

## **An approach to learning by construction**

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### **THE ABSTRACT**

This paper proposes an innovative idea for providing affordable, sustainable, and meaningful education for students in Least Developed Countries (LDCs). The authors show how a Digital Learning Environment (DLE) can play a central role in community development. The authors develop and validate an approach for introduction of an ICT education program for Higher Order Cognitive Skills (HOCS) improvement, building capacity and infrastructure in a LDC using the DLE tool. 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 is described. It combines sound educational approaches such as cognitive apprenticeship and situated learning with industrial design models to create an interdisciplinary solution that potentially results in job creators, not job seekers. Since there are many infrastructure-deprived educational institutions, financially struggling students, especially in LDCs, the proposed approach is a viable way to provide systematic training in HOCS and Knowledge, Skills and Attitudes for these students. The authors discuss how education itself also plays a role in the introduction of DLE. The overall learning system has not yet been extensively validated by data since there is no learning environment working accordingly. The validity of this approach and its soundness is discussed by describing an introduction plan.

### **1.1 INTRODUCTION**

Higher Order Cognitive Skills (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 importance of HOCS improvement is acknowledged by academia and industry (Bagarukayo and Mbarika, 2008). However the current traditional methods have been criticized for failing to impart these skills to graduates. 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 job seekers 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 Information and Communication Technologies (ICT) in LDCs cannot be overstated, especially to aid students’ learning of HOCS improvement and solving of the digital divide issue. The mobile phone has been successful in alleviating the digital divide problem in LDCs. People in LDCs can now access information at any time at a low cost. The authors therefore believe that an ICT education program introduced based on a proper design can be successful. For example, introduction of low cost computers that can stand hard conditions in LDCs can solve the building capacity and infrastructure problem. The authors propose a solution

for building capacity and infrastructure in the LDCs that also improves graduates' HOCS needed for the real world work environment. An approach for the introduction of an ICT education using low cost initiatives is proposed.

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). The 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. In this paper, an approach for introducing an ICT education program in LDCs for HOCS improvement, building capacity and infrastructure is proposed. The authors answer the research question 'what approach is used to introduce ICT education program to improve HOCS, build capacity and infrastructure in a LDC using the DLE tool?'

Our approach can be related to the apprenticeship model which also agrees with the situated learning theory, which emphasizes that the idea of cognitive apprentices supports learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity (Brown *et al.*, 1989). This model is defined as:

*Apprenticeship is 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. Apprentices build their careers from apprenticeships. Most of their training is done while working for an employer who helps the apprentices learn their trade or profession, in exchange for their continuing labor for an agreed period after they have achieved measurable competencies. For more advanced apