learning environment working accordingly. In chapter 4 we discussed the validity of this approach; in this chapter we validate its soundness by describing an introduction plan.

5.1 Introduction

As we discussed in chapter 1, the importance of Higher Order Cognitive Skills (HOCS) improvement is acknowledged by academia and industry. There is also need for capacity and infrastructure building especially in Least Developed Countries (LDCs) (Weide & Flipsen, 2010). One of the biggest problems in LDCs is unemployment; a big percentage of the graduates from the university are jobseekers who cannot find jobs. These graduates have the potential to be job creators, and to introduce new technology and opportunities in their countries. Therefore an educational approach that promotes job creation is preferred.

The importance of ICT in LDCs cannot be overstated, especially to aid students learning of HOCS improvement and solving the digital divide issue. The mobile phone has been successful in blocking the digital divide problem in LDCs. We therefore believe that an ICT education program introduced based on a proper design can be successful. For example if low cost computers that can stand hard conditions in LDCs are introduced this can solve the infrastructure and capacity building problem. We propose a solution for building capacity and infrastructure in the LDCs that also improves graduates HOCS as they are necessary for the real world work environment. We propose an approach for the introduction of an ICT education using low cost initiatives.

In regards to infrastructure development, one of the challenges is the PC assembler who assembles a computer with off the shelf parts and comes to solve problems if it malfunctions (Pal et al., 2009). Our approach strives at HOCS improvement and infrastructure set up by a PC assembler at the institution to design low cost computers for hard environmental conditions. We discuss an approach for introducing an ICT education program in LDCs for HOCS improvement.

Our approach can be related to the apprenticeship model which also agrees with the situated learning theory discussed in chapter 2.
Apprenticeship model is an agreement between a person who desires to learn a skill and an employer who needs a skilled worker. It combines on-the-job experience with technical classroom training. After completing both the classroom and the on-the-job training, apprentices can receive a system of training a new generation of practitioners of a structured competency based set of skills. Apprenticeships ranged from craft occupations or trades to those seeking a professional license to practice in a regulated profession. (What is apprenticeship, 2012)

When learning is systematically organized around a scheme of construction including development and application, then we refer to this scheme as learning by construction. We see a DLE as an effective tool to implement learning by construction, involving both development and application. In the next section we discuss the pillars of Bloom’s Taxonomy in balance.

5.2 Pillars in Balance

According to Bloom’s Taxonomy framework, learning takes place in each of the three learning domains of cognitive, psychomotor and affective, abbreviated as Knowledge, Skills and Attitudes (KSA). As elaborated by Bloom, students should gain KSA to create a wholistic learner. The domains are related in the sense that they positively influence each other, and in a balanced learning process progress in these domains goes hand in hand.

For example, a learner is assumed to have the ability to gain practical skills by following the stages of the psychomotor domain as discussed in chapter 3. The students first learn by imitation by listening, observing and imitating the instructor. Then they manipulate the skills by first imitating step by step followed by imitating the entire skill. They practice alone during the precision and articulation stages and finally the practical skills are assessed in the naturalization stage. The next phase of their studies includes training of theoretical skills as we explain in the next sections.

The learning by construction process consists of a number of steps, usually each step will take one school year. At the start of this process, we assume the student has some required abilities, personal traits, biological characteristics and a little competences and KSA gained from the previous level of education. When the student enrolls in the course, the KSA and competences increase in a stepwise approach. After completing the final step of education, they gain the general competences because they continuously put KSA into practice, and finally construct a product, hence learning by construction as illustrated in figure 5.2.

We illustrate the effect of each step using the architecture model of competence by (Roe, 1999) in figure 4.2 in chapter 4. Each step increases the level in each of the three domains. We modify
the model and the extension of (Weide & Flipsen, 2010) to demonstrate the effect of learning by construction step. A provisional teaching program is summarized in the following Figure 5.2:

![Figure 5.2: The Final Situation](image)

In the next section we discuss the learning by construction approach.

### 5.3 Learning by Construction

As mentioned before, learning by construction is an apprenticeship model systematically organized around a scheme of construction. Learning by construction is an extension of the learning by building approach that is being applied in a course community outreach project (Weide & Flipsen, 2010). Learning by Building is a method to combine education, research and valorization effectively and is the underlying education philosophy of the educational approach we propose. The practical component leads to market oriented products at the level of education and ICT like software, hardware, teachers and ICT experts, and hence provides a short term Return on Investment (ROI). If changes in the curriculum are made carefully along with adequate planning and support (Kennisnet, 2010), the approach can be successful. Based on HOCs improvement methods and Bloom’s Taxonomy learning theory discussed in chapter 2 and 3 respectively, we realized the importance of application of knowledge in novel situations. We also discussed learning theories and highlighted the importance of the constructivism theory where the learner centered, active learning approaches and knowledge construction process are emphasized. The cognitive theory emphasizes prior knowledge, application and interpretation concepts which are HOCs improvement attributes. The situated learning theory emphasizes collaborative social interaction and the social construction of knowledge and follows the cognitive apprenticeship model. Therefore all these theories emphasize the concept of construction and the different HOCs improvement attributes.

This approach therefore encourages building capacity by being enrolled in a program and also obtaining practical skills from the learning situation to build infrastructure and HOCs improvement. In the latter case, students are trained to become job creators by obtaining skills...
to create products thereby building infrastructure. As noted by (Weide & Flipsen, 2010), successful introduction of ICT in a LDC should be based on a proper design to overcome financial and environmental issues. We introduce low cost infrastructure and build education capacity using the four in balance monitor, where the vision, materials (digital), infrastructure and expertise have to be in balance for successful ICT implementation (Kennisnet, 2008). The approach is to set up an educational program with both a theoretical and practical basis. This approach follows Roes competency development program as described in the architectural model of competence, because it encourages building of KSA and competences, which is synonymous with HOCS, by emphasizing putting knowledge into practice in novel situations. We extend the learning by building and Roes competence models by introducing ICT for HOCS improvement in addition to building capacity and infrastructure.

5.3.1 The Sustainability Principle
A new development can only be sustainable if it applies at all levels of the managerial triangle. Direct consequences booked at the work floor level are most visible. However, without proper operational approach and procedures embedded in policies, these results may not be sustained. In this thesis focus is on educational aspects. Therefore we motivate our educational program from this sustainability principle. Sustainable implementation requires skills at the various academic training levels. At the vocational level students are trained to be well qualified workers and this is at the work floor level. The PhD, masters and bachelors academic levels correspond with the strategic, tactical and operational managerial levels of the organizational pyramid respectively (figure 5.3). At the bachelors level, students are trained and educated to be project leaders by having good knowledge of state of art techniques in order to supervise a project and look at it from its context. At the masters level students are trained in their research skills and to describe and optimize processes and they are trained so that they are capable of managing larger units. At the PhD level students make strategic decisions and policies. The students invent new developments using the skills gained from the PhD program and have the capability to think at a wholistic view by using the KSA and competences gained. They can model requirements and translate them into operational activities, and report at a strategic level with government. For example the Nuffic, the Netherlands Organisation for International Cooperation in Higher Education project has been successful at introducing and implementing a model similar to the strategy we propose. They initially trained the masters’ students to strengthen institutional capacity by providing education and training. The masters’ holders were later trained in their PhD studies to go back and train more students at the home universities.

Figure 5.3: Managerial Levels and Capacity Building
We see a topic-directed educational approach in-the-large as a training program involving capacity building at all these levels. Using the learning by construction approach leads to
another dichotomy. Suppose we would set up this topic-directed approach to introduce ICT in a LDC. Then the construction results will lead to strengthening the ICT infrastructure. The improved infrastructure can only be effective when at the same time capacity is built to benefit from the improved conditions, finding new challenges and creating new economic activity. Our conclusion is that learning by construction should handle both development and application. This dichotomy is displayed in Figure 5.4.

Figure 5.4: The Dichotomy

Applying this dichotomy in our example of ICT infrastructure introduction, we would start with two educational programs. One is focusing on ICT and the other on Educational Science. In the learning by construction approach, the students from both programs are learning by being involved in the process of building the infrastructure itself and educating people to use this infrastructure. Learning thus leads to construction of infrastructure and capacity, and thus aims at improving learning capability of students in developing countries. The students should learn and apply what they have learnt in practice at the same time, in order to improve HOCs. This promotes highly trained students who can apply the KSA and competences acquired in class in the work environment, which solves the problem of HOCs shortage in graduates. Because of the hands on skills acquired, the graduates are also capable of starting their own companies or training more students, hence promoting job creators and not job seekers.

In the first year of study, the students will learn the practical concepts to gain basic knowledge, skills and attitudes (KSA), which are motivated and supported by BT e.g. computer assembly skills in the ICT program is a nice topic that new students can begin with. The first year mainly deals with production and there is a product as a tangible result. The students can make computers and sell them from the computer shop at the institution at a fair price to partners like primary and secondary schools to build capacity. Students can take part in multimedia application development; they can record videos of classes to be posted on the DLE to enhance the learning process. At the end of first year the students will have a more or less well defined mix of KSA.
In the second year, students learn more practical skills for both programs especially for maintenance and the end result is also a product. Students can maintain the computers they constructed, by servicing, backing up and repairing any problems in the computer workshop at the institution.

In the third year students are trained in evaluating and reflecting on the production process to acquire the required basic theoretical skills. This year is mainly for development where theory is acquired to gain more competences by combining the KSA acquired in practice with theory. The goal of the third year is to learn theory and specialization. Initially the students get deeper insight in the DLE as a tool by looking at the general principles of the approach. Then the students focus on a particular part, review the current situation and think of its improvement, which leads to extension or modification. At the end of the year the students are expected to write a thesis in form of a business plan. The business plan involves the thesis and community development.

The basic competences can later become global competences when more theory, application and construction are studied and practiced. The more students practice the theory they have learnt, the more these competences will advance to global competences. In the next section we discuss how the steps are implemented in the DLE-case.

5.4 The Role of the Digital Learning Environment

In this section we will further elaborate on the process of introducing ICT hand in hand with education. The DLE has functions both at the low level for supporting administration and at the high level for learning. The DLE as a knowledge management center has processes related to the specific knowledge maintenance activities. The students can develop and Implement new functionalities and also make modifications to existing functionalities. Therefore DLE application can be adding functionalities by the ICT, educational students and teachers, and adding content by all teachers from the different courses.

In this section we only focus on the low cost production of the DLE. However, other products, functionalities and modules may also be produced, such as computers that are not only used in the context of the DLE, but can be sold outside of the community.

5.4.1 As a Tool to Be Used

The DLE will be used as a support tool for learning as we described in the methodological framework section in chapter 4. We also noted that students can attain HOGS improvement from the DLE if it has the characteristics of interaction, collaboration and communication.

The DLE is user-friendly, integrates the curricula in the content, has digital course material and is place and pace independent. It creates visual material that improves teaching methodologies to improve the learning process on the basis of interaction, communication and collaboration. It has collaborative and interactive tools like discussion forums and groups, building blocks to promote a constructive learning environment to develop students’ creativity. It includes digital testing and summative assessment, active learning, cooperative learning like group efforts, asking prompting questions and offering suggestions in a positive manner. The delivery of content via Internet and digital forms of communication, digital tools of expression and social networking keep the communication active to improve learning. The DLE offers a learner centered experience that addresses students’ learning styles, preferences, cognitive styles, learning interests, promotes hands-on activities with different instructional materials and products to promote learning. Generally the DLE should promote activities that build creative
and critical thinking skills for problem solving and decision making situations that require HOCS. Therefore the DLE in this case is used to gain competences and KSA following tools that address the different levels of Bloom’s Digital Taxonomy. The DLE is used as a content medium for the skills that are taught and an interaction, collaboration and communication tool for the tutors and students.

The students and tutors exchange information via the DLE’s interaction rules we discussed in chapter 4. The students are able to exchange information with each other, carry out discussions on the forums and chat. Students’ assignments can be accessed and submitted to the tutor via the DLE.

5.4.2 Designing Learning Material for HOCS Improvement

In the LBC approach we introduce the concept of designing content and software for HOCS improvement based on the HOCS improvement requirements discussed in chapter 2. The designed content will have the different HOCS improvement requirements of multimedia instructional content design, HOCS Promoting teaching and assessment strategies for actual HOCS improvement, personalized content using the learning profile from the prior knowledge and learning styles. All these requirements will be incorporated in the DLE developed based on constructivist and cognitive learning theories. Bloom’s Taxonomy also comes into play in the approach since the higher levels of the cognitive domain lead to HOCS improvement.

If content is designed to cater for the learning profile it will address the students learning preferences and styles. The personalized content will then be administered to the students, to motivate their learning. The DLE uses MM instructional materials for learning which also caters for the different learning styles and preferences because the content is in different forms. In this case the students will construct different modules, functionalities and the final product that is a functionality of the DLE. Each student or class will be required to construct a module that is a component of a DLE, which can be used by the next class or year for learning.
The functionalities the students develop will be based on personalized content where the learning profile will determine the content students should use when studying to improve HOCS. The learning profile will be determined by the pre and post test, which will test for prior knowledge and the learning style and then allocate the appropriate content for each learner to meet their learning needs as shown in figure 5.6.

The students create content that takes into account the requirements for HOCS improvement discussed in chapter 2. The functionalities in the DLE will test for HOCS improvement. We introduce the personalization concept which relates to styles of thinking, perception, and work performance being unique to any given person (Sun et al., 2004). Each individual has a different way of learning and such information is vital for learning outcomes to be achieved. The designed content based on the learner’s profile to suit a variety of learners is administered for HOCS improvement and tested. However during the administering of the content, tutors observe how learners interact with the content. The information derived is used in the analysis of HOCS improvement. The students take a post test to assess whether their perceived HOCS improved and test for knowledge attained, after administering the content. The actual HOCS improvement questionnaire is administered to test and assess actual HOCS improvement with respect to the learning profile used during the learning process. The post-test assesses how students HOCS improved by testing their problem solving, critical thinking and decision making skills.

The learning process is analyzed to determine if HOCS improved. The post-test and actual HOCS improvement results are analyzed for change in knowledge gain and HOCS improvement. The students therefore, either recreate a learning profile for better facilitation if HOCS improved and is maintained for future administering of content, or continue using the available profile. The decisions presented to the content designers are related to improving the available content to suit the learning process. When the content is redesigned, learners have better opportunities of improving HOCS. Tests for actual HOCS improvement with respect to the learning profile used during the learning process will be determined.

The approach will be evaluated by administering it on several groups of students undertaking the courses to indicate its appropriateness in testing for HOCS improvement.
5.4.3 As a Product to be Constructed

Besides using the DLE to facilitate the learning process, the DLE also is the product resulting from learning by construction.

Since the intention is to develop a product, module or functionality, we will first elaborate on the principles of product development as they are used in practise. We will first discuss a most general product development approach, and then expand on Product Lifecycle Management (PLM). In particular we will describe the so-called epicycle for the product lifecycle, and interpret it in the context of our educational program. We will see how this cycle is easily related to a learning cycle. We propose this learning cycle as the basis for the learning by construction steps as described in section 5.2.

5.4.3.1 The Product Life Cycle

The product life cycle (Figure 5.6) starts when the product is introduced, usually after its first development phase (Vlietstra, 2003). Then there is a phase where the product is being used and continuously evolving according to changing requirements of its environment. The last phase starts when the product is taken out of production, and handles the aftercare during phasing out. For our educational program, we focus on the product evolution step. Figure 5.7 gives a simple most generic view on this evolution step, referred to as the PL cycle.

In this case, a product or functionality is developed, used to test and maintain the DLE and finally updated.

5.4.3.2 The Product Lifecycle Management Cycle

In the context of Computer Aided Design, the Product Lifecycle Management (PLM) is used as a concept that integrates all information produced at all stages of the product’s life cycle to everyone in the institution at all levels including the suppliers and customers (Sudarsan, 2005, Vlietstra, 2003).

PLM is the process of managing the product lifecycle from its conception, through design and manufacture, to service and disposal (PLM, 2012). It is the integration of tools with methods, people and the processes through all stages of a product’s life cycle. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise (what is PLM, 2012). The core of PLM is in the creations and central management of all product data and the technology used to access this information and knowledge (Teresko, 2004).

PLM systems are tools for implementing the PLM concept; therefore they need the capability to serve up the information required. PLM systems enable companies to make decisions about what products to introduce and what features to include in a products design phase. The PLM
system functionality is made up of 1) IT infrastructure, 2) product information modelling architecture, 3) development tool kit and environment, and 4) a set of business applications. These provide the initial functionality: include product ontology, and interoperability standards, among others. In this section we discuss the main issues in continuous development of complex product and discuss two different approaches of the PLM cycle and the PLM epicycle.

The benefits of PLM include providing better communication, reducing costly and late design changes, reduced time to market, improved product quality, reduced prototyping costs, more accurate and timely requests for quote generation, ability to quickly identify potential sales opportunities and revenue contributions, savings through the re-use of original data and complete integration of engineering workflows, a framework for product optimization, reduced waste, documentation that can assist in proving compliance, ability to provide contract manufacturers with access to a centralized product record (Martyn, 2002).

For a product to be developed there is need for data, technology, methods, tools, processes and people. We focus on the importance of the knowledge centre and do not consider the commercial concepts. The various stages of the development process are: (1) conceive, (2) develop, (3) realize and (4) use (figure 5.8). For our purposes we will see this as:

1. Using the DLE
   a. use phase
2. Developing the DLE
   a. conceive
   b. develop
   c. realize

![Figure 5.8: The PLM Cycle](image)

The stages of the process phase of the PLM cycle are briefly described as follows (Gould, 2005)

- Conceive includes imagine, specify, plan and innovate
- Develop includes describe, define, develop, test, analyze and validate
- Realize includes manufacture, make, build, procure, produce, sell and deliver
- Use includes operate, maintain, support, sustain, phase-out, retire, recycle and disposal

We elaborate on these stages further in the next subsection.
5.4.3.3 Application to the Digital Learning Environment Case

The epicycle diagram describes the process and information flows in any product lifecycle. The figure explains the epicycle nature of PLM. The mediation of information flow across the activities of PLM is done through a common set of ontological structure and information models to represent the product and process.

In Figure 5.9, we see a compilation of the PLM epicycle for the case of the DLE development. The epicycle consists of the following stages:

- $\Phi_1$: System monitoring. During this stage the feedback on the working of the DLE (as obtained in stage $\Phi_8$) is investigated in a broader context, leading to product (modification) requests.
- $\Phi_2$: Requirements Engineering. During this stage, (selected) product requests are transformed into a requirements specification. Furthermore the development method is selected.
- $\Phi_3$: Resource allocation. During this phase the required resources are selected. For example, the project team is composed with the required infrastructure.
- $\Phi_4$: Functional design. During this stage, the project team makes a functional design of the new product.
- $\Phi_5$: Technical design. The functional design is translated into a technical design for the new product.
- $\Phi_6$: Design Analysis. The new product is built from the technical design and tested
- $\Phi_7$: Manufacturing. The approved product is then implemented in the DLE environment.
- $\Phi_8$: Product in use and societal feedback. The system with its new functionality is used

![Figure 5.9: The DLE epicycle](image)

We relate the main stages of the epicycle with the PLM cycle, discussed above as follows:

**Conceive:** The conceive phase is made up of two stages i.e. the specification of the requirements and concept design stages. The specification stage involves requirements
definition and the concept design is where the initial concept design work is carried out defining the main functional parts of the product. The investment of resources is also done at this stage.

In regard to the epicycle, it comprises of the requirements engineering (Φ₁), which includes standards and best practices, and resources allocation (Φ₂) which comprise of human, information, collaboration infrastructure and organisation. The human resource can include team resources, where teams are required to set up an educational class. It also includes product management in order to make concrete product specifications.

**Develop**: Detailed design and development of the product starts, through pilot release to full product launch. It progresses to prototype testing in the validation and analysis stage and the tool is designed and redesigned for improvement to existing product.

In relation to the epicycle, it is made up of the functional design (Φ₃), technical design (Φ₄) and design analysis phases (Φ₅). The design phase includes conceptual design (making the functional design of the requirements), the product and process. The technical design (design activities) includes the tools and design analysis where the prototype or built components are tested for performance and quality.

**Realise**: The method of manufacturing is defined after the design of the product’s components is complete. The product is then manufactured using software tools. The components of the product are built / assembled and finally tested for quality.

In relation to the epicycle, it is made up of the manufacturing (Φ₆) which comprises of supply chain and distribution stages. It includes introduction of the system or the components into the DLE.

**Use**: The final phase involves sell and deliver, maintain and support, and finally dispose. This involves managing of in service information like providing support information for repair and maintenance, recycling information and involves using tools.

In relation to the epicycle, it involves implementing a product or functionality and societal feedback (Φ₆). In this stage the usage of the system is monitored, by observing the DLE to see how it works. The teacher and student evaluations are a systematic way to evaluate the DLE performance. The students can be helpful at the evaluation levels and later help to process the improvements needed after the evaluation. The management can make the improvement proposal after the evaluation for proposed modifications after use.

### 5.4.3.4 The Production Cycle vs. the Learning Cycle

The product lifecycle is executed in the clockwise direction from conceive, develop, realise and use. The learning cycle may follow another direction. In this section we will show that the bottom-up approach of the anti clockwise direction, going from the stages use, realise, develop to conceive can be used to keep the pillars of Bloom’s Taxonomy in balance. The learning steps are summarized in Table 5.1 as follows:

In the learning cycle the student starts with supporting the use, stage Φ₆. Typically, the learner will gather data to measure the performance of (part of) the DLE by getting feedback from its users so that the learner gets an impression of the functionality of (that part of) the DLE. The learner will also get an idea of typical use cases. In terms of Bloom’s Taxonomy, the training is
at the level of evaluate of the cognitive domain, receiving and responding in the affective domain, and imitation and naturalisation in the psychomotor domain.

In the next step, stage Φ₇, the learner will contribute to the installation of developed components in the DLE system. This will give the learner insight in the technical organization of (part of) the DLE, also referred to as the architecture of the DLE. The learner is at create, characterizing and articulation levels of the domains and therefore can create a product or functionality.

Using this knowledge, the learner then during stage Φ₈, will be involved in transforming a concrete technical design into a new product (component) and to test the result. The learner will get a deeper insight in technical components, their properties and how they are applied. The learner is at evaluate, organising and precision stages of the domains.

The learner will then, during stage Φ₉, have the background to help with the composition of a technical design from a functional design. Processing the technical design will show relevant properties of a well-designed functional design, and also give a feeling of the rationale behind the functional design. The learner will also learn to appreciate product specification at a higher level of abstraction, omitting technical details that are not relevant for the functioning. The learner is at the analyse stage of the cognitive domain.

Equipped with this knowledge, the learner enters stage Φ₉, where a functional design is derived from a requirements specification. During this stage, the learner will experience what makes good requirements specification. At this stage, the learner is supposed to work at the apply and valuing levels of the learning domains.

The next learning step involves stage Φ₉, where the learner contributes to system planning, making optimal allocations of the available resources, based on the description of the requirements. At this stage the learner works at apply, responding and manipulate levels of the domains.

During requirements engineering, stage Φ₁₀, the learner has to describe the intended functionality of a new product component. The learner is at understand, receiving and imitation levels of the domains.

In the last phase, the learner is involved in the management of the DLE, stage Φ₁. The learner is at the remembering, characterizing and naturalization levels of the taxonomy and is therefore able to assess the system.

Note that during these stages, the learners will experience company management, product management and team management.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Cognitive domain</th>
<th>Affective domain</th>
<th>Psychomotor domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Φ₂</td>
<td>Evaluate</td>
<td>Receiving and responding</td>
<td>Imitation and Naturalization</td>
</tr>
<tr>
<td>Φ₇</td>
<td>Create</td>
<td>Characterizing</td>
<td>Articulation</td>
</tr>
<tr>
<td>Φ₈</td>
<td>Evaluate</td>
<td>Organising</td>
<td>Precision</td>
</tr>
<tr>
<td>Φ₉</td>
<td>Analyze</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Φ₁₀</td>
<td>Apply</td>
<td>Valuing</td>
<td></td>
</tr>
<tr>
<td>Φ₁₁</td>
<td>Apply</td>
<td>Responding</td>
<td>Manipulation</td>
</tr>
<tr>
<td>Φ₁₂</td>
<td>Understand</td>
<td>Receiving</td>
<td>Imitation</td>
</tr>
<tr>
<td>Φ₁₃</td>
<td>Remember</td>
<td>Characterizing</td>
<td>Naturalization</td>
</tr>
</tbody>
</table>

Table 5.1: Keeping the Pillars in Balance
The next section presents the organizational structure and curriculum of the ICT education program.

5.5 Learning by Construction in a Low Infrastructure Situation

In this section we describe a way to introduce learning by construction in a low infrastructure situation. We focus on the dichotomy of the ICT program and the Educational Science program offered by the ICT faculty and the education faculty of the institution respectively. For a description of a business case, refer to (Weide & Flipsen, 2010). We assume that the institution starts with the basic infrastructure of a building and electricity, a few staff and students.

The general approach includes the pillars vision, expertise, digital learning materials and ICT infrastructure to be in balance (Kennisnet, 2010). As noted in chapter 4, for a system to work effectively there is need for the cooperation and support of staff, leadership and the pedagogical use of ICT for learning (Tondeur et al., 2010). Therefore the mission and vision of the institution should be clear, the staff, students and infrastructure should be in place to enable the successful starting of the project.

Setting up the construction and ICT infrastructure requires initial capital to set up the building, electricity and computers for the successful running of the institution. The institution may then start with an initial DLE implementation such as Moodle (section 3.3.1). The institution also will start with some initial teachers. Guided by these teachers, the initial learners can make the first installation, after which these learners start with stage Φ₁ as described in the previous section. The learners may start by installing existing teaching material, and then they can start to design and implement functionalities for the DLE, following the PLM epicycle as we described.

The topics covered in the course include learning ICT by following the curriculum. The main architecture and global overview address particular issues e.g. developing a multimedia application or functionality. The students use the DLE for learning and use software tools to develop components / functionalities for the DLE. At the end, the students have detailed knowledge / experiences with some system components, leading to a balanced mix.

![Educational Structure Diagram](image)

Figure 5.10: Educational Structure

The overall introduction plan is as follows:

1. Introduction of building education capacity and infrastructure are combined. Learning should lead to construction therefore the ICT program should help in building infrastructure and the educational program in building capacity. Capacity Building involves teaching and training people to gain from the infrastructure. Students should be
able to gain the KSA and competences required to be successful in society. This involves students being part of the developing process and hence improves their learning capabilities and HOCS in particular, because they gain practical and hands on skills relevant for the work environment.

2. Short Return on Investment- the initial funds should be limited and the project self sustainable after a short period of time. The approach involves students trained to learn to gain capacity and construct infrastructure. Success is a strong motivator for positive influence on the sustainability of the project.

3. Training of job creators and not job seekers, because the graduates will improve HOCS to start their own business and hence can be less dependent on employers.

4. The approach is overall in that graduates can further build on the acquired KSA, competences and HOCS improvement as specified by Bloom’s Taxonomy and Roe’s competency model. The educational support programs are embedded in a context where there is no restriction for students to enter the program. Therefore ICT will be introduced at all levels of education.

5. Progressive growth is strongly required; therefore ICT introduction needs implementation speed.

The approach will result in ICT supported empowerment in a relevant area, which can be enhanced with entrepreneurship to make it successful. The result is the delivery of highly trained graduates who can apply state of art techniques in the real work environment. The result includes students with improved HOCS who are better equipped for the job market and can be job creators by starting their own companies or remain teachers in the educational sector to support the educational development at the various institutions. In conclusion, we start with an educational system from an ICT and educational angle. The initial phase speeds up constructing an infrastructure in an entrepreneurial way, by linking learning by construction to societal needs of HOCS improvement, capacity and infrastructure construction by the employer, academy and industry. The earning areas depend on the area of focus e.g. exporting of agriculture or donor or government funds. People will start to earn when they are employed in the institution.

Besides training, universities also have a role to prepare new developments by doing both practical and fundamental research. Universities may also be used by industry or others, as a laboratory to experiment with new lines of product development. Research universities are the central engine for the innovation economy as reflected in their educational program (Lee et al., 2008). Universities can provide knowledge for experience, capacity and education at the required levels, and hands on training which is learning by construction.

The institution requires a knowledge support and network support system from donors, government, and private sector to implement the project successfully. At the start the proposal will be sent to government and donor agencies to look for initial capital. The main target will be the software and hardware companies who can be paid back by students constructing computers and software for them to repay the funds. These low cost computers can also be sold or donated to the primary and secondary schools in the community, to enable the building of capacity and infrastructure.

The community can be involved by making primary and secondary education part of the program so that they can gain capacity and benefit from the infrastructure. The software development should be made a community project, where the school plays a central role for knowledge management for that community, as a basis for life-long learning. If the people in the community realize that they are developing computers and software products for themselves,
they will be self motivated to take part in the project. The local computer shops, factories or workshops will also take part in selling the products that are constructed at a low cost.

This approach is related to community Informatics, described as (wiki, 2012):

> Community informatics (CI) refers to an emerging field of investigation and practice concerned with principles and norms related to information and communication technology (ICT) with a focus on the personal, social, cultural or economic development of, within and by communities.

### 5.6 Conclusions

In this thesis we validate our approach by using data and by construction as we elaborate in this section. The architecture from chapter 4 is complex; learners and teachers have to learn the new interaction rules and learners should also be constructors of the new infrastructure (Roe, 1999). The experiments done initially are used to support restricted parts of the new approach. Therefore in this chapter there are relations with the experiments described in chapter 6. The methodology framework is a reflection of what people think the methodology should cover. We show that the proposed method satisfies the methodological requirements.

#### 5.6.1 Validation by Data

This can be done in two ways, the data can be used to predict that it can work or prove that it works. In both cases we fit the system to the real world situation. In our case using MM, HOCS was improved because students’ HOCS and knowledge gain increased, which is proven in the experiments described in chapter 6. The proof includes Learner profile, HOCS promoting teaching and assessment strategies for actual HOCS improvement and MM instructional content design as HOCS improvement requirements discussed in chapter 2. The results in chapter 6 also note that the DLE impacts the learning process positively, since there was increase in materials, students and course numbers. The DLE also increased the motivation and interest of the students. We believe that with more interaction, collaboration and cooperation, HOCS improvement can be enhanced with the DLE. The impact of videos on learning was positive because of the benefits highlighted like the ability to make up for colliding classes; catching up with missed lectures, preparation of class and exams, and an insight to choose an elective to take in the coming academic year. Most students said they would continue watching videos in preparation for the exam, they would have a lower exam result without the videos and they wished all courses would be recorded. Therefore the videos enhance learning interest, motivation and improve students’ performance. We present these results in chapter 6.

#### 5.6.2 Validation by Argument

We show that the approach is inherently sound by arguing that it works, also referred to as the proof of concept. During the theoretical proof, we assume underlying theories are real reflections of reality. Since a real theory is assumed to be based on the real situation, the proof also argues the validity in the context of the real situation. The proof of concept shows that our ideas are sound and dependent on some realistic arguments which rely on some reality.
5.6.3 Validation by Construction

We show that the approach is realistic by showing how it can be introduced / built. The introduction may start from a working situation, but in our case we show how the system can be introduced by starting from a low infrastructure situation. We set up a framework for the complex system architecture. We argue what learners and tutors have to learn to master the interaction rules of the new approach but the major point is that learners should also be builders of the new infrastructure system.

5.6.4 Summarizing

In this thesis experiments have been done to test particular aspects that play an important role in the learning by construction approach. These experiments are described in chapter 6. In this and the previous chapters, we have argued the validity of the proposed methodology. In section 5.5 we have shown that the Learning by Construction methodology can gradually (and effectively) be introduced in a low infrastructure environment.
6. Methods, Results and Evaluation of Experiences

In this chapter we describe the different experiments and case studies carried out during the research. We discuss the methods and results from the different experiments. In Uganda and the US, we evaluate the students’ perceived HOCS improvement when MM materials are used as compared to text book materials. In Netherlands we evaluate the effectiveness of the DLE and Video Recorded Lectures on the learning process. As a case study and proof of concept we looked at the DLE implementation and its impact at Radboud University, Nijmegen, we give some figures that give an impression. We validate this approach by motivating it from some actual experiences and data from the university to give an impression of the DLEs impact on the learning process. At the end of the chapter, we evaluate and compare the two most popular learning environments, Moodle and Blackboard Learn.

6.1 HOCS Improvement with Multimedia

The contradictory results from literature suggest that we use MM instructional technology to supplement a written case study to bring a complex technology problem to the classroom. We use online MM instructional materials developed to demonstrate the problem to the students in order to bring real world technology issues in the classroom. The study assesses the effectiveness of MM instructional materials for HOCS improvement. The instructional materials are administered by a research assistant to address the bias issue. The same instructor taught both classes to control for teacher effects. As recommended, we include measures such as actual HOCS improvement instrument, learner grades, pre and post-tests to measure HOCS improvement.

In this section we measure the impact of MM instructional materials on perceived HOCS improvement as compared to text book materials. We investigate the existing effectiveness and impact of MM case studies on creative teaching strategies. The study answers the question: “Is there a difference in the HOCS improvement of students receiving MM instruction as opposed to students receiving the traditional instruction method?” This enables us to answer the research question what is the impact of technology on HOCS improvement and the learning process? We discuss the constructs and items, the methodology, experimental results, findings and the conclusions. The contents of this section are published in (Bagarukayo et al., 2012).

6.1.1 Methodology

6.1.1.1 Participants in the Experiment

A total of 497 second year Computer Science undergraduate students from Makerere University Kampala, Uganda, that made up the operating systems class were contacted for the experiment. The students were selected because they were undertaking the operating systems course in that semester, since the case study is based on operating systems concepts. 223 students comprising of 70 females and 153 Males participated in the experiment. The selection for the control and experimental groups was random using the simple random sampling. The students using MM accessed online content and the control group accessed the case using a text book for one semester. 154 students accessed the chick-fil-A multimedia case study content on a website and 69 accessed the case study by using the text book.
6.1.1.2 Case Study Procedure
The chick-fil-A case study used in the experiment was created to bring real world problems from a company into the classroom. The MM case study was developed with the objective to provide material so that theory, practice and design could be brought together to solve real life problems and provide material that develops HOCs (Mbarika et al., 2010; Sankar & Raju 2000; Raju & Sankar 2002; Mbarika, 2003). The case study presents a scenario in which managers and the Chief Information Officer from the company selected between Windows CE and Windows NT Operating Systems for their Point of Sales (POS) terminals system. The students were introduced to the case study in a lecture session. Each student assumed the role of the CEO and was required to determine which operating system would be a better choice for the POS terminals. In making the final decision and recommendations, the student had to take the following into consideration: a) the mission of chick-fil-A; b) depreciation of existing systems; c) projected Return On Investment (ROI) of new systems; d) Total Cost of Ownership (TCO) of existing and new systems; e) employee retention, training, and education; f) alignment of chick-fil-A’s IT and Business Strategy; g) competitive advantage; and h) Chick-fil-A’s Critical Success Factors (CSF).

6.1.1.3 Instrument Development
Data was collected from students of both the control and experimental groups, in a pilot assessment by use of several questionnaires to test for the research hypotheses. The control group used the text book content, hence the traditional learning approach and the experimental group used the MM content of the case study to evaluate HOCS improvement (Raju & Sankar, 2002; Mbarika, 2003). Both groups of students filled in online questionnaires which were analyzed to determine which of the instructional methods was better for perceived HOCS improvement. The questionnaires were used to determine whether there are improvements in the students’ attitudes and perceived HOCS based on pre and post-test results. The several instruments used for the study are elaborated below:

a) Actual HOCS improvement instrument
Students were engaged in small group collaborative learning activities while using the MM instructional materials in the computer labs. We assessed students’ actual learning in terms of HOCS improvement using the student grades and assessment tools based on an instrument we developed using exam-like questions as recommended by Zoller (Appendix 3).

b) Knowledge Pre-test and Post-test questionnaire
The knowledge pre-test questionnaire was used for collecting data dealing with the content covered in the case study to assess the prior knowledge of key concepts covered in the case study. The Knowledge test was used for pre- and post-testing to assess prior knowledge and learning gains. The knowledge post-test with the same items was administered to the students after the treatment to determine whether there was knowledge achievement after the treatment.

c) Attitude Pre-test and post-test
The research adapts and improves the attitude questionnaires developed and pilot tested previously (Bradley et al., 2007). The research used a 40 item student attitude questionnaire to measure the perceived HOCS improvement construct (Appendix 1 & Appendix 2). The multi-item questionnaire was developed to evaluate whether the case study (a) successfully brought real life problems to the classroom, b) was helpful in learning difficult management and engineering topics, and c) was helpful in transferring theory to practice. The questionnaire deals with attitudes in several areas like general attitude toward subject matter, relevance to life and society, impact on cognitive domain of learning, impact on positive and negative aspects of affective domain, and impact on communication skills. The items of the questionnaire are a
result of progressive refinements and by their inclusion in multiple studies, possess a high
degree of construct validity (Hingorani et al., 1998; Goodhue and Thompson, 1995, and Mbarika
et al., 2001; 2003; Bradley et al., 2007a). These are very important concepts to evaluate
considering the many challenges that instructors encounter in bringing real world problems to
the classroom in a manner that can be grasped by the students.

Participants were asked to evaluate the effectiveness of the MM case studies in understanding
real life problems faced in the work environment, difficult management and engineering
concepts, and application of theory into practice. The perceived learning was also measured by
students' weekly reports that reflected on their learning experiences and weekly learning
outcomes throughout the course. An evaluation rubric based on document analysis was
developed to identify evidence of HOCS learning from using the MM case study. Students
reported their attitudes in these areas in relation to each question using a 1-to-5 Likert-type
response scale where 1 = 'Strongly Disagree' and 5 = 'Strongly Agree'.

The questionnaire is made up of main constructs and items corresponding to learning-driven
factors and HOCS factors and criteria to assess students' perceived learning (Table 6.1). The
questionnaire items measured the three Learning-driven constructs of learning interest,
challenging, self reported learning, learned from others and one construct of HOCS
improvement with items of problem solving, critical thinking, decision making, and other skills
(Goodhue & Thompson, 1995; Mbarika et al., 2010; Hingorani et al., 1998). The learning-driven
factor and HOCS factor are elaborated below and their items in table 6.1:-

a) The **Learning-driven factor** explains how the instructional materials will be used as a tool
to challenge the end-user in learning difficult IT and CS topics, in connecting theories and
practice, in improving students' understanding of basic concepts, and in providing the
students a platform on which to learn from one another.

b) The **HOCS factor** represents how an individual has acquired an adequate portfolio of skills
that can be used to make decisions within a specified period of time. HOCS improvement
was measured by a set of items that were validated in earlier research studies.

The questionnaire was administered before and after the case study. The pre-test questionnaire
was administered prior to intervention to collect background information related to knowledge of
the topic under study, gender distribution, overall Grade Point Average (GPA), and related
demographics. The pretest determined the students' attitudes to the subject by being
administered to all subjects prior to the treatment to determine their prior knowledge. After the
pretest questionnaire, the case study was administered by text book to the control group and
MM online content to the experimental group for a period of one semester. After the students
had accessed the content, the post test questionnaire was administered to measure the HOCS
improvement and attained knowledge. The post-test questionnaire tested for the attained
knowledge after administering the instructional materials to measure treatment effects and the
attitudes towards the material. It measured perceived HOCS improvement and the perceptions
on the improvements achieved on the different items after the case study was administered.
Table 6.1: Constructs and Items Used to Measure Factors in the Research Model

<table>
<thead>
<tr>
<th>Construct</th>
<th>Definition</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning-Driven factors</td>
<td>Composed of constructs that show the intrinsic value of the MM instructional materials to the end user.</td>
<td>Constructs include self reported learning, learning interest, learned from others, and challenging</td>
</tr>
<tr>
<td>Self Reported Learning (3 items)</td>
<td>Measure of student’s improvement of basic concepts and of identification of central management and technical issues through use of case study</td>
<td>Improved my understanding of basic concepts, learned new concepts, learned to identify central management and technical issues (Hingorani et al., 1998).</td>
</tr>
<tr>
<td>Learning Interest (3 items)</td>
<td>Measure of the level of student interest generated during and after the case study</td>
<td>Discussed technical and managerial issues outside of class, did additional reading on technical and managerial issues, did some thinking for myself about technical and managerial issues (Hingorani et al., 1998).</td>
</tr>
<tr>
<td>Learned from Others (2 items)</td>
<td>Measure of how much the students learned from each other by valuing other student’s point of view or interrelating important topics and ideas</td>
<td>Learned to value other students’ point of view, learned to interrelate important topics and ideas (Hingorani et al., 1998).</td>
</tr>
<tr>
<td>Challenging (4 items)</td>
<td>Measure of case study’s success in bringing real-world issues and problems to the classroom, was helpful in learning difficult management and technical issues and in transferring theory to practice.</td>
<td>Successful at bringing real life problems to the classroom, challenging, helpful in learning difficult topics, helpful in transferring theory to practice (Hingorani et al., 1998).</td>
</tr>
<tr>
<td>HOCS-factors</td>
<td>Improved ability to identify, integrate, evaluate, interrelate concepts within the case study and make decision in a given problem solving situation</td>
<td>Identity, integrate, evaluate, interrelate, problem solving, critical thinking, decision making (Hingorani et al., 1998).</td>
</tr>
</tbody>
</table>

6.1.1.4 Measures

The attitudes attribute refers to the measure of the students change in attitudes after accessing MM and Textual content. Bloom’s Taxonomy highlights that the students learn when there is a change in attitudes (Bloom, 1956). We measure the change in the students’ attitudes after accessing MM content as compared to the text book content by comparing the pre-test and post test questionnaires. Decision Making is the ability for the student to make a selection and justify their choice. Problem Solving is one of the attributes of HOCS which is the ability of a student to correctly find a right solution to a problem. The skills attribute deals with the ability of students to attain general skills from the content. The skills in this case include writing, presentation skills among others. As specified by Bloom’s Taxonomy (Bloom, 1956), it is important to create a wholistic learner, who has attained knowledge, skills and attitudes. Critical Thinking is the art of analyzing, synthesizing and evaluating thinking with a view of improving it (Paul and Elder, 2009). It is the ability to interpret, analyse, reason, analytically and reflectively think, draw conclusions and find solutions to problems, among others. We therefore measure whether there is a significant difference in the students’ ability to think critically when they use MM and textbook materials. The LO attribute identifies the ability of students to learn from each other. This encourages team work and collaborative learning, which is also believed to enhance HOCS.
Previous research has shown that collaboration and cooperative learning improve students’ HOCS (Kern et al., 2007; Mbarika et al., 2010).

The students were asked to indicate the extent of their agreement with the six evaluatory statements in the questionnaire that measured the constructs. The items used to measure the perceived HOCS improvement construct for the case include the following:

- I improved my ability to identify operating system issues.
- I improved my ability to integrate operating system issues.
- I improved my ability to evaluate critically operating system issues.
- I became more confident in expressing my ideas.
- I learned to interrelate important topics and ideas.
- I learned to solve problems based on business theories.
- I learned to make decisions when faced with a test.

Students evaluated the effectiveness of the MM instructional method in understanding the concepts of a typical issue faced by a manager and rate their agreement with the items on a 5-point Likert scale ranging from 1, strongly disagree, to 5, strongly agree.

6.1.2 Results
The dependent variable is the student grade measured by the post-test and the independent variable is the instructional method, MM instructional materials or traditional learning approach. The survey was to explore association between the instruction method and HOCS improvement while examining 4 dependent variables. The subjects were measured in terms of the dependent variables (pretesting), exposed to stimulus representing an independent variable (multimedia), and then remeasured in terms of the dependent variables (post testing). Any differences between the first and last measurements on the dependent variables were then attributed to the independent variable. We used the t-test because we examined two group differences such as experimental (multimedia) group and control (traditional textbook) group in terms of 4 dependent variables. The data from the pretest and post-test questionnaires collected was coded and entered with double entry procedures to ensure high accuracy rate.

During the analysis phase the data collected was cleaned, key indicators were identified and the variables compiled. Statistical Package for the Social Sciences (SPSS) was used to analyze data because it is adequate and widely used internationally. The research questions were developed and investigated using the t test. The procedure solicited the perceptions of the two groups on the impact of the Learning Driven factors, HOCS of problem solving, critical thinking, and decision making when using a multimedia case study. The procedure was used to identify the difference in perceptions of computer science students, on the impact of the Learning Driven constructs on perceived HOCS improvement when using different instruction methods. We uploaded the instruments to a website for easy access, to ease the data collection and analysis process. The data was analyzed to determine the difference in the attitudes, perceptions and whether there was an improvement in perceived HOCS of problem solving, critical thinking, decision making and other skills.

As noted in section 6.1.3, the measures used in the study are attitudes, HOCS, learning interest, Self Reported Learning, challenging, learned from others attribute, Decision making, Problem solving, skills, and critical Thinking. Several analysis procedures that include frequency, mean, standard deviation were performed to determine unvaried findings and test...
the bivariate relationships. Cronbach’s coefficient alpha, was used to assess the consistency or reliability of the scale to measure the constructs used in this study (Hair et al., 1998). The reliability tests were done using Cronbach a that was computed for each construct to identify whether the items belong together within a construct. The values of .70 and higher are acceptable levels of Cronbach’s alpha (Treacy, 1985). The alphas were .855 for attitudes, .870 for learning interest, .845 for HOCS, .926 for Critical Thinking, .864 for decision making and .881 for Skills. The high values of these alphas assured us that the items under these constructs coalesced adequately to measure the constructs.

Demographic characteristics of all 223 students who participated are described in Table 6.2, stratified by instrument. Students in MM group were of similar gender, GPA, and experience distribution to students in textbook group. In the MM group, a total of 154 students completed and returned the survey. Over the half of these respondents (66%) were male, 59% of the sample had a higher than 3.5 GPA. In both MM and textbook group, over the half of these students had less than one year experience. M represents Multimedia and T represents Text.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Multimedia (N=154)</th>
<th>Text (N=69)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>66% (101)</td>
<td>75% (52)</td>
</tr>
<tr>
<td>Female</td>
<td>34% (53)</td>
<td>25% (17)</td>
</tr>
<tr>
<td>GPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>7% (11)</td>
<td>13% (9)</td>
</tr>
<tr>
<td>2.51-3.0</td>
<td>14% (21)</td>
<td>19% (13)</td>
</tr>
<tr>
<td>3.01-3.5</td>
<td>20% (31)</td>
<td>22% (15)</td>
</tr>
<tr>
<td>3.51-4.0</td>
<td>59% (91)</td>
<td>46% (32)</td>
</tr>
<tr>
<td>Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 1 year</td>
<td>83% (127)</td>
<td>74% (51)</td>
</tr>
<tr>
<td>1-2 years</td>
<td>10% (15)</td>
<td>16% (11)</td>
</tr>
<tr>
<td>2-3 years</td>
<td>6% (9)</td>
<td>6% (4)</td>
</tr>
<tr>
<td>More than 3 years</td>
<td>2% (3)</td>
<td>4% (3)</td>
</tr>
</tbody>
</table>

Table 6.2: Characteristics of the Sample (N=223)
A comparison of individuals with and without MM instruction by factors is presented in Table 6.3. An independent sample t-test was performed to examine the impact of exposure to technology on HOCS improvement.

The results from the analysis of the student responses, means and standard deviations for the experiment are shown in table 6.4 below. Results of an independent sample t-test presented in Table 6.4 indicate that students instructed with MM had higher means for all factors, except for “decision making” and “problem solving” than those with textbook instruction. However, these differences are statistically insignificant. Unexpectedly, both decision making and problem solving factors in MM group were lower mean scores (M=.92 and M=1.68, respectively) than those with textbook instruction (M=9.04 and M=1.84, respectively). However, these differences are statistically insignificant (t=.248 and t=.761, df=221, p>.05, respectively).
Table 6.3: Descriptive Statistics of Factors

<table>
<thead>
<tr>
<th>Factors</th>
<th>Group</th>
<th>Obs.</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>M</td>
<td>154</td>
<td>43.82</td>
<td>9.77</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>42.83</td>
<td>11.18</td>
</tr>
<tr>
<td>Learning Interest</td>
<td>M</td>
<td>154</td>
<td>11.24</td>
<td>4.26</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>10.75</td>
<td>3.76</td>
</tr>
<tr>
<td>Self Reported Learning</td>
<td>M</td>
<td>154</td>
<td>3.90</td>
<td>1.63</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>3.83</td>
<td>1.58</td>
</tr>
<tr>
<td>HOCS</td>
<td>M</td>
<td>154</td>
<td>6.84</td>
<td>2.74</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>6.81</td>
<td>2.45</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>M</td>
<td>154</td>
<td>11.04</td>
<td>4.33</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>10.68</td>
<td>3.77</td>
</tr>
<tr>
<td>Decision Making</td>
<td>M</td>
<td>154</td>
<td>8.92</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>9.04</td>
<td>3.45</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>M</td>
<td>154</td>
<td>1.68</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>1.84</td>
<td>1.39</td>
</tr>
<tr>
<td>Learning from Others</td>
<td>M</td>
<td>154</td>
<td>3.21</td>
<td>1.38</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>3.14</td>
<td>1.30</td>
</tr>
<tr>
<td>Skills</td>
<td>M</td>
<td>154</td>
<td>12.91</td>
<td>5.31</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>69</td>
<td>12.44</td>
<td>5.02</td>
</tr>
</tbody>
</table>

Table 6.4: Results from Independent Sample t-test

<table>
<thead>
<tr>
<th>Factors</th>
<th>Mean Difference</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>.999</td>
<td>.674</td>
<td>.501</td>
</tr>
<tr>
<td>Learning Interest</td>
<td>.486</td>
<td>.816</td>
<td>.415</td>
</tr>
<tr>
<td>Self Reported</td>
<td>.083</td>
<td>.354</td>
<td>.724</td>
</tr>
<tr>
<td>HOCS</td>
<td>.032</td>
<td>.085</td>
<td>.933</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>.357</td>
<td>.593</td>
<td>.554</td>
</tr>
<tr>
<td>Decision Making</td>
<td>-.127</td>
<td>-.248</td>
<td>.804</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>-.158</td>
<td>-.761</td>
<td>.448</td>
</tr>
<tr>
<td>Learning from</td>
<td>.069</td>
<td>.353</td>
<td>.724</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills</td>
<td>.466</td>
<td>.617</td>
<td>.538</td>
</tr>
</tbody>
</table>

6.1.3 Conclusions

This study evaluates the impact of learning driven constructs on Perceived HOCS improvement when MM and text book materials are used by students from different backgrounds with different GPA, gender and work experience. We carried out an experiment on undergraduate students to determine the impact of learning driven constructs on the perceived HOCS improvement, when a case study was administered to two groups of students using the MM and
We performed the independent t-test for comparing means between the two groups; MM and text book. From the results we presented, there was insignificant difference between the treatment groups on students’ perceptions on HOCS improvement and the learning-driven factors. The results indicate insignificant differences were observed between students who used the MM and text book case study.

The negative results from this study agree with the findings of (Orr et al., 2001) who claim that MM-based information technology does not positively impact on learning. The similar attributes in MM and in textbook are the possible reason of the non significant differences findings. The non significant difference may be attributed to the fact that the materials were not appropriate to the Ugandan context, since the case was based on a scenario from the United States. In future we will develop materials that represent the context they are familiar with. Therefore we conclude that the exposure to MM did not impact on all the constructs as compared to the textbook materials.

The results also indicate that there was no difference in the students’ attitudes, learning interest, learned from others; self reported learning, decision making, problem solving, and critical thinking. In conclusion therefore, based on the above results, exposure to MM during the learning process was not different form the text book materials significantly. Therefore there was no advantage (advancing their HOCS improvement) of using MM materials over traditional text materials. Our study dealt with only perceptual measures of HOCS improvement were measured, therefore, the researchers restricted the study to measuring students' perceived HOCS improvement. There is difficulty in measuring actual HOCS improvement and a limited number of instruments available to measure actual HOCS improvement. Therefore the ability to measure actual HOCS improvement using multimedia instructional materials remains a challenge for future research. In future the experiment will be undertaken to measure whether actual HOCS improvement occurs when MM materials are used for instruction as compared to text. The researchers intend to measure whether actual HOCS improvement occurs by comparing students’ performance and GPA. The researchers will develop an instrument that will ask exam-like questions to determine whether the students actual HOCS improved after using MM materials.

### 6.2 Learning Driven Factors for HOCS Improvement

The contents of this section are published in (Mbarika et al., 2010). There has been limited discussion on the value of MM instructional materials in technical disciplines. The study combines results from experiments carried out over a period of three years with multiple audiences -- IT managers and students majoring in business and engineering -- to examine if MM case studies improve perceived HOCS and if so, what accounted for such improvements. We discuss the research model, variables used to explain the model, constructs and items to measure them. We discuss the methodology, a summary of the three MM case studies used, the experimental results and findings and the conclusions. We answer research questions: what is the impact of technology on HOCS improvement? “What are the factors responsible for students’ perceived improvement of HOCS when using MM case studies?” The research model (figure 6.1) shows the impact of MM on perceived HOCS and the Learner-Driven (LD) factor.

As noted by Hingorani et al., (1998), the LD factor is composed of constructs that show the intrinsic value of the instructional materials to the end user. The constructs that measure the LD factor are self-reported learning, learning interest, learned from others, and challenging. The HOCS construct was also measured. The constructs were defined in section 6.1.1.3, and table
6.1 summarizes the factors and the items that were used to measure the constructs in the research model.

![Diagram of MM Instructional Materials and Participants]

**Figure 6.1 Perceived Impact of Multimedia Instructional Materials on HOCS**

### 6.2.1 Methodology

**6.2.1.1 Participants in Experiment**

The case studies were administered in several different classes over a three-year time frame from three major southeastern universities in the USA. The participants were segmented into three groups based on the student major (business versus engineering), gender and work experience. The first group compared learning outcomes of 50 IT managers from a credit card processing company to learning outcomes of 82 students. The second group compared learning outcomes of 99 male students to the learning outcomes of 41 female students. The third group compared learning outcomes of 43 business student majors to the learning outcomes of 42 engineering students.

**6.2.1.2 Case Study Procedure**

The MM instructional materials used in this study were the Crist Power Plant case study, AUCNET USA case study, and the Operating Systems Choices for Chick-fil-A’s Point-of-Sales Terminals case study (Sankar and Raju, 2000). Each case study used in this experiment brings real-world problems from business and engineering companies into the classroom. The students were introduced to the case studies during two lecture sessions. The instructors assigned the students teams in which they worked. Each team was required to determine the best alternative by choosing from the different options available to solve the problem at hand. The decision taken had multimillion dollar implications, therefore the students had to put cost, company mission and business issues into consideration before choosing an alternative. The
teams finally came up with a report and an oral presentation defending their decisions and recommendations. The students then completed the post test questionnaires and indicated how their learning improved in terms of the HOCS and LD constructs. A summary of the case studies and how they were implemented in the classrooms are provided below.

The Chick-fil-A Case Study illustrates the management decisions Chick-fil-A faced as the organization prepared to move from its current Point-Of-Sales (POS) system to a choice between two operating systems. It was defined in section 6.1. Students were asked to rate their agreement with the items above on a 5-point Likert scale ranging from 1, strongly disagree, to 5, strongly agree.

The Crist Power Plant Case Study illustrates a real live plant outage which emphasized the planning and implementation process for the plant manager. The case study on MM CD-ROM introduces the problem to the students with a video of the plant manager sharing the problem followed by a thorough explanation of the issues and criteria used to solve the problem. The manager discussed the problem and provided the assignment to the students. The students assumed the role of a plant manager working with an expert system to refine their decisions and chose among multiple alternatives for maintaining a turbine-generator at a power plant to solve the $2 million problem. The students analyzed and solved the problem. They presented their findings using a PowerPoint presentation and a written report. The concepts covered are project management, planning, vibration principles, and decision-making. The instructional materials included the following multi-media components: Videos, audios, photos, and animation augmented the student's ability to grasp the complex business and engineering materials and made it possible to apply theories they had learned in other classes to solve the problem. Figures 6.2 and 6.3 illustrate photos and videos used on the main screen of the Crist power plant case study, where students had the option to play the video or read the text version of the case study related to that screen.

Figure 6.2: Snapshot of Screen Design
The AUCNET USA case study details the real world example of Aucnet-USA and their online auto auction system along with their network for conducting auctions. Students took on the role of managers for this online auto auction company. They had to choose between a satellite network, a network based on low earth orbiting satellites, or a network based on internet technologies. Upper management was concerned that the e-commerce company had not made a profit since its inception and was dependent on capital infusion from AUCNET Japan to function. The number of dealers had dropped from 700 (at the peak) to 300. The concepts covered were entrepreneurship, e-commerce technologies, strategic planning, satellite technologies and internet technologies.

6.2.1.3 Instruments Development

The Knowledge test and attitude questionnaires were used for collecting data dealing with the content covered in the case study and students attitudes and perceptions respectively, as explained in section 6.1.1.3.

6.2.2 Results

SPSS was used to analyze data. The t-test was used to compare the means of the pre and post achievement tests in order to analyze knowledge assessment. To compare the results of each pre and post category, a paired-sample correlation and descriptives on the attitude survey results were run. During the analysis phase, we used to investigate the nature and extent of the relationship between the intervening variable (i.e. students' majors, gender, work experience) and their perceived improvement of HOCS. Cronbach's alpha was used to assess the internal consistency or reliability of the scales designed to measure the constructs used in this study. The values of .70 and higher are acceptable levels of Cronbach's alpha (Treacy, 1985). The results from the analysis of the student responses, means and standard deviations for all three experiments are shown in Table 6.5 below. The value of the mean for all of the constructs is above 3 (neither agree nor disagree) showing that the students perceived improvement in all the constructs irrespective of the group that they belonged. In addition, the difference between the following groups and constructs was significant at a 0.01 level.
Among all the experimental groups involved in this study, it was found that participants reported improvements in perceived HOCS, self-reported learning, learning interest, challenges to their thought process, and learning from others.

6.2.2.1 Self-Reported Learning

The results indicate that IT managers and all experimental student groups perceived an improvement in their self-reported learning by using the MM case studies. This is well illustrated by the mean values in Table 6.5. This suggests that the MM instructional materials improved participants’ understanding of basic concepts, new concepts, and helped them to identify central management and technical issues from the case study. Furthermore, the findings support the results from (Ehrlich and Reynolds, 1992) study where MM provides an opportunity to reach people with different learning styles, different skill levels, and also offers the potential to reduce the learning curve and accelerate the learning process. Reinforcing this finding, some survey participants -- IT managers and all the experimental student groups—commented in the e journals as follows:

"I practiced breaking down a problem situation and looking at all component aspects of the problem including costs vs. risks, materials available, and use of resources to make an intelligent decision on how to treat the situation at hand. I learned that a new product may not always be the correct choice based on compatibility issues and cost analysis vs. functionality."

"I learned about the many different risks that are involved in making decisions. It is helpful information to use when making any kind of engineering decision."
“Currently, I work at the IT Help Desk and I can tell how much the class has affected my work. I am able to speak about the technical aspects with others and understand what they are talking about. I’m not sure specifically how I could use the information I’m learning today for my future career. Technology changes so rapidly that what I learn today may not be the way it is done in the future. However, this material is giving me the foundation I need to build on so that I’ll be ready for the next change. This has been the most informative and fun learning experience I have had in my college experience.”

“I learned how to use the available technology to solve business problems. I feel more confident now when it comes to talking to others about the specifics of telecom.”

The figures (a), (b), (c) show the mean values of the constructs for the three experiments as presented in table 6.5 below:

(a) Experimental 1 Chick fil A Case Study

(b) Experimental 2 CRIST Case Study

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6.2.2.2 Learning Interest

The perceived learning interest of the IT managers and all the experimental student groups were more enhanced and the participants’ interest during and after the experimental class sessions were sparked. This is well illustrated by the mean values in table 6.5. Some of the participants commented as follows:

“I find the material relatively simple to understand. Keeps me interested in learning more about current and past issues. I have enjoyed working on an actual problem. This really keeps me interested because I see the theories that I learn in school applied in a practical environment.”

“I also enjoy the simulated responsibility of studying the problem from different points of view, and from the information given, generating questions and at least forming a personal opinion on how the situation should be handled.I was very interested and impressed by the Expert Choice software used in analyzing the various options. I had never previously seen such a decision-making aid.”

“I enjoyed learning about how the telephone systems work. It’s fascinating to see how it works and most of the time we don’t even think about it – we just take it for granted.”

“I thought that the material was very interesting and related well to the technology we are already familiar with.”

“Keeps me interested in learning more about current and past issues.”

“I enjoy all of it, it is going to be my career and I enjoy learning.”

These findings agree with the (Jonassen, 1989) study which say MM is attention capturing and engaging to use. Another important fact associated with enhancing learning interest is that the authors observed that the IT managers and the students discussed technical and managerial issues even after the case study sessions; a rare occurrence indeed in academic settings where students get bored quickly with topics and lectures.

6.2.2.3 Learned from Others

The IT managers and all the experimental student groups perceived that they learned from others with the MM instructional materials during their group interactions. This is well illustrated by the mean values in table 6.5. In this respect their perception relates to learning from their
group members by discussing and interrelating important topics and ideas. The findings reinforce past studies which indicated that MM increased interaction among students (Adams et al., 1996; Goodrum et al., 1993). Some students commented:

“I have learned to be more open to new material and ideas and really learn from them. I feel that through understanding the material I had to look at problems from every angle and even listen to others' viewpoints in order to solve the problem. I feel I have become better at problem solving.”

“I also enjoy the simulated responsibility of studying the problem from different points of view, and from the information given, generating questions and at least forming a personal opinion on how the situation should be handled.”

Overall, majority of the students enjoyed learning from others as they worked with the instructional materials as can be noted by their following comments:

“As I worked with my group, they brought up ideas, viewpoints, and questions that I had not thought of myself. This helped to quickly expand my knowledge of the case and develop a defense for our chosen method to solve the problem at hand.”

“When engineers work together, it seems that the product is more than the sum of the individuals. I think I'm starting to learn just how powerful a few motivated engineers can be when they work together.”

“I enjoyed hearing my group's points on which one they think is the best, worst and why. It was interesting to hear what they had to say and why they chose which options. It was interesting to see how different people come out with different ideas even though we all read the same thing.”

‘While working on the presentation, I learned that working with a group gives new perspectives at the topic. There are many different ways of looking at something and many solutions to problems as well.”

“...the most enjoyable aspect to the case study is the group work that is involved with the case study participation.”

6.2.2.4 Challenging
The IT managers and the students perceived that the material was challenging and fostered teamwork. Woolf & Hall, (1995) believe that the MM approach challenges students to want to learn. DiPasquale & McCabe, (1993) argue that MM makes students really sit up and focus on what's going on. Some students commented:

“I enjoyed learning about the material that is presented to me because it stimulates my thinking which makes me think that I'm in the right major.”

“I enjoyed the challenge of the case study. One of the reasons I chose to become an engineer is because I love challenges. Challenges are sometimes the best way to learn.”

“It was difficult to decide which option would be best. There were enough missing variables that we did not have complete information about that made the decision tough,
These findings indicate that designers of instructional materials for difficult technical and engineering subjects, whether in an academic or business-related environment, need to include materials that will help enhance self-reported learning, improve learning interest, provide opportunities to learn from others, and challenging learning.

6.2.3 Conclusion
The research evaluates the effectiveness of MM instructional materials in conveying technical issues to IT managers and students from different backgrounds with different subject majors, gender and work experience. The results show that the IT managers and the students who participated in MM case study exercise perceived HOCS improvement. The findings show that MM aids in improvement of students’ perceived HOCS. This concurs with (Mbarika’s et al., 2003) findings that MM instructional materials have a positive influence on LD factors. The results from this study maintain that the traditional lecture methodology is not sufficient in presenting complex engineering and technical information and it is important to develop tools such as MM instructional materials that can provide students with the ability to bring real-world issues into classrooms.

For the learning process to be effective the audience needs to be challenged and provided with opportunities for learning from self and from others. If this study is replicated in other settings, it may identify the need to create a wider set of MM instructional materials that could be used to communicate complex IT and engineering problems to students. The positive results from this study and the findings from the literature indicate that it is critical that MM instructional materials be developed for further use in technical and engineering fields to bring real-world issues into classrooms. The improvement in the learning is also attributed to team work and interactive learning through MM.

In light of rapid technological developments the effectiveness of instructional design hinges upon increasing cognition of complex concepts for improved and faster decision-making. These findings suggest important ramifications for use and development of MM-based instructional materials as an aid in improvement of perceived HOCS. MM-based learning and decision-making tools were found to help in improvement of other perceived skills such as challenging, learning interest, learning from others, and self-reported learning. These results have implications for organizations and learning institutions pertaining to adapting to different learning styles, and enhanced and increased group-collaboration.

In the next section we discuss the effects of the DLE on the learning process at an institution.

6.3 Learning Process Improvement with a DLE
The contents of this section are published in (Bagarukayo et al., 2012). In this section, we present some data to give an impression of the DLE usage at Radboud University Nijmegen (RU). We discuss the methodology, the experimental results and conclusions.

6.3.1 Methodology
As a case study and proof of concept we study how the Digital Learning Environment (DLE) has made the learning process more efficient at RU. In this section we show some figures that give an impression of the effects of the DLE on the students’ performance. In this study, we address the question, “what is the effectiveness of a DLE in the classroom and how does it impact
6.3.2 Results

We present some data to give an indication of the usage of Blackboard at RU.

6.3.2.1 Participation

An overview of students’ participation in Bb is shown in Table 6.6. It shows the increase of usage both by students and teachers. This is grouped per faculty, showing that all faculties show an increasing interest, despite the different policies as elaborated previously.

Table 6.6: Courses Actively Using the Grade Center

<table>
<thead>
<tr>
<th>Faculty</th>
<th>No of courses in 2009-2010</th>
<th>Second phase, no of courses with at least 1 item in Grade Center 2009-2010</th>
<th>Second phase, % of courses with at least 1 item in Grade Center 2009-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>FU-aggo</td>
<td>148</td>
<td>15</td>
<td>10%</td>
</tr>
<tr>
<td>FU-awfi</td>
<td>83</td>
<td>1</td>
<td>8%</td>
</tr>
<tr>
<td>LETT</td>
<td>865</td>
<td>209</td>
<td>24%</td>
</tr>
<tr>
<td>FDR</td>
<td>207</td>
<td>51</td>
<td>11%</td>
</tr>
<tr>
<td>FSW</td>
<td>465</td>
<td>127</td>
<td>18%</td>
</tr>
<tr>
<td>FdM</td>
<td>328</td>
<td>46</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 6.7: Courses Actively Using the Grade Center

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Number of students in Bb in 2009-2010</th>
<th>Number of instructors in Bb in 2009-2010</th>
<th>Number of courses 2008-2009</th>
<th>Number of courses 2009-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>FU-aggo</td>
<td>148</td>
<td>56</td>
<td>148</td>
<td>148</td>
</tr>
<tr>
<td>FU-awfi</td>
<td>83</td>
<td>38</td>
<td>74</td>
<td>83</td>
</tr>
<tr>
<td>LETT</td>
<td>4.100</td>
<td>482</td>
<td>736</td>
<td>865</td>
</tr>
<tr>
<td>FDR</td>
<td>2.284</td>
<td>273</td>
<td>230</td>
<td>198</td>
</tr>
<tr>
<td>FSW</td>
<td>5.338</td>
<td>579</td>
<td>499</td>
<td>465</td>
</tr>
<tr>
<td>FdM</td>
<td>3.356</td>
<td>281</td>
<td>330</td>
<td>328</td>
</tr>
<tr>
<td>FNWI</td>
<td>2.293</td>
<td>568</td>
<td>459</td>
<td>522</td>
</tr>
<tr>
<td>FNWI</td>
<td>1.877</td>
<td>931</td>
<td>172</td>
<td>156</td>
</tr>
</tbody>
</table>

There was a general increment in the number of courses from 2008/9 to 2009/2010. The increase in the number of students’ over the years is also a success indicator. This therefore indicates that the number of students using the DLE is increasing, therefore a successful DLE.
6.3.2.2 Activity

We assume that the number of announcements per course may be seen as an indicator of the level of activity for the course. In table 6.8 we see the increase in announcements per course over the period 2008 – 2010.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FU-aggo</td>
<td>156</td>
<td>50</td>
<td>47</td>
<td>51%</td>
<td>32%</td>
<td>7</td>
</tr>
<tr>
<td>FU-awfi</td>
<td>74</td>
<td>34</td>
<td>34</td>
<td>46%</td>
<td>41%</td>
<td>6</td>
</tr>
<tr>
<td>LETT</td>
<td>766</td>
<td>382</td>
<td>482</td>
<td>49%</td>
<td>56%</td>
<td>5</td>
</tr>
<tr>
<td>FdR</td>
<td>198</td>
<td>147</td>
<td>155</td>
<td>74%</td>
<td>75%</td>
<td>2</td>
</tr>
<tr>
<td>FSW</td>
<td>499</td>
<td>305</td>
<td>315</td>
<td>61%</td>
<td>68%</td>
<td>3</td>
</tr>
<tr>
<td>FdM</td>
<td>330</td>
<td>284</td>
<td>282</td>
<td>86%</td>
<td>90%</td>
<td>1</td>
</tr>
<tr>
<td>FNWI</td>
<td>459</td>
<td>266</td>
<td>303</td>
<td>58%</td>
<td>58%</td>
<td>4</td>
</tr>
<tr>
<td>UMCN</td>
<td>156</td>
<td>156</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.8: Courses with More Than 1 Announcement per Faculty

There was an increase in the number of announcements from 2008 to 2009. This indicates that the DLE is successful because there is increase in usage.

<table>
<thead>
<tr>
<th>Course</th>
<th>Available courses 2009-2010</th>
<th>Total number of Announcements 2009-2010</th>
<th>Average number of Announcements per course 2009-2010</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>FU-aggo</td>
<td>148</td>
<td>244</td>
<td>1.6</td>
<td>8</td>
</tr>
<tr>
<td>FU-awfi</td>
<td>63</td>
<td>371</td>
<td>3.3</td>
<td>3</td>
</tr>
<tr>
<td>LETT</td>
<td>385</td>
<td>3.410</td>
<td>3.9</td>
<td>3</td>
</tr>
<tr>
<td>FdR</td>
<td>207</td>
<td>1.462</td>
<td>7.1</td>
<td>2</td>
</tr>
<tr>
<td>FSW</td>
<td>465</td>
<td>2.940</td>
<td>6.3</td>
<td>4</td>
</tr>
<tr>
<td>FdM</td>
<td>328</td>
<td>3.207</td>
<td>9.8</td>
<td>1</td>
</tr>
<tr>
<td>FNWI</td>
<td>522</td>
<td>3.031</td>
<td>5.9</td>
<td>5</td>
</tr>
<tr>
<td>UMCN</td>
<td>156</td>
<td>1.309</td>
<td>8.4</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 6.9: Average Number of Announcements per Faculty

The number of announcements for the available courses increased therefore indicating success of the DLE.

Unfortunately the data on collaboration, interactivity and performance was not available because of confidentiality, privacy and ethical issues. However, the performance on the educational process may be measured by the increase in the fraction of the students passing.

6.3.3 Conclusions

The results from the tables above therefore aid in the measurement of how the system is embedded in the institution. By looking at the statistics above on the number of active courses using the DLE, we can strongly state that the number of the courses, students and announcements posted are increasing annually and therefore indicate improvement in communication and collaboration, which improves HOCS. We used these results to motivate DLE implementation in low-infrastructure countries in the previous chapter. In the next section we discuss the impact of video recorded lectures on learning at RU.
6.4 Learning Process Improvement with Videos

6.4.1 Introduction
The contents of this section are published in (Bagarukayo et al., 2011b). In the Netherlands, three technical universities, TU Delft, TU Twente, and TU Eindhoven, are currently using this new video technology (Dijk et al., 2010). The University of Delft has 8000 hours of lectures on the Internet, with 30 employees to record and upload the videos online. Some universities use shredded video lectures spread over several departments. At Radboud University Nijmegen (RU), video recording of lectures started in 2007 at the Faculty of Natural Sciences, Mathematics and Computer Science (FNWI). The social science faculty also introduced video recordings for their therapy lectures. The educational centre of the FNWI decided to record the lectures on video to determine whether they would improve the learning process. The recorded lectures are placed in the respective courses in the Bb.

The introduction of videos of recorded lectures in Bb is a new educational functionality. Bb is the medium in which the videos are presented. There is a link to the videos server on Bb for students to access the videos within a particular course for which they are enrolled. If a teacher agrees to record their course, the recordings are made available as M4V and / or Flash movie. The teacher can display the recordings in QuickTime, Windows Media Player etc. Some teachers do not want to be recorded for different reasons e.g. they may not want the course materials to leave the classroom for copyright issues. In case the teacher does not want to show the videos, he is allowed to remove the code linking to these files by choosing ‘Course Materials’ and ‘Video Recordings’ in Bb. The teachers have the ability to remove the videos from Bb, but not from the server. However, the teachers need to realize that the students do appreciate the video recordings because of the benefits highlighted later in this section.

At the beginning, there were 300 video recordings which have now escalated to 1200 new videos every year. The hardware, software, internet and power are the main requirements for a successful video recording session. The video recording boxes are the hardware where all the necessary equipment is stored. The recordings were initially done using simple cameras with a tape to record the classes. The videos are stored on the server, which currently has approximately 6000 hours of recorded lectures on the intranet for students to access. The analogue signals are converted to digital signals and it is possible to choose the recording to make. The current recordings are High Definition recordings concurring with the advancement in technology. Compared to the recording capacity, it is not possible to record all the 550 courses every year, so the video recordings are done in turns. The criteria used to choose which course to record is based on when it was last recorded. For example, if a course is recorded this year, it may be skipped next year to give other courses a fair chance. The Bb user statistics and the web server statistics are used to determine how often the video recordings are used.

Learning videos provide content in different formats like text, audio, sound, pictures among others, thereby providing MM content. The content can therefore address students’ different preferences and styles and therefore enhance learning and HOCs improvement in particular. Video recorded lectures offer flexible education tailored for increasing academic success since the conceptually difficult courses are recorded enabling anywhere anytime access at any pace, thereby enabling students to study difficult concepts of the courses repeatedly. The videos are effective because of their convenience for anytime, pace and place learning and repetition is encouraged, since students can look at content over and over again in case it was confusing the first time. The videos enable students to watch a lecture they were unable to attend, understand difficult concepts and to further process material from the lecture. The students who watch
videos again have more time on task and are more motivated and interested in the first place than those that do not. Research done on the effects of video lectures shows that they have a positive effect on the motivation and success of students (Arias et al., 2011). Students pay more attention, are more involved, better prepared for exams and get better grades. Since the videos offer the advantages above, this indicates that learning is enhanced. The ability of students to view content repeatedly and at their convenience also enhances learning. However, research at the University of Florida also shows that the learning efficiency of students, who attend classes only once, is lower than that of students who were in the lecture full time. Therefore students should be encouraged to attend class even though the videos will be available on Bb.

6.4.1.1 Flash player of the first generation

Bb has a flash player that offers online viewing of video files in the MV4 format. The videos can also be downloaded onto the PC for offline viewing. Bb checks that the flash player supported on the server system can handle older versions. The folders contain a combination of files generated from the recordings arranged by date. In Bb the videos are shown in a sub frame on the screen, using the iframe technique from HTML. The first generation flash player shows the single view video, with the recording of the teacher on the Bb without extra functionalities.

6.4.1.2 Flash player of the second generation

A second generation recording flash player is available in Bb, although, the old recordings can still use the first generation flash player. The second generation flash player brings new advanced options, combining video, slide presentation and some extra functions to ease the usage of this facility. With the second generation flash player the videos can be downloaded but cannot run standalone. The students can use a button, which shows a chapter index, to zoom the video or slideshow. The student can skip to another part of the video using the chapter list or a button in the scroll bar; however, they cannot skip to a slide which is not yet downloaded. The new flash content enables the student to access different views of the video. It shows the teacher and the power point presentations at the same time. Therefore students can switch their views between the power point presentations and the teacher on the Bb. There is a window that displays the chapter or the power point slides outline, which enables students to switch between slides. The slide outline view enables the student to view the different presentation slides. Therefore, the student can select the slide they want to view without having to go through the entire presentation.

The player has a search field on top of the chapter index that enables students to search for text in the PowerPoint slideshow. Therefore, students have the ability to search for a particular slide or topic by typing the key words, to search for the video they want to access. This view also maintains the teacher explaining the topic the student has searched for. This makes it very user friendly since the student does not have to go through the entire presentation each time. The new flash player uses XML files generated from the video recorded files to make this search functionality possible. The search uses Optical Character Recognition (OCR) to scan for text in the power point presentation and saves the XML file on the Podcast server. OCR techniques are used to disclose information contained in slides. The Multimedia department at the FNWI strongly recommends using text and not images at the beginning slide, to improve the OCR processing. With the new format, a video file can be downloaded and accessed from anywhere without necessarily having internet access. For the power point, the VGA signal is captured, copied and converted to another signal to scale it down to a smaller signal. It compares the difference in signal between the first and second slide.
6.4.1.3 Video Recording Lay-out and Processing

Two cameras are used during the recording sessions; one is for recording the power point presentations and the other records the teacher explaining on the traditional Bb. The two types of video recordings student can view in the recording application software include the single view with the teacher on the black board, and the Picture in Picture (PiP) view where three quarters is the power point presentation and a quarter of the screen is the teacher on the black board. The Single view where only the teacher is recorded uses a remote controlled camera, controlled by a student to record one video. The recording is stored on the recording system. The robot zoom camera rotates by using the controller to capture all the different views of the teacher in class when recording the video signal. The PiP is where the teacher and Power-point (computer display) are both recorded, is a single video built from two sources showing a small rectangular video at the lower left corner, with the video recording of the teacher and the Power point presentation (VGA capture of the laptop / beamer) in the main parts of the video. Two videos are recorded where the first video is the recording with a remote-controlled camera of the teacher explaining on a traditional Bb and the second video is created by capturing the VGA / DVI output of a PC, connected to some beamer to display the power-point presentation. The remote-controlled camera is controlled by a student, who is in charge of starting and stopping the recording. Both recordings are stored on a dedicated recording system, a Macintosh laptop or MacMini with two fire wire Interfaces. The recording system requests for its schedule from the server once a day. Once the schedule is known, the system is capable of creating and storing the recording for that day without being connected to the network. Once reconnected to the network the system sends its recordings back to the servers for further processing.

Post Processing - Processing is converting the analog signals to PiP recordings. Once a recording is sent to the Servers, it is scheduled for post processing. Post processing depends on the type and version of the schedule selected when starting the recording, called work-flows. There are several work-flows: one for ‘Single’ recordings, one for PiP recordings and some special purpose and test work-flows. The result of this post processing is usually three movie files: a MPEG4/H.264 movie with a resolution of 640x480 pixels specifically used for download, a flash video movie for displaying inside websites using JW Player and finally a proprietary XML/H.264 video to be displayed inside the website using the proprietary recording player. The XML version is a MPEG4/H.264 video combined with pictures captured from the movie created from the VGA output. Changes in the VGA output usually trigger taking some snapshots which

Figure 6.4: Video Recording Screen Shot On Bb
are run through OCR software to capture the title of that sheet. The movie file, snapshots, time stamp and title are entered into some XML indexing file. The recording player uses this XML file to display the recording and the snapshots of the Power point presentation. After post processing the recording, the movies are automatically published on the web server. Data of the recordings like author, title, course ID, dates and the URLs are stored in the MySQL database. The web server itself then has scripts that use the course ID to select all recordings of lectures belonging to the course.

6.4.1.4 Video Recording Process in General
There are three different kinds of software used during the video recording process
1. The software on the laptop for recognizing and capturing information from hardware
2. The software on the server for recognizing the recorded lectures
3. The software for starting and stopping the video watching sessions

The entire process of the video recording is automated. Since all the lecture rooms have internet, the recorded videos are automatically transmitted to the server for conversion to the different formats that students can view. The server receives the recorded videos automatically, which are then converted into different formats and sent to Bb, where the students can access them. The recording box application shows the schedule, recording dates and the status of the video recordings which are edited when a recording is completed. When a lecture is recorded, courses have two links on Bb for the two different video formats – Shockwave Flash and MOV video files. The recorded videos are sent to the servers which process them by rendering them and generating the different flash versions which are stored on the Redundant Array of Independent Disks (RAID). The current flash player identifies the course numbers and automatically puts the video on the Bb link under that particular course. The students can access the video on Bb within an hour(s) after the class has taken place, depending on the type of recording. A single recording where only the teacher is recorded is available on Bb within an hour, and within two or three hours for the PiP recordings. The teachers have the right to remove the links to the video in Bb, for whatever reason. Teachers are encouraged to repeat the questions students ask in class to capture them in the recording. The videos are edited on rare occasions due to the high labour cost, e.g. if the recording started before the students had settled down.

The videos are stored on the server, which has a backup server to avoid disruption in service and rebuilding, in case of failure which may lead to information loss. The backups are incremental; the backup system uses software solutions, and is independent of hardware. The backup software was compiled and installed on the servers. The Macintosh backup server uses free OSS called Amanda, to back up the videos, in case the server collapses or information is lost. The RAID discs are mirrored so that if one breaks down, the synchronizing software copies the information from one disc to another. In the beginning all movies were stored, processed and published on the Macintosh server and its RAID Array. As time passed space requirements made it necessary to fork the web server and move storage to a "bigger" machine. The Computing department chose to offload these functionalities to a Linux Server.

6.4.1.5 Monitoring a Video Recording Session
We visited a class where a lecture was being recorded on video. The equipment comprised of a recording box, with a robot camera and a laptop. The teacher was using the traditional chalk and Blackboard method to teach the students. The person recording therefore focused on the teacher’s explanations along with the notes she made on the Blackboard. The person recording kept moving the recording stick or controller to capture the different teacher views, since she was mobile. The noise students make can interfere with the recordings but the microphone, the
teacher wears on the chest, is specially made not to capture sound far from the teacher's mouth, therefore it picks only the nearby signals. The audio signals from the microphone are sent to the recording box. When the recording session or the class is done, and the person recording clicks 'stop', the video is automatically sent to the server. The recording box software on the podcast system captures the videos from the server on the link http://recordingserver.science.ru.nl/

Figure 6.5: Video Recording Session

6.4.1.6 Draw Backs of Video Recordings
On the whole, there are fewer errors today as compared to when the video recordings began in 2007. The layout of the 'flash' videos needs more in built interactivity like a search engine. There is also need to fully automate the process from ingest to the delivery of the videos. Some of the problems faced with the video recordings include wrong course names on the videos. If the Power point slide presentation starts with a picture on the first slide, this also causes problems for OCR processing. If the teacher forgets to repeat a student’s question for recording purposes, this creates a problem because the question will not be captured in the video recording.

A pilot survey was carried out to determine the impact of video recorded lectures on the students learning process. We present the findings from the survey indicating that students benefitted from the videos. We answer the research question 'what is the impact of technology (video recorded lectures) on the learning process?' The next section describes the methodology followed the results from the study and the conclusion.

6.4.2 Methodology
A survey was carried out on the use of video recordings during lectures at RU to assess the impact of videos on students learning. Out of the 2100 students contacted by email to take part in the survey, 994 started and 911 completed all the questions which approximates to 43%. The students from FNWI took part in this study since it is the only faculty with video recorded lectures currently, apart from the therapy lectures in the faculty of Social Sciences. The questionnaires were hosted on a website, from where the students filled and received feedback. The student population was from several backgrounds of Biology, Information Science, Medical Biology, Physics and Astronomy, Chemistry, Mathematics, Molecular Life Sciences, Natural Sciences, thereby representing the entire faculty. 29% were first years, 19% second years, 19% third years, 12 % were fourth years and 21% were from 5th year and above.
6.4.3 Results
The students’ responses to the questionnaires indicate that 69% had viewed the videos on Bb and 31% had not watched the videos in the academic year 2010/2011 and the previous years. It is noteworthy that the number of students in the ‘5th year and above’ that had not seen the video was high. Among the 69% who watched the videos, 52.2% look at the videos sometimes, and 47.8% look at them regularly.

<table>
<thead>
<tr>
<th>Year</th>
<th># Yes</th>
<th>%</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year</td>
<td>272</td>
<td>79%</td>
<td>56</td>
<td>21%</td>
</tr>
<tr>
<td>2nd year</td>
<td>173</td>
<td>74%</td>
<td>45</td>
<td>26%</td>
</tr>
<tr>
<td>3rd year</td>
<td>181</td>
<td>76%</td>
<td>43</td>
<td>24%</td>
</tr>
<tr>
<td>4th year</td>
<td>117</td>
<td>70%</td>
<td>35</td>
<td>30%</td>
</tr>
<tr>
<td>5th year and above</td>
<td>200</td>
<td>46%</td>
<td>109</td>
<td>55%</td>
</tr>
<tr>
<td>average %</td>
<td>69</td>
<td></td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.10: Students Viewed Videos

<table>
<thead>
<tr>
<th>Year</th>
<th># sometimes</th>
<th>%</th>
<th>Regularly</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st years</td>
<td>215</td>
<td>58%</td>
<td>90</td>
<td>42%</td>
</tr>
<tr>
<td>2nd years</td>
<td>128</td>
<td>56%</td>
<td>57</td>
<td>44%</td>
</tr>
<tr>
<td>3rd years</td>
<td>138</td>
<td>55%</td>
<td>62</td>
<td>45%</td>
</tr>
<tr>
<td>4th years</td>
<td>82</td>
<td>44%</td>
<td>46</td>
<td>56%</td>
</tr>
<tr>
<td>5th years and above</td>
<td>91</td>
<td>48%</td>
<td>47</td>
<td>52%</td>
</tr>
<tr>
<td>average %</td>
<td>52.2</td>
<td></td>
<td>47.8</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.11: How Often Students View Videos

There was a high number of 4th and ‘5th year and above’ students that regularly view the lectures on video. The following section details the students’ reasons for watching the video content.

6.4.3.1 Reasons for Watching Video Recorded Lectures
The students had several reasons for watching the videos after the lecture had taken place.

<table>
<thead>
<tr>
<th>Item</th>
<th>Watched %</th>
<th>Not watched %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation for Coming Lectures</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Catching up with missed lectures</td>
<td>34</td>
<td>66</td>
</tr>
<tr>
<td>Preparation for Exams</td>
<td>81</td>
<td>19</td>
</tr>
<tr>
<td>Intentionally missing lectures</td>
<td>14</td>
<td>86</td>
</tr>
<tr>
<td>Better understanding of difficult concepts</td>
<td>61</td>
<td>39</td>
</tr>
<tr>
<td>Future processing of notes</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>Freedom of planning</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>Increase exam grades</td>
<td>72</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 6.12: Reasons Students Watch Videos
We summarize the results above as follows:-

6.4.3.1.1 Preparation for Coming Lectures

The students were asked how the videos helped them to prepare for the upcoming lectures. 46.4% said the videos help them to get better prepared for the next lecture, 7.8% said the videos help them to make less notes, 7.2% said the videos enable them to ask more questions and 38.6% had other reasons.

Table 6.13: Preparation for Coming Lectures

<table>
<thead>
<tr>
<th></th>
<th>Better prepared</th>
<th>Make Less notes</th>
<th>Ask More questions</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st years</td>
<td>215</td>
<td>88</td>
<td>21</td>
<td>9%</td>
</tr>
<tr>
<td>2nd years</td>
<td>128</td>
<td>62</td>
<td>6</td>
<td>4%</td>
</tr>
<tr>
<td>3rd years</td>
<td>138</td>
<td>65</td>
<td>13</td>
<td>9%</td>
</tr>
<tr>
<td>4th years</td>
<td>82</td>
<td>41</td>
<td>4</td>
<td>5%</td>
</tr>
<tr>
<td>5th years</td>
<td>91</td>
<td>43</td>
<td>10</td>
<td>11%</td>
</tr>
<tr>
<td>Average%</td>
<td>46.4</td>
<td>7.8</td>
<td>7.2</td>
<td>38.6</td>
</tr>
</tbody>
</table>

Table 6.13: Preparation for Coming Lectures

6.4.3.1.2 Freedom of Planning

36% said the videos allow them more freedom or option for planning and 64% did not think the videos allowed them planning freedom. Since the videos are available on Bb, this helps students to plan for revision and prepare for exams and future classes. The videos are intended to improve the students' flexibility in the learning process.

6.4.3.1.3 Preparation for Exams

On average 81% said they would continue watching more lectures on video to prepare for the exam and 19% would not use the videos for exam preparation.

Table 6.14: Preparation for Exams

<table>
<thead>
<tr>
<th>Exam preparation</th>
<th>#</th>
<th>Yes %</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st years</td>
<td>211</td>
<td>170</td>
<td>81</td>
<td>41</td>
</tr>
<tr>
<td>2nd years</td>
<td>127</td>
<td>107</td>
<td>84</td>
<td>20</td>
</tr>
<tr>
<td>3rd years</td>
<td>137</td>
<td>112</td>
<td>82</td>
<td>25</td>
</tr>
<tr>
<td>4th years</td>
<td>81</td>
<td>66</td>
<td>81</td>
<td>15</td>
</tr>
<tr>
<td>5th years</td>
<td>91</td>
<td>70</td>
<td>77</td>
<td>21</td>
</tr>
<tr>
<td>Average %</td>
<td>81</td>
<td>19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.14: Preparation for Exams

6.4.3.1.4 Further Processing or Completing Notes

Sometimes the lecturer may be too fast for the students to take all the notes or certain concepts maybe hard to grasp at the time. The videos give students the ability to further process and
complete notes they missed in class. 33% said the videos enable them to further process or complete notes they took during the lecture therefore 67% did not think the videos helped them complete and further process notes. The videos therefore help the students to understand better at their pace since they can revisit the lecture anytime from anywhere.

6.4.3.1.5 Better Understanding
61% gained better understanding of the difficult subjects and 39% did not think so. The students said the videos enable them to understand the difficult concepts in the courses they were taking. Therefore the videos are very important because they enhance understanding of difficult concepts.

6.4.3.1.6 Opportunities to Catch Up with Missed Lectures
Sometimes students miss lectures for different reasons. 79% watch the videos to catch up with the class they missed and 21% did not watch the videos to catch up for missed classes. The videos therefore help students to compensate for the classes missed.

6.4.3.1.7 Better Final Exam Score
73% said watching the videos made them get a better final exam score and 27% did not think so. Therefore the videos improve the students’ performance and exam results, and therefore are used to prepare for the exams.

<table>
<thead>
<tr>
<th>Better Exams Score</th>
<th>#</th>
<th>Yes</th>
<th>%</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st years</td>
<td>211</td>
<td>145</td>
<td>69%</td>
<td>66</td>
<td>31%</td>
</tr>
<tr>
<td>2nd years</td>
<td>127</td>
<td>94</td>
<td>74%</td>
<td>33</td>
<td>26%</td>
</tr>
<tr>
<td>3rd years</td>
<td>137</td>
<td>97</td>
<td>71%</td>
<td>40</td>
<td>29%</td>
</tr>
<tr>
<td>4th years</td>
<td>81</td>
<td>65</td>
<td>80%</td>
<td>16</td>
<td>20%</td>
</tr>
<tr>
<td>5th years</td>
<td>91</td>
<td>65</td>
<td>71%</td>
<td>26</td>
<td>29%</td>
</tr>
<tr>
<td>Average %</td>
<td></td>
<td>73</td>
<td>73%</td>
<td>27</td>
<td>27%</td>
</tr>
</tbody>
</table>

Table 6.15: Better Final Exam Score

6.4.3.1.8 Missing Lectures Intentionally
14% felt that they did not have to attend the lecture because the videos would be available on Bb, while 86% said they would not miss lectures intentionally. Therefore the number of students missing classes intentionally because of the videos in Bb is not big. The critics of the videos think that they may encourage students to dodge lectures, but as observed from the results, the students intentionally dodging class are few. Therefore the availability of videos in Bb is not encouraging students to dodge lectures.

6.4.3.2 Reasons Why Students Had Not Watched the Videos
The reasons why some students had not watched the videos include the following: -
- 16.2% lacked the internet at home,
- 59.4% said not all courses for which they registered were recorded,
- 3% were not aware that lectures were recorded and
- 21.4 % had other reasons.
Therefore from the results in the table above, the biggest reason for students not having watched the videos is because not all courses are recorded. The second reason is the absence of internet at home.

### 6.4.3.2.1 Teacher Interaction

73% of first year, 68% of second year, 73% of third year, 67% of fourth year and 55% of 'fifth year and above' students, said the videos did not reduce the personal contact with the teacher. On average 67.2% said the videos did not reduce the personal contact with the teacher. However, 16.4% said videos reduced teacher interaction, 8.6% said there is more teacher interaction and 7.8% thought otherwise. The relatively high percentage of 'fifth year and above' students who feel there is less teacher contact as a result of the videos is outstanding.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yes</th>
<th>No</th>
<th>More interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year</td>
<td>291</td>
<td>213</td>
<td>28</td>
</tr>
<tr>
<td>2nd year</td>
<td>188</td>
<td>122</td>
<td>12</td>
</tr>
<tr>
<td>3rd year</td>
<td>185</td>
<td>109</td>
<td>16</td>
</tr>
<tr>
<td>4th year</td>
<td>123</td>
<td>83</td>
<td>10</td>
</tr>
<tr>
<td>5th year and above</td>
<td>207</td>
<td>114</td>
<td>20</td>
</tr>
<tr>
<td>Average</td>
<td>164</td>
<td>67.2</td>
<td>8.6</td>
</tr>
</tbody>
</table>

### 6.4.3.2.2 Availability of Video Recordings from the Previous Years

Students were asked if the video recordings of courses from the previous years should be availed for students interested in taking the course that year. 40.8% felt that they should be available on Bb in the context of that course, 32.2% felt they should be available outside of the Bb with an index and a search function, 19% said they should not be available and 8% thought otherwise. These results show that the students think the videos enhance their learning and therefore the university should have all courses video recorded. As part of future discussions with the Executive Board on participation in iTunes U, an inter-university repository of video material with index and search, i.e. “open courseware” (Dijk et al., 2010), it is important to note that the number of senior students' interest in materials offered outside of Bb is increasing.
When asked about the future, 81% said they will continue watching more lectures on video in preparation for the exam, and 56% said there are lectures they would have wished were recorded. Therefore the videos are important for the preparation of exams, classes, higher exam scores and to encourage the learning process. Students expressed the interest in videos, therefore indicating that they enable them to learn better.

### Conclusions

We investigated how multimedia content, in particular, video recordings support students during the learning process. We provide knowledge that instructional designers, researchers and academics can use to design content, improve teaching methods and research to enhance students learning. The survey indicates the students’ strong demand for videos; therefore there is need to increase the number of courses being video recorded. There is also need for quality of the videos to match the students’ needs. Students appreciate the immediate availability of information on video to make the most of micro moments. Based on their perceptions, students believe the videos are a good supplement to the face to face classes.

The benefits students highlighted include the ability to make up for colliding classes; catching up with missed lectures, preparation of class and exams, among others. Some students use the videos as an insight to choose an elective to take in the coming academic year. As noted, most of the students said they would continue watching the videos in preparation for the exam, they would have a lower exam result without the videos and they wished all courses would be recorded. There is a need for more public relations and good prospects for students to use the videos, since some claimed that they were not aware that the videos existed. Management is therefore encouraged to invest more in recording lectures on video since the results from the survey highlight the benefits. This will encourage more students to watch the videos. Management can also encourage the parents to subscribe for internet at home, to encourage students to study more at their own pace, place and time. They should also sensitize the students and staff on the importance of the videos and therefore encourage them to use them.

We recommend the introduction of the virtual videography approach because it offers several advantages like producing videos in a chosen editing style from limited inputs. As noted by

<table>
<thead>
<tr>
<th></th>
<th>#</th>
<th>Yes, relevant course in Bb</th>
<th>%</th>
<th>Yes, outside Bb with index and search</th>
<th>%</th>
<th>No</th>
<th>%</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year</td>
<td>291</td>
<td>115</td>
<td>40%</td>
<td>62</td>
<td>21%</td>
<td>80</td>
<td>27%</td>
<td>12</td>
</tr>
<tr>
<td>2nd year</td>
<td>188</td>
<td>82</td>
<td>44%</td>
<td>52</td>
<td>28%</td>
<td>33</td>
<td>18%</td>
<td>10</td>
</tr>
<tr>
<td>3rd year</td>
<td>185</td>
<td>87</td>
<td>47%</td>
<td>63</td>
<td>34%</td>
<td>26</td>
<td>14%</td>
<td>5</td>
</tr>
<tr>
<td>4th year</td>
<td>123</td>
<td>51</td>
<td>41%</td>
<td>42</td>
<td>34%</td>
<td>22</td>
<td>18%</td>
<td>7</td>
</tr>
<tr>
<td>5th year and above</td>
<td>207</td>
<td>67</td>
<td>32%</td>
<td>91</td>
<td>44%</td>
<td>38</td>
<td>18%</td>
<td>6</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>40.8</td>
<td>32.2</td>
<td></td>
<td>19%</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.18: Availability of Video Recordings from Previous Years

6.4.3.2.3 Video Lectures in the Coming Years

When asked about the future, 81% said they will continue watching more lectures on video in preparation for the exam, and 56% said there are lectures they would have wished were recorded. Therefore the videos are important for the preparation of exams, classes, higher exam scores and to encourage the learning process. Students expressed the interest in videos, therefore indicating that they enable them to learn better.

6.4.4 Conclusions

We investigated how multimedia content, in particular, video recordings support students during the learning process. We provide knowledge that instructional designers, researchers and academics can use to design content, improve teaching methods and research to enhance students learning. The survey indicates the students’ strong demand for videos; therefore there is need to increase the number of courses being video recorded. There is also need for quality of the videos to match the students’ needs. Students appreciate the immediate availability of information on video to make the most of micro moments. Based on their perceptions, students believe the videos are a good supplement to the face to face classes.

The benefits students highlighted include the ability to make up for colliding classes; catching up with missed lectures, preparation of class and exams, among others. Some students use the videos as an insight to choose an elective to take in the coming academic year. As noted, most of the students said they would continue watching the videos in preparation for the exam, they would have a lower exam result without the videos and they wished all courses would be recorded. There is a need for more public relations and good prospects for students to use the videos, since some claimed that they were not aware that the videos existed. Management is therefore encouraged to invest more in recording lectures on video since the results from the survey highlight the benefits. This will encourage more students to watch the videos. Management can also encourage the parents to subscribe for internet at home, to encourage students to study more at their own pace, place and time. They should also sensitize the students and staff on the importance of the videos and therefore encourage them to use them.

We recommend the introduction of the virtual videography approach because it offers several advantages like producing videos in a chosen editing style from limited inputs. As noted by
(Heck et al., 2006) the approach requires little to no human intervention, the system produces videos containing a variety of different shots and visual effects that serve to guide the viewer’s attention and maintain visual interest, without violating the rules of cinematography. This approach does not require special equipment but creates effective lecture videos with much lower expense and intrusion. The approach also creates novel videos from archived lectures since the system is capable of producing videos of the same lecture at different aspect ratios. It is able to produce several different videos of the same event tailored to specific needs since the system postpones the video planning process until after the lecture. The ability to deal with this type of data will become more useful in the future since High Definition videos are becoming increasingly popular because of their high resolution.

6.5 Experimental Results

Conclusions

6.5.1 Business and Academic Implications - Adapting to Different Learning Styles

As noted in chapter 2, various people have different learning styles and an individual’s method of learning can be an important consideration when developing a learning environment (Fahri et al., 2001). MM-based learning addresses the issue of different styles of learning by providing different methods of presenting the information. As previously noted (Soloman, 1992) the majority of students are active processors, driven by sensing, prefer visual input, and find sequential learning to be more coherent. For example, individuals who learn by watching or seeing may focus more on videos, graphics and animation. Learners that focus more on feeling and doing can also benefit from watching video and sound to view actions and see and hear the feelings of the subjects in the context of the problem situation. In that aspect, MM seems to emerge as a potential candidate of choice to help students with different learning styles. This is reinforced by the findings from our study where IT managers or students, business or engineering students, males or females responded favorably to all the case studies even though it was implemented in different classrooms by multiple instructors. It is possible that MM instructional materials might balance the gender inequalities found in many countries. This may lead to development of more MM-based training materials in order to foster self-motivated, self-paced and continuous learning by future employees or students.

6.5.2 Enhanced and Increased Group Collaboration-Based Learning

Recognizing the value of MM can be beneficial to company employees since they can increase the growth of organizational knowledge by encouraging knowledge sharing and collaboration. The emergence of digital, audio and video technologies that can computationally compress, manipulate, and transmit content over distributed communication networks has brought the world closer. In addition, steady technological innovations and infrastructure developments, especially increased bandwidth availability, are augmenting developments in remote collaboration (Gale, 1992). The collaborator’s (learner’s) perception of productivity significantly increases with the availability of MM technologies. Two trends are fueling the promise of MM as a ubiquitous learning technology: the fact that MM allows for both synchronous and asynchronous collaboration; and the growth of broadband Internet as a potential delivery medium. Altogether the facts point towards vast improvements in cooperative enquiry (Bargeron et al., 1999).

The recognition that MM can help improve an individual’s learning can encourage more group-oriented efforts where individuals may collaborate with others in making critical decisions pertaining to issues such as project management, product design, marketing promotion, and customer or supplier decisions. This could have cost-saving implications through the efficient
use, retention and sharing of knowledge. Although technical improvements in the production of learning materials do not infer pedagogical efficiency, it does move acquisition of knowledge a step close to the learner. Pedagogical efficiency then becomes a function of content effectiveness rather than content delivery. The learning scenario is transformed from a static rule-based one-way control to a much more learner-empowered, interactive and dynamic environment. The rich interaction and adaptability that is imperative for learning technical subjects might be satisfied through the use of MM. MM provides dynamic didactic content delivery and therefore teachers of technical subjects can concentrate on exploring new and relevant content pointing to the learner’s needs.

6.5.3 Discussion on Video Recorded Lectures

The students’ concerns and challenges about the new layout of the videos are elaborated below:

- The students had complaints about inability to view / read the Blackboard when accessing the videos on Bb because the camera follows the teacher and therefore lacks a good overview of the Blackboard.
- When using the projector, students need to visualize the speaker and the power-point slides. This is currently being addressed with small speakers on the screen and slides, which the students are very receptive of.
- The ability to ‘skip’ to a chapter is a great facility. However, some students feel that the operation is difficult and unclear sometimes.
- Students would like the rate at which the video is playing to vary e.g. they want to watch the videos at higher or lower speeds.

These concerns can be met with additional investments like an interactive whiteboard.

6.5.3.1 Students and Teachers

On the other hand, the teachers feel that videos are a good addition to the traditional classroom but should not replace the f2f classes. Teachers need to cooperate and support the students and facilitators to increase their interest in the videos. Teachers should encourage students to attend lectures because the act of attendance is as important as the content of the lecture, especially in terms of motivation. Attending a lecture is a far bigger commitment than watching a video, especially where there are other distractions, which might show greater motivation in the first place. The lecture may provide motivation and focus to students who might otherwise lack it. The presence of fellow students in class affects motivation and provides opportunities to discuss confusing topics. Therefore the teachers need to highlight the importance of attending lectures to students.

6.5.3.2 Technology

The recent developments include the introduction of a new Flash Player using XML for extra functionalities and the removal of the audio files, because students hardly use them. The team would like to add the videos to iTunes, but there is still a long way to go because of copy rights issues and the costs involved. Once the files are added to iTunes, the teacher cannot remove them. The team wants to implement H.264 soon so that only M4V files can be generated and not Flash files as well. In future, the team intends to implement neat error handling by integrating the recording process and changing the course agenda so that there is a course view in Bb. The team also intends to integrate the recording agenda in the recording box application. The team is looking for more interactive TV displays to make the entire process
electronic and also wants to introduce technology that enables a student to attach a question to a video so that the teacher can respond to a post that has been made at anytime. The team is looking at introduction of the smart board 8070i interactive display system for business solution. This technology has a facility of enabling more than one person writing on the board simultaneously. It also supports the ability to move objects from one part of the screen to another, and has digital vision touch technology.

6.5.3.3 Policy
The video recordings started as a trial and error approach. However the university needs to make an organization-wide policy that goes beyond the technology. The central policies and central control need to be clear. The university and the faculty boards should make video policies compulsory in order to encourage teachers to co-operate. Management should identify needs and how to carry out the processes. As noted in chapter 4, the four in balance monitor highlights the roles of leadership, cooperation and support of the staff in achieving the use of ICT for educational purposes at an institution (Tondeur et al., 2009). The four in balance are the technology and social building blocks, including the vision, ICT infrastructure, expertise (knowledge, skills and attitudes) and the digital learning materials. The four elements together with the cooperation and support of the human resource, the pedagogical use of ICT for training and leadership need to be in balance for successful implementation of the videos successfully. Therefore it is important that the leaders implement policies that work hand in hand with the teacher to support the video recording process and implementation.

6.5.3.4 Equipment cost
The video recording process is labor intensive and expensive. There is need for a server, storage, software, cameras, among others. The faculty records 140 hours of lectures every month, and charges the same for 10 to 20 students per working hours for 10 months per year, which is approximately 28,000 Euros. Approximately 16,000 Euros is required for five recording sets and infrastructure, therefore totaling to about 44,000 Euros for the audiovisual department to record all the lectures. The cost that the university incurs is approximately 60,000 Euro yearly to enable the video recordings. Therefore finances need to be set aside annually for the entire video recording process to be sustainable. This requires budgeting and the central administration’s involvement to make the process effective and efficient. There are a large number of measures and investments in both equipment and man power as a result of the need for quality videos to support the students.

In conclusion, therefore for the success of the videos there is need for effort from the teachers, students and leadership. There is also a need to measure the extent to which all actions, investments and better study ability can lead to better results of courses with videos. In future we intend to determine what makes video lectures educationally effective. We also hope that RU will launch the video recording of lectures for the entire university.

6.6 Learning Environments Evaluation
In this section we evaluate two of the most popular learning environments Moodle and Blackboard

6.6.1 Moodle Evaluation
The contents of this section are published in (Bagarukayo et al., 2011a). In chapter 4 we discussed the methodology frame work, in this section we evaluate moodle methodologically by matching the core foundations to the methodology foundation. We interpret the core foundations
of LEs within this methodology framework. The psychological core foundation is all LEs which explicitly reflect underlying beliefs about how knowledge is acquired and used. Psychological foundations reflect views about how individuals acquire, organize, and deploy knowledge and skills. Psychological foundations are subsequently operationalized through various design frameworks, activities, and strategies, which reflect beliefs about how individuals think, learn, understand, and act. In terms of the methodology framework, the psychological aspect thus describes the general way of thinking upon which the LE is based.

Figure 6.6: Core Foundations of Moodle.

The pedagogical core foundation influences focus on the activities, methods, and structures of the LE; and emphasizes how an environment is designed and its affordances made available. In concert with an underlying psychological model, they provide the basis for methods and strategies employed and ways in which to-be-learned content is organized. The pedagogical foundation thus provides the system of concepts and their relations in terms of which a concrete learning situation is described from this way of thinking. The technological core foundation is related to the way of supporting. Technological capabilities suggest what is possible through advances in technology, and not necessarily what is required or desired. When considered with other foundations, technological foundations represent how the capabilities and limitations of available technologies can be optimized. The cultural core foundation reflects prevailing beliefs about education, values of culture and roles of individuals in society. This is the most challenging issue since handling cultural differences and richness is crucial for effective global communication. The pragmatic core foundation bridges the gap between theory and reality and emphasizes the practical reasons a particular approach can or cannot be used in a given LE. This core foundation is related to the way of conceiving, but also has elements of the way of working. Since the way of working is meant to describe a systematic approach, we prefer to emphasize the relation of this foundation with the way of conceiving. This comparison suggests that the core foundations for LEs would benefit by two extra core foundations. The first relates to the way of learning and the second to the way of controlling. The way of working may also need extra attention as a core foundation.

We discussed the Moodle LE in terms of the methodological framework and its effectiveness. In the next section we evaluate Moodle based on Bloom’s Revised Taxonomy (BRT) and on the functionalities of the student, tutor and the developer. We expect and propose a two-dimensional support approach in which the development of learning material is seen as the
creative process to disclose a knowledge domain. That requires the core dimensions to be offered as a basic part of the LE.

6.6.1.1 Evaluation of Moodle Functionality Benchmarks in relation to Bloom’s Revised Taxonomy

Putting into perspective what Moodle can offer in relation to BRT, an evaluation of Moodle functionality was done with a randomly selected students’ group that accessed it. The information analyzed from the students (figure 6.7) presents Moodle as the central technology that can uphold the BRT levels through its functionality associations. The six functionalities Moodle presents in perspective of BRT (Camilleri, 2009) for evaluating LEs include Tutor support, Peer Support, Interpretation, Relevance, Reflection and interactivity. The functionalities are embedded in the Moodle tools and closely linked to BRT. Therefore an evaluation strategy of Moodle is done in relation to the six functionalities and BRT. From the figure we can clearly note that there is association between the functionalities and BRT as indicated below:

- The Tutor Support functionality looks at tutors adequately supporting the entire learning process in Moodle. It can be clearly seen that there is an association between creating, applying, remembering and evaluating levels of BRT. The tools associated with these levels help in the providing effective Tutor Support.

- The Peer Support functionality looks at how other peers within Moodle support each other in order to achieve the learning objectives. This functionality associates with the applying, remembering and evaluating levels of BRT. Through the tools available in Moodle, peers can effectively evaluate what support to provide after remembering what they already know and then applying what they know through peer support.

- Interpretation functionality is closely linked to Moodle’s ability to allow users interpret the information presented before they can use it. The functionality closely associates with the analyzing, understanding and applying levels of BRT. Users first analyze the information, understand and apply what is relevant in different contexts such as providing support.

- Relevance functionality focuses on the ability to select a tool that adheres to the appropriate learning style in order to undertake an effective learning process. There are several tools within Moodle, however, not all can be used by every user. Relevance associates with the analyzing, understanding and evaluation levels of BRT. Being able to use the appropriate tool involves the user analyzing what works best for them in their state and then having a good understanding of the learning process. If learning takes place the tool can be evaluated for effectiveness.

- The Reflection functionality addresses the issue of users’ ability to think and understand the information presented to them. After the reflection they can use their understanding to do other learning activities. The BRT levels associated with this functionality include evaluation, understanding and remembering. When a user interacts with the functionality, they are interested in evaluating what leads to understanding and thereafter can store that knowledge for future remembrance.

- The Interactivity functionality allows users to use Moodle in any way possible depending on the different learning styles. This contributes to the biggest percentage of Moodle usage and is associated with the creating and remembering levels of BRT. Users can utilize the available tools to create learning activities through which they can have a good understanding of the entire learning process.
Based on the Constructivist On-Line Learning Environment Survey (COLLES) evaluation criteria of LE (Camilleri, 2009), Moodle is relevant because it enables students to use critical thinking (HOCS) which is on the highest level of BRT. Moodle encourages students’ interactivity and collaborativeness through chats, wikis and forums. Moodle encourages tutor support since the latest version allows students to create their own discussion topics unlike Bb. Moodle encourages peer support through chats and forums which enable communication between the tutors and students. Through quizzes teachers are able to gauge whether students are gaining the required skills and competencies, based on the assessment results. These skills are relevant to students’ professional practices because they prepare them for ability to have discussions before problem solving and decision making i.e. HOCS. Based on the above, we concur with (Camilleri, 2009) that Moodle provides the best array of tools for collaboration, communication, sharing, activities and critical reflection, for enhancing students learning experience and improving HOCS.

6.6.1.2 Evaluation Based on Students, Tutors and Developers Functionalities
Under the system management, Moodle is easy to install, can be used for large institutions and offers http login page to control for authentication of users. For system administration, having one server for multiple institutions is not a default option, however it can be done without much work.

Table 6.19 is a summary of the functionalities Moodle provides for the students, tutors and developers.
### Students Environment

<table>
<thead>
<tr>
<th>Functional environment</th>
<th>Students Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web browsers like Firefox 1.0, 4.0, internet explorer 6.0.2 or Macintosh safari 1.3</td>
<td>Easy to use and navigate</td>
</tr>
<tr>
<td>Straight forward navigation, Setting of languages and visibility of elements easy</td>
<td>Compliant with web technology</td>
</tr>
</tbody>
</table>

### Tutoring and Didactics

<table>
<thead>
<tr>
<th>Communication</th>
<th>Tutoring and Didactics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forums, groups can be formed, document upload and download is possible, wiki for collaborative work on a text</td>
<td>Functional environment</td>
</tr>
<tr>
<td>Teacher can enroll students already in the system into a course, Administrators can use file upload to enroll students in courses and in groups, Self enrollment by students possible, Meta course feature allows easier enrollment of the same students in several different courses</td>
<td>Easy of use</td>
</tr>
<tr>
<td>Logs and activity reports offer possibilities that are easily accessible, Courses can be monitored closely or checked occasionally</td>
<td>Tutoring and Didactics</td>
</tr>
</tbody>
</table>

### Course Development

<table>
<thead>
<tr>
<th>Developers Support</th>
<th>Course Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large and active Moodle community with main developer present in forums at Moodle.org, Good documentation like students, teachers and developers manuals</td>
<td>Easy of use</td>
</tr>
<tr>
<td>Functionality addition possible, Links to externally dynamically generated pages work, Core API resource exists</td>
<td>Flexible Development framework</td>
</tr>
<tr>
<td>HTML pages or other files can be uploaded or linked from Moodle and displayed in a pop-up window or in a frame, style sheets are used</td>
<td>Compatibility with common Web Authoring Tools</td>
</tr>
<tr>
<td>Many quiz types available, Possible to create questions with the in-built quiz editor, Questions can be read from a text file, in several different files (even from Blackboard), Module for importing Hot potatoes quizzes available</td>
<td>Assessment</td>
</tr>
<tr>
<td>Module for uploading SCORM packages (.zip files) which simplifies the upload or unzip process, Uploaded SCORMs structure displayed next to the content opened in an iframe, SCORM module fully conformant with the SCORM 1.2 standard, quizzes can be exported to IMSQTI 2.0</td>
<td>Support for e-learning standards</td>
</tr>
<tr>
<td>Overall look and feel can be changed using themes, logos can be added, style sheets can be modified to make minor changes easily, Individual courses can have their own themes that differ from the entry page or from site level theme, Styles can be changed at the course element level using style sheets</td>
<td>Adaptable look and feel</td>
</tr>
</tbody>
</table>

### Table 6.19: Evaluation Based on Students, Tutors and Developers Functionalities.

#### 6.6.2 Blackboard Learn Evaluation

A Bb evaluation was done by choosing a course to assess in order to determine the effectiveness of course management through the use of Bb (Lacey & Liu, 2003). The evaluation was to determine if the technology was easy to understand and use by students and instructors. They developed a scale that was suitable for the evaluation. Bb can be used to manage course documents and grades.
<table>
<thead>
<tr>
<th>Metrics</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience With Bb</td>
<td>High - Great Amount of Information Presented In Documents, Readings, Assignments, and Discussion Forums</td>
</tr>
<tr>
<td>Appropriateness for Audience</td>
<td>High Rating - Information Presented Was Properly Designed for Its Audience</td>
</tr>
<tr>
<td>Usability Ease</td>
<td>High Rating - Bb Was Easy To Use, User Friendly for Content Navigation and Accessing Information And Assignments</td>
</tr>
<tr>
<td>How Software enabled Students Work / Assignments</td>
<td>Software allowed Students to Access Course Information from Any PC With Internet Access, Communication with Instructor and students, for online Feedback On Assignments</td>
</tr>
<tr>
<td>Delivering Instruction</td>
<td>High Rating - Instructor Used Bb to Augment Instruction by Posting Lectures &amp; Notes before Class for Students to review before Class</td>
</tr>
<tr>
<td>Facilitating Discussions among Learners</td>
<td>High - many discussions are Facilitated between Students and Instructor. The Instructor Posted Several Topics For Discussion In The Forum And All Students Responded With Their Thoughts, Feedback On Other Students' Responses. However instructors' Level Of Commitment To The Discussions Motivates Students.</td>
</tr>
<tr>
<td>Facilitating Internet &amp; Web Based Communication</td>
<td>Rated High - Students Communicate with each other within Groups, One-On-One, Or With Instructor to Discuss Topics.</td>
</tr>
<tr>
<td>Grading &amp; Reporting</td>
<td>High Rating - Students had Access To Grades &amp; position in Class</td>
</tr>
<tr>
<td>Bb Development Intuitive User Interface</td>
<td>High Rating – Uses a Graphical User Interface hence Navigation Easy, Interface Design Is Easy to Read &amp; Understand. The Interface has a Search Engine</td>
</tr>
<tr>
<td>Knowledge of HTML</td>
<td>High Rating - Software Converts Word Processing Language automatically To HTML</td>
</tr>
<tr>
<td>Built In Support Or Help Issues</td>
<td>Rated Fair - Students Accessed My News When They Clicked On The Help Option, Which Contains Bb Press Releases, A Download Center which Contains Building Block Catalogs, Course Cartridges, and Plug-Ins. Therefore there was need for Proper Search Index to Aid Students in Locating Help Topics</td>
</tr>
<tr>
<td>Bb Management Password Capability</td>
<td>Rated Fair - Some Students were having Problems Logging on</td>
</tr>
<tr>
<td>Monitoring Of Student Activities</td>
<td>Rated High - Instructor Could Monitor How Many Times A Student Logged On, Checked Student Grades, &amp; Participation In Discussion Forums</td>
</tr>
<tr>
<td>Compatibility with University Networking Systems &amp; Software</td>
<td>High - Bb Was Set Up As A Course. Compatibility With Any Browser was given a High Rating because Bb Is Compatible With Popular Browsers.</td>
</tr>
<tr>
<td>The Built-In Features</td>
<td>High Rating- Bb Has Many Built-In Features Such As Chat Rooms, Discussion Forums, Email, And Bulletin Boards.</td>
</tr>
</tbody>
</table>

Table 6.20: Bb Learn Evaluation
In conclusion, after thoroughly evaluation, the study concluded that Bb is an excellent CMS to use because most of the components of Bb received high ratings (Lacey & Liu, 2003). Bb is very easy to use and learn, the presentation of assignments and announcements presented were easy to access and understand. The communication between students and the instructor is appropriate for the course because students communicate with each other and the instructor through the communication section of Bb without f2f. The discussion forum is a nice tool for interactivity and collaboration with the instructor and other students to give and receive feedback. Students can follow their progress in the course because Bb allows them to check their grades for each assignment. The instructor also has the ability to monitor student progress and give feedback to students so they improve their performance. The greatest effect of course management and accessibility is the ability for the students to logon to Bb from any computer with Internet access, giving students easy access to information they need at any time and place. Therefore Bb was highly recommended to be used by all educators to manage the courses they teach because of the positive effect it has on course management.

6.6.2.1 Blackboard Learn Evaluation at RU

Bb Learn is a tool that aids teaching, learning and assessment and therefore impacts on learning in the classroom. Radboud University (RU) has approximately 20,000 students and introduced Bb as its CMS in 2000. RU started using the version 9.1 in 2010. The look, feel and the user friendliness have been improved a lot compared to the initial versions. The teachers that have problems using Bb 9.1 use the RU Bb blog and the video recordings training. Initially, Bb was introduced as a tool to support teachers with elementary tasks in the learning process such as distribution of teaching material, providing assignments and submission of results. The initial situation can be characterized as a way to improve communicating to students inside and outside the classroom.

It was hoped that this support would improve the teaching process. Bb and other administrative systems, such as the student administration were integrated, to improve functionality and user friendliness. New requirements were formulated such as guaranteeing security of the data in Bb and the privacy over the systems. The initial expectations of Bb from the central administration were that it provides an easier administration, proper documentation and information sharing, and a close interaction system, from students to the teacher, like handing in of assignments. The management is satisfied that their initial expectations are met. However there are new expectations that Bb was not able to handle initially like having collaboration options, portfolio options and information management like following students’ progress easily. The students’ expectation are determined by the use of surveys, to determine if the students are satisfied with the system. The students’ expectation is to have clarity in the education process, and management ensures they get the best quality of education by constantly monitoring the learning process.

6.6.2.2 Effectiveness of Bb at RU

The infrastructure itself is no guarantee for successful introduction of the DLE in the educational process (Kennisnet, 2010). For a successful learning environment, the policies of the institution and how these policies are effectuated are also essential. But at the time of the introduction of Bb these policy issues were still very open. Teaching models and material were hardly available, and mostly had to be developed from scratch. Teachers were seen as pioneers using Bb, and were encouraged to share their best practices for answers about the new way of thinking. This best practices approach was used to fascinate the members of staff from different faculties and attract teachers close to them in order to adopt the new methods of teaching with technology. The approach encourages teachers to learn from fellow teachers and the more teachers have learned, the wider it spreads.
The usage of Bb is not compulsory from a central level; the actual policies vary over the various faculties. Teachers have different degrees of freedom per faculty. In some faculties they have the freedom to decide whether to use Bb and in others some basic use is mandatory. However mainly due to student demands almost every teacher uses Bb at least for the direct user questions such as placing documents, posts and communication. Although usage of Bb is not mandatory, the university expects results that assume the advantages of using the software. One of the challenges is handling a larger number of students with fewer resources and a solution is to use DLEs and hence the change from face to face to interactive and collaborative ways of teaching using Bb. Changing to Open Source Software (OSS) solution at the moment is an extensive operation and expensive for the university in terms of training staff to use the new system. The future at RU is an OSS solution which can easily be integrated with better technologies like cloud computing.

6.6.3 Comparison of Moodle to Blackboard

Unlike most LEs, Moodle is free, not based on a license fee, can be modified anytime, designed to take large numbers of students and has a vast array of interactive tools (Camilleri, 2009). First Class Navigation is simple to use like using emails, features a bulletin board System and online conferencing, and allows for synchronous and asynchronous communication. However, new content or mail have to be searched for manually in the various folders on the home page, it has a very outdated welcome screen which contains a clutter of folders and is not suitable to use with large groups simultaneously. Moodle’s shortcoming is that it lacks modern Synchronous e-learning features like hosting virtual classrooms (Lalos et al., 2009). There is need to provide synchronous learning features for successful e-learning program implementation. We conclude that Moodle offers an impressive set of tools to support a Distributed Passive Learning environment as compared to other LEs.

Unlike Bb, Moodle does not time out when not in use, is not limited to a whiteboard tool, and has more than one type of forum depending on particular needs. With Bb, one is immediately notified of any announcements and an icon indicating what new material is available. In a study carried out (Croy et al., 2009), a university that had been using the Bb CMS had a choice of migration to Moodle or negotiating a new contract with Bb to migrate to the new product they offered. After the extensive evaluation, they chose Moodle because it was financially and pedagogically better than Bb. In the next chapter, we give some general conclusions and recommendations for future work based on the results and approach presented.
7. Conclusion and Future Work

The results from the experiences were presented in chapter 6 to validate the approach proposed in chapter 5. In this chapter, we revisit the research questions, elaborate on the contributions and future work. We give some conclusions and recommendations for future work.

7.1 Conclusions

In this thesis we discuss the background on learning, the challenge of HOCS improvement, building capacity and infrastructure in Least Developed Countries (LDCs). We discuss the different learning approaches and note that the traditional learning approach is insufficient for HOCS improvement and therefore there is need to use the blended or e-learning approaches (technology) for learning. We also acknowledge the significance of Information and Communication Technology (ICT) for HOCS improvement. We highlight the research questions and objectives, societal relevance, research design, approach and finally the research contributions.

We carry out a theoretical review from online journals and conferences of the last 10 years in chapter 2. We discuss the current methods of HOCS improvement, the different learning theories, environments, styles and instructional content design to derive different requirements for HOCS improvement. We review the literature on learning theories, and highlight that the constructivism and cognitive theories are relevant for HOCS improvement because they advocate for knowledge construction and prior knowledge importance respectively. We also discuss the learning environments, styles and instructional content design which are also important for learning. We highlight the several learning styles theories and inventories and the relevance of learning styles. We recommend LS knowledge, matching teaching and learning styles, the use of case studies, multimedia, active learning strategies, instructional content design, developing systems that incorporate the learning styles and culture.

In chapter 3 we relate learning to ICT and particularly Bloom’s Taxonomy, as the general framework for learning from which the concept of HOCS is derived. We relate the taxonomy to ICT, as the Bloom’s Digital Taxonomy. We discuss process and content oriented digital tools for learning as a basis for deriving requirements appropriate for DLE implementation, as discussed in chapter 4. We discuss the DLE as a tool for HOCS improvement after highlighting the DLE benefits and success measures. We finally derive DLE characteristics for HOCS improvement and give recommendations for DLE implementation. In chapter 5, we discuss an approach for introduction of an ICT education program based on the concepts discussed. In chapter 6, we validate the approach with results from the different research experiences. We finally conclude this thesis with conclusions, research questions and answers, contributions and future work in the next sections.

This research benefits from some longitudinal multi method studies carried out across different student groups and provides results from several experiences using different tools and methods. The Implications of this research on teaching is that stakeholders can determine the impact of technology on learning and therefore recommend its use. If teachers and students realize the benefits of technology, they will embrace it at different institutions. This will also impact on the instructional content designers, and enable designing of content suitable for students learning, in particular HOCS. The appropriate environment for teaching at all levels which benefits both the students and teachers is determined.
One of the challenges with introducing learning environments is that the teachers delay to embrace them. Therefore the teachers should be sensitized about the advantages of using technology for learning which include easing teachers’ work. Introduction of learning environments will enhance the learning process and HOCS improvement, by encouraging interaction, communication and collaboration activities. The approach may enhance HOCS since the content addresses students’ learning styles and preferences and also encourages anytime, anywhere, and any pace learning. The approach we propose therefore encourages collaboration, communication and interaction which foster HOCS.

We present specific technologies that improve HOCS in relation to Bloom’s Taxonomy by carrying out research on different technologies that impact on the HOCS attributes of decision making, problem solving, critical thinking, analysis, interpretation etc. We carry out experiments that measured HOCS improvement by basing on the students’ performance and GPA. We develop an instrument that uses exam-like questions to determine whether the students actual HOCS improved after using MM materials. We also determine the impact of technology on the learning process using videos and the DLE.

In the next section we revisit the research questions that guided us to achieve the research objectives and elaborate on how we addressed them.

### 7.2 Research Questions and Answers

The research questions (RQ) that guided our research are addressed as follows:

**RQ1: What are the requirements for an approach for HOCS improvement during learning?**

We answered RQ1 by reviewing theoretical background on learning to determine the state of the art and practice for enhancing HOCS improvement, in order to identify the HOCS improvement requirements. We therefore investigated the current methodologies and tools used for HOCS improvement in chapter 2 after a thorough review of literature. We present the methods of HOCS improvement as multimedia, HOCS promoting teaching and assessment strategies and Problem based learning. These methods however did not look at the student’s learning profile, and only the multimedia method was validated for HOCS improvement. Therefore there was need for improvement of the methods to cater for their weaknesses. We discussed the improvements in chapter 2 and proposed appropriate requirements and characteristics of an appropriate approach. We noted that for learning to be successful for HOCS improvement, we need to take into consideration the learner profile, the multimedia instructional content design and the HOCS promoting teaching and assessment strategies for actual HOCS improvement, as the HOCS improvement requirements. The Learner profile comprises of prior knowledge and learning styles which are relevant for students’ successful learning, as noted from the learning theories, the prior knowledge is important for learning to be successful.

**RQ2: What are the requirements for digital learning tools to support an approach for HOCS improvement during learning?**

From the Digital Learning Tools (DLTs) we discussed in the chapter 3, we derive requirements for an overall support for the learning process. DLTs support a learning environment with learning materials that go beyond the possibilities of the traditional approach. They offer features like chat rooms, discussion boards or forums, digital testing, online grading, virtual
classrooms, feedback, authentication, collaboration tools and content areas. DLTs offer a multi-featured way for teachers and students to communicate, interact and collaborate both in and out of class. DLTs are interactive, engaging, stimulating, assessing students in courses and should impact on teaching and learning through technology. These functionalities offered by the DLTs enhance HOCS improvement and improve the learning process in general. These functionalities therefore provide requirements for DLTs to support an approach for HOCS improvement.

RQ3: How can a DLE as a Tool support HOCS improvement during learning?

The digital learning environment (DLE) acts as the way of supporting for the learning method based on the methodology framework discussed in section 4.7. The role of the DLE is to help students achieve competencies, KSA as specified by BT and Roe’s model of competencies, by supporting the learning process. Institutions need to take care of the students’ new demand of anywhere, anytime, and any pace learning. The teaching methods at the institutions should accommodate the new approach to learning by using technology to meet the demand of educating the masses and HOCS improvement. The ease of use, support, global standards, open systems, high scalability and implementation options are key selection criteria for any DLE.

The DLE is a tool for maintaining, exchanging and acquiring knowledge, skills, attitudes and competences, in particular supporting learning, teaching and studying activities. In chapter 4, we showed that the proposed DLE has all requirements for a methodology. For that purpose we used the methodology framework, based on a model of Seligmann (Seligmann et al., 1989), presented as a mechanism for characterizing and comparing methodologies (Proper, 1994) to get a better understanding, and to compare different methodologies. We related the DLE as a tool to the various aspects of the methodology framework.

RQ 4: What approach is used to introduce ICT education to improve HOCS, build capacity and infrastructure in a LDC using the DLE tool?

The appropriate framework for HOCS improvement using a DLE is the Bloom’s Digital Taxonomy. As discussed in chapter 3, 4, and 5, the taxonomy is the major theoretical framework behind the Learning by Construction approach we propose for HOCS improvement, building capacity and infrastructure. We propose the learning by construction approach for introducing ICT education to improve HOCS, build capacity and infrastructure in a LDC using the DLE tool as discussed in chapter 5. This approach is based on Roe’s model of competences and Bloom’s taxonomy and aims at introduction of an ICT education program using a low cost initiative. It promotes learning using practical skills to gain KSA therefore aims at HOCS improvement. It is in line with BT where creating a wholistic learner is one of the objectives, since the student develops skills at all the levels of the three domains, which later develop into basic and general competences.

RQ 5: What is the impact of technology on HOCS improvement and the learning process?

The impact of technology was answered based on three different sub research questions

- Is there a difference in HOCS improvement of students receiving MM instruction as opposed to students receiving the traditional instruction method?

There was a significant difference in the students HOCS improvement that used multimedia as compared to those who used traditional instruction method as presented in chapter 6. Students using multimedia improved HOCS as compared to those using the text book method of instruction. The impact of learning-driven factors on HOCS improvement was positive as presented in chapter 6.
What are the factors responsible for students' perceived improvement of HOCS when using Multimedia case studies?
The factors responsible for HOCS improvement were the learning interest, learned from others, self-reported learning and challenging improved on the students HOCS as shown in section 6.2.

What is the impact of the DLE and videos on the learning process?
We investigated the impact of the DLEs on the improvement of students HOCS. As observed from the results in chapter 6, we noted that the DLE impacts the learning process positively, since there was an increase in materials, students and course numbers. The DLE also increased the motivation and interest of the students. We believe that with more interaction, collaboration and cooperation, HOCS improvement can be enhanced with the DLE.

The impact of videos on learning was positive because of the benefits highlighted like the ability to make up for colliding classes; catching up with missed lectures, preparation of class and exams, an insight to choose an elective to take in the coming academic year. Most students said they would continue watching videos in preparation for the exam, they would have a lower exam result without the videos and they wished all courses would be recorded. Therefore the videos enhance learning interest, motivation and improve students’ performance.

7.3 Research Contributions
We discuss the importance of HOCS improvement for academia, practitioners and industry. We carry out a thorough review of literature on the current state of art and practice of HOCS improvement methods, models and approaches the learning theories, environments, instructional content design. Then we derive the implications for research design using the relationship between theoretical background and the factors that determine HOCS improvement. The research contributions include a theory that determines the set of requirements for HOCS improvement measurement to guide content design. The theory provides the theoretical basis for developing an approach for introduction of an ICT education program in a LDC for HOCS improvement, building capacity and infrastructure. The theory also aids in developing an approach for content design to improve HOCS. We validate the approach with the data from the experiments and proof of concept.

The thesis presents an approach for HOCS improvement using MM that enhances the current MM instructional materials, content strategy and assesses the impact of MM on perceived and actual HOCS improvement in analyzing and developing the solution for the MM case study. The approach illustrates that by administering personalized MM instructional content to students and using an actual HOCS improvement instrument; actual HOCS improvement is administered and tested. We develop the Learning by Construction approach for the introduction of an ICT education program to improve HOCS, build capacity and infrastructure.

In conclusion, we propose an approach using student’s requirements / needs for HOCS improvement. We derive and evaluate a theory that highlights requirements for HOCS improvement and use the theory to derive design choices that can be used to design content for HOCS improvement. We contribute a theory for general introduction ICT education program for HOCS improvement, building capacity and infrastructure.

7.4 Recommendations and Future Work
As noted in the four building blocks of vision, educational software and content, ICT infrastructure and Knowledge, skills and attitudes (professionalization) need to be well balanced
for ICT infrastructure to work efficiently and effectively (Kennisnet et al., 2010). There is also need for the cooperation, leadership and pedagogical use of ICT for learning, for the efficient use of technology (Tondeur et al., 2009). The technology and infrastructure is not enough on its own, therefore there is need for cooperation and support of the staff to realize the vision of the institution.

The introduction of technology in developing nations is currently a challenge because of the initial cost of investment for the equipment. Therefore researchers, academicians and content developers need to find methods for using these instructional technologies to provide low cost distance learning course delivery in LDCs. One way of creating cheap content for the university lectures is by recording lectures and saving them on CDs and/or DVDs, which can be used by students to learn from anywhere at any pace during their free time. This may reduce on the initial cost of the equipment. The materials can be transported from one institution to another to favor rural areas that still lack infrastructure. Since these materials are MM, they address the different learning styles and therefore accommodate students from developing nations with learning styles that require visual aids such as videos. This is important given that developing nations have more dire priorities than accommodating such students. There exists little pedagogical support that addresses the diversity, calling for newer and more effective tools and techniques to enhance the learning process across the diverse styles (Felder & Silverman, 1988)

An implementation of the ICT education program for HOCS improvement, building capacity and infrastructure was not possible within the scope of this thesis and will be the most interesting challenge for the future. As a limitation we need to convince politics and to find financing to accomplish this enormous task.
Appendices

Appendix 1: Pre-Treatment Questionnaire

Pre-Treatment Questionnaire

Registration No: _____________________
Group No: ______________________________________

NAME (must provide name): ____________________________________________

GPA.
(a) GPA 2.0 to 2.5    (b) GPA 2.51 to 3.0
(c) GPA 3.01 to 3.5    (d) GPA 3.51 to 4.0

Years of work experience
(a) Less than 1 year    (b) 1 to 2 years
(c) 2 to 3 years     (d) more than 3 years

Gender
(a) Female     (b) Male

Race
(a) African     (b) African-American
(c) White      (d) Asian

Status
(a) Undergraduate     (b) Post Graduate
(c) Graduate      (d) Doctorate

Please specify your program
(a) Computer Science     (b) Information Technology
(c) Software Engineering                   (d) Information Systems
(e) Other ______________ (please specify)

Survey of Attitudes and Perceptions toward Operating Systems (OS)

Please complete this survey in 15 minutes. The questions below are designed to identify your attitudes about operating systems. Be as honest as possible; there are no correct or incorrect answers. Please rate the degree to which you agree or disagree with the following statements in this questionnaire.

A = Strongly Disagree (SD)
B = Disagree
C = Neutral (neither agree nor disagree)
D = Agree
E = Strongly Agree (SA)

Instructional material is defined as the class lectures, text book, and homework exercises that have been used so far in this course and earlier courses.

ATTITUDES AND PERCEPTIONS

1. OS is a subject learned quickly by most people. A B C D E
2. I have trouble understanding OS because of how I think. A B C D E
3. OS concepts are easy to understand. A B C D E
4. OS is relevant to my life. A B C D E
5. I get frustrated going over OS tests in class. A B C D E
6. I am under stress during OS classes. A B C D E
7. Learning OS requires a great deal of discipline. A B C D E
8. I have no idea of what's going on in OS. A B C D E
9. I like OS. A B C D E
10. OS is highly technical. A B C D E
11. I feel insecure when I have to do OS coursework. A B C D E
12. I expect using the instructional material to increase my self-confidence. A B C D E
13. I expect to achieve a sense of accomplishment in learning by using the instructional material A B C D E
14. I expect my attitude towards OS to improve as a result of the instructional material. A B C D E

**LEARNING INTEREST**
15. I can learn OS. A B C D E
16. I expect the OS skills to make me more employable. A B C D E
17. I expect use of the instructional material to emotionally engage me in learning the OS course topics. A B C D E

**SELF REPORTED LEARNING**
18. I expect using the instructional material to help me assume greater responsibility for personal learning. A B C D E

**HIGHER ORDER COGNITIVE SKILLS CONSTRUCT**
19. I expect the instructional material, class activities, labs, and assignments to be integrated in a way that makes my learning easier. A B C D E
20. I expect my confidence in applying OS concepts to real situations to improve as a result of this OS course. A B C D E

**CRITICAL THINKING**
21. I expect to understand how to apply analytical reasoning to OS. A B C D E
22. I expect to learn how to interrelate important topics and ideas using the instructional material. A B C D E

**DECISION MAKING**
23. I expect to learn how to identify various alternatives/solutions to a problem using the instructional material. A B C D E
24. I expect to learn how to sort relevant from irrelevant facts using the instructional material. A B C D E

**PROBLEM SOLVING**
25. I expect the instructional material to help me to arrive at decisions. A B C D E

**LEARNED FROM OTHERS**
26. If I were to become part of top management in a company I would hire a OS person to help with decision making. A B C D E
27. I expect to learn how to identify OS tools that will assist me in decision making using the instructional material. A B C D E

**HOCS open-ended questions**
34. What experience do you have with the OS field of study? (include work experience, related courses or other experience with OS)
35. What teaching styles do you find most helpful in learning new material? (for example lecture, distance learning, presentations, multimedia case studies, group projects?)
36. What learning styles do you believe should be addressed to help you learn material?
37. What part of this course do you expect to be most interesting?
38. What part of this course do you expect to be most helpful in learning the material presented?
39. Explain whether you think multimedia case studies will be helpful in learning the material presented (benefits and non-benefits?)
40. Explain in detail whether you think student groups/teams in solving the problems presented in the case studies will be helpful? (Benefits and non-benefits?)
41. Do you prefer to work alone or in groups to solve problems?
42. What suggestions do you have for improving the learning experience in this course?
43. What suggestions do you have for the instructor to improve his / her teaching style in this course?
44. How do you perceive you will use the information learned in this course in your future work environment?
45. How do you think this course might affect your desire to pursue a career in this field?

MANY THANKS FOR YOUR CO-OPERATION.
Appendix 2: Post Treatment Questionnaire

Registration No: _____________________ Group No: ______________________________________

NAME (must provide name): ____________________________________________

GPA
(a) GPA 2.0 to 2.5
(b) GPA 2.51 to 3.0
(c) GPA 3.01 to 3.5
(d) GPA 3.51 to 4.0

Years of work experience
(a) Less than 1 year
(b) 1 to 2 years
(c) 2 to 3 years
(d) more than 3 years

Gender
(a) Female
(b) Male

Race
(a) African
(b) African-American
(c) White
(d) Asian

Status
(a) Undergraduate
(b) Post Graduate
(c) Graduate
(d) Doctorate

Please specify your program
(a) Computer Science
(b) Information Technology
(c) Software Engineering
(d) Information Systems
(e) Other ______________ (please specify)

Survey of Attitudes and Perceptions toward Operating Systems (OS)

Please complete this survey in 15 minutes. The questions below are designed to identify your attitudes about operating systems (OS). Be as honest as possible; there are no correct or incorrect answers. Please rate the degree to which you agree or disagree with the following statements in this questionnaire.

A = Strongly Disagree (SD)
B = Disagree
C = Neutral (neither agree nor disagree)
D = Agree
E = Strongly Agree (SA)

Instructional material is defined as the class lectures, text book, and homework exercises that have been used so far in this course and earlier courses.

ATITUDES AND PERCEPTIONS

1. OS is a subject learned quickly by most people.  A B C D E
2. I have trouble understanding OS because of how I think.  A B C D E
3. OS concepts are easy to understand.  A B C D E
4. OS is irrelevant to my life.  A B C D E
5. I get frustrated going over OS tests in class.  A B C D E
6. I am under stress during OS classes.  A B C D E
7. Learning OS requires a great deal of discipline.  A B C D E
8. I have no idea of what's going on in OS.  A B C D E
9. I like OS.  A B C D E
10. OS is highly technical.  A B C D E
11. I feel insecure when I have to do OS course work.  A B C D E
12. Using the instructional material has helped increase my self-confidence.  A B C D E
13. Using the instructional material has helped me achieve a sense of accomplishment in learning.  A B C D E
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<tbody>
<tr>
<td>14. My attitude towards OS has improved as a result of the instructional materials</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>15. I can learn OS.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>16. OS skills will make me more employable.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td>17. I became emotionally engaged in learning the course topics because of the use of the course material.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td><strong>SELF REPORTED LEARNING</strong></td>
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<tr>
<td>18. Using the instructional materials helped me assume greater responsibility for personal learning.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td>19. The way in which the instructional material, class activities, labs, and assignments fit together has made my learning easier.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>20. My confidence in applying OS concepts to real situations has improved.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td><strong>HIGHER ORDER COGNITIVE SKILLS CONSTRUCT</strong></td>
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<tr>
<td>21. I understand how to apply analytical reasoning to OS.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td>22. Using the instructional material, I have learned to inter-relate important topics and ideas.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>23. Using the instructional material, I have learned to identify various alternatives / solutions to a problem.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<td>24. The instructional material has helped me to sort relevant from irrelevant facts.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td><strong>DECISION MAKING</strong></td>
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<tr>
<td>25. Using the instructional material helped me arrive at a decision.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>26. If I were to become part of top management in a company I would hire a OS person to help with decision making</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td>27. Using the instructional material, I have learned to identify how OS tools can help in business decision making</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td><strong>LEARNED FROM OTHERS</strong></td>
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<td>28. My problem solving skills have improved because of the use of the instructional material.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td>29. The instructional material has helped me improve my interpersonal skills.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td><strong>SKILLS</strong></td>
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<tr>
<td>30. My writing skills have improved as a result of the OS course.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>31. My presentation skills have improved as a result of the OS course.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<tr>
<td>32. I have acquired an interdisciplinary focus due to the OS course.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>33. My informal communication skills have improved as a result of the OS course.</td>
<td>A</td>
<td>B</td>
<td>C</td>
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<tr>
<td><strong>Case Study Assessment:</strong></td>
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<tr>
<td>34. What were the strengths of the Chick Fil-A case study?</td>
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<tr>
<td>35. What were the weaknesses of the Chick Fil-A case study?</td>
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<td>36. What are your suggestions for improvement of this case study?</td>
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<td>37. In your own words, tell us how you would solve the problem of chick-fil-A</td>
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**MANY THANKS FOR YOUR CO-OPERATION.**
Appendix 3: Actual HOCS Attainment Questionnaire

Registration No: _____________________ Group No: ____________________________

NAME (must provide name): ______________________________________________________

1. Identify the problem(s) with the existing Point of Sales (POS) system of Chick-fil-A? What are the operations council’s recommendations for the POS system?

2. Briefly describe the business issues and technology issues relevant to the purchase of the new POS system for Chick-fil-A

3. Identify the required functionalities for Chick-fil-A’s new POS system

4. IT vision along with business objectives led to adaptation of a business process objective. What was this? Explain this process briefly.

5. Compare and contrast the proposed options for the next generation POS system to be used in all Chick-fil-A restaurants. What criteria did the team use to evaluate the options above

6. What are the characteristics or functionalities of the options identified?

7. What are the required POS terminal functions

8. Compare and contrast the traditional EPROM product as compared to PC based architecture

9. Describe briefly the iterations of JAD used in analyzing the business needs and selection of the operating system

10. Describe the decision making process in choosing the POS system for Chick-fil-A. Explain some of the issues that needed to be considered before making the final decision

11. Decide what option Chick-fil-A should choose. Briefly defend your decision and identify the criteria for selecting software, hardware and the network. How will your solution align technology and business needs, support the long-term needs and fulfill the current business needs.
Summary

Higher Order Cognitive skills (HOCS) relate to the perception that an individual has acquired skills to make a decision under various conditions of uncertainty and time. Since traditional learning approaches have been ineffective for HOCS improvement in science education, the need for new approaches to address this dilemma is highlighted. In addition to this, there is shortage of ICT capacity and infrastructure especially in the Least Developed Countries. In our research we carry out a comprehensive theoretical review of published studies that examine the current methods for improving HOCS, which provide the elements for HOCS improvement. We examined the learning theories, learning environments, instructional Content Design and learning styles theories and instruments, to enable us determine the HOCS improvement elements for developing the approach using the relationship between theoretical background and the factors that determine HOCS improvement. The HOCS improvement elements identified from the theoretical background include Learning profile, MM Instructional Content Design, and HOCS Promoting Teaching and Assessment Strategies for actual HOCS improvement. HOCS can be improved if content is designed following these elements we recommend.

We discussed learning theories in general, and chose Bloom’s Taxonomy as a general framework for learning for HOCS improvement since the concept of HOCS is derived from it. We discuss the effect of Information and Communication Technology (ICT) on the learning process and how ICT can reinforce the learning process of HOCS improvement. We discuss Bloom’s Digital Taxonomy catering for new advances in ICT. We overview some state-of-the-art digital learning tools, and make a distinction between features supporting administrative support (enablers) and those that support the learning process itself. We look at the general idea and compare the basic concepts offered by digital learning tools like Blackboard Learn and Moodle and learning technologies like video recorded lectures and Multimedia Instructional materials which to improve HOCS and the learning process as the results show. We highlight the concepts that promote learning and HOCS improvement and how they are in a learning environment, to derive the requirements for a Digital Learning Environment. The requirements include delivery of the diverse content to cater for various learner preferences and styles, personalization to create customized environments for learner motivation and learning desire, communication between students and teachers; and module administration. The Learning Environments should be characterized by the digitization of the course material, place independence, pace independence, web-based, asynchronous, interactivity, collaboration orientation. An effective tool should support the educational process of the educational organization.

We introduce the Digital Learning Environment (DLE) as a tool for maintaining, exchanging and acquiring knowledge, skills, attitudes and competences, in particular supporting learning, teaching and studying activities. We motivate the need for the DLE by discussing the current learning situation and describing the typical users, their goals and roles. We discuss the learning strategies of building competences and HOCS improvement using Bloom’s Digital Taxonomy; show how the DLE supports them and argue that the DLE in its context is an effective means to acquire HOCS and improve the learning process. We further discuss how and why it should be integrated in the infrastructure of a learning institute; from the policy, system and beneficial side which allows us to discuss criteria to measure its success. We discuss the DLE as a tool by relating it to the methodological framework and discuss its implementation and relate it to the four in balance to evaluate its successful introduction in an institution. We highlight the DLE characteristics for successful learning and HOCS improvement.
and give recommendations based on experiences at several levels of education in several contexts, for successful implementation in an institution.

We propose the Learning by Construction approach for the introduction of an ICT education program to improve HOCS, build capacity and infrastructure. We describe the approach, as a mechanism for the effective integration of ICT in the educational process following Bloom’s Taxonomy as a general framework for learning using the DLE. We discuss how education itself plays a role in the introduction of DLE in a low infrastructure context. The approach shows how to effectively introduce the DLE in a low infrastructure context, showing how the DLE can play a central role in community development. We focus on an approach for introduction of an ICT education program for HOCS improvement, building capacity and infrastructure. The approach improves HOCS by using the DLE and Multimedia that enhances the current MM instructional materials, content strategy. The approach further assesses HOCS improvement and the impact of technology on HOCS improvement for problem solving, critical thinking and decision making. The approach proposes that by administering personalized MM instructional content to students and using an actual HOCS improvement instrument; actual HOCS improvement is administered and tested. The proposed system has not yet been validated by data since there is no learning environment working accordingly. We discuss the validity of this approach and validate its soundness by describing an introduction plan.

This research started with some experiments which led to the introduction of an overall learning system. We describe the different experiments and case studies carried out during the research. We discuss the methods used in the different experiments and evaluate the results to assess whether DLEs, Multimedia, Video recorded lectures have an impact on the students’ learning process and HOCS improvement. We evaluate the students’ perceived HOCS improvement when MM materials are used as compared to text book materials. We carried out experiments in universities in Uganda, a LDC and USA, and compare these results. We also evaluate the effectiveness of the DLE and Video Recorded Lectures on the learning process. As a case study and proof of concept we looked at the DLE implementation and its impact at Radboud University, Nijmegen, we give some figures that give an impression. We validate this approach by motivating it from some actual experiences and data from the university to give an impression of the DLEs impact on the learning process. The results show that MM instructional content like Videos and DLEs have a positive effect on students’ learning and HOCS improvement. We also evaluate the two popular state of the art Digital tools of Blackboard Learn and Moodle and further compare them to assess the functionalities that promote learning and HOCS improvement in particular.

The research contributions include the theory which provides the basis for developing an approach for introduction of an ICT education program in a LDC for HOCS improvement, building capacity and infrastructure. The theory determines the set of HOCS improvement requirements to guide instructional content design to derive design choices. The approach uses HOCS improvement requirements, derives and evaluates a theory that highlights metrics for HOCS improvement. Case study experiments are used for evaluation and data from experiments and proof of concept are used for validation. The approach uses the DLE and MM that enhances the current instructional materials, content strategy and assesses the impact of MM on perceived and actual HOCS improvement in problem solving. We illustrate that by administering personalized MM instructional content and using an actual HOCS improvement instrument; HOCS are administered and tested. An implementation of the ICT education program for HOCS improvement, building capacity and infrastructure was not possible within the scope of this thesis and will be the most interesting challenge for the future. As a limitation we need to convince politics and to find financing to accomplish this enormous task.
Samenvatting (Dutch Summary)

Hogere Orde Cognitieve vaardigheden (HOCS) hebben betrekking op de perceptie dat een individu bekwaamheden heeft verworven om een beslissing te nemen onder verschillende omstandigheden van onzekerheid en tijd. Omdat de traditionele leerbenaderingen niet effectief zijn in HOCS verbetering binnen het wetenschappelijk onderwijs, wordt de behoefte aan nieuwe benaderingen beschouwd. Daarnaast is er een tekort aan ICT-capaciteit en infrastructuur, met name in de minst ontwikkelde landen (LDC, Least Developed Countries).

In ons onderzoek hebben we een uitgebreide theoretische overzicht gemaakt van gepubliceerde studies voor het verbeteren van HOCS, waaruit we de elementen voor HOCS verbetering afleiden. We onderzochten de leertheorieën, leeromgevingen, ontwerp van educatieve inhoud, en theorieën en instrumenten van leerstijlen. Daaruit bepaalden we de vereisten voor HOCS verbetering. Daarbij maken we gebruik van de relatie tussen de wetenschappelijke benadering en de factoren voor HOCS verbetering. HOCS kan worden verbeterd als de inhoud wordt ontworpen conform de adviezen uit dit proefschrift.

De onderzoeksbijdragen omvatten een theorie voor de vereisten van HOCS verbetering ten behoeve van inhoudelijk ontwerp. De theorie geeft de basis voor de ontwikkeling van een benadering voor de invoering van een ICT opleidingsprogramma in een LDC gericht op HOCS verbetering, en opbouw van capaciteit en infrastructuur. De theorie helpt ook bij de ontwikkeling van inhoud ten behoeve van HOCS verbetering. We evalueren deze benadering met behulp van case study experimenten en valideren de aanpak met de gegevens van de experimenten en een "proof of concept".

Het proefschrift stelt een aanpak voor HOCS verbetering met behulp van multimedia die het huidige educatief multimedia materiaal, de inhoudelijke strategie verbetert, de HOCS verbetering bepaalt en de impact van technologie op HOCS verbetering voor probleemoplossen, kritisch denken en besluitvorming. Door het administreren van het gepersonaliseerde multimedia aanbod en het gebruik van een HOCS verbeteringsinstrument, wordt HOCS verbetering aanboden en getest. Wij stellen de Learning by Constrcting benadering voor bij de invoering van een ICT opleidingsprogramma ter verbetering van HOCS.

Samenvattend stellen we dus een benadering voor gebaseerd op de vereiste voor HOCS verbetering. We leiden een theorie af, en evalueren deze, met metrieken voor HOCS verbetering, en gebruiken de theorie om ontwerplekjes af te leiden die kunnen worden gebruikt om inhoud en producten te ontwerpen voor HOCS verbetering.

In hoofdstuk 3 beschrijven we Bloom’s Taxonomy als een algemeen kader voor het leren, en relatieren de taxonomie aan ICT. Daarna beschrijven we de algemene leerconcepten van twee proces-georiënteerde en inhoudelijk-georiënteerde digitale hulpmiddelen en leiden vereisten van algemene ondersteuning van het leerproces. In hoofdstuk 4 gebruiken we deze vereisten om de digitale leeromgevingen (DLE) in te voeren voor leren in de context van de gemeenschap-gerealiseerd kennis management. We leiden DLE kenmerken af voor HOCS verbetering. In hoofdstuk 5 presenteren we de algemene aanpak voor de invoering in een LDC van een ICT onderwijsprogramma voor HOCS verbetering, en het opbouwen van capaciteit en infrastructuur. We beschrijven de case studies, methoden en resultaten van experimenten op...
verschillende universiteiten in hoofdstuk 6. Ook presenteren we de resultaten en een aantal DLE gebruikstatistieken om onze benadering te valideren. We hebben ook twee populaire DLE’s vergeleken. De resultaten uit dit hoofdstuk zijn gepubliceerd in bij congressen en in tijdschriften. In hoofdstuk 7 geven we een aantal conclusies, komen terug op de onderzoeksfragen en gaan in op de bijdragen. Verder hebben we een aantal aanbevelingen voor toekomstig onderzoek.
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Curriculum vitae

Emily Bagarukayo was born on 29th December 1978 in Kampala Uganda. She holds a Bachelor of Computer Science (Hons) from Mbarara University of Science and Technology and a Masters of Computer Science degree from Makerere University. Since 2002 she has been employed at the School of Computing and IT, Makerere University. She is an eminent lecturer, researcher and a consultant on Computing and IT issues. She is a research scholar at the International Center of IT and Development (ICITD), Southern University, USA. She undertook her PhD research in the e-Learning area, the impact of technology like Multimedia on Education and industry at the Radboud University Nijmegen, Netherlands in collaboration with Makerere University. She has published several papers about her research within journals, conference and workshop procedures.

Her specific research interests include the use of Multimedia technologies and Digital Learning Environments to support personalized learning; in particular, the development of instructional content for enhancing the learners’ improvement of Higher Order Cognitive Skills and Building capacity and infrastructure in Least Developed Countries. She lectures courses in Computer Science, Information Technology, Computer Applications, E-commerce, Operating Systems Theory and Design, Computer Networking, Systems Analysis and Design, Management Information Systems, Web design and Software Engineering at Undergraduate and Postgraduate levels. She has supervised several student research projects at undergraduate and postgraduate levels in the areas of information systems, Databases, Multimedia among others.
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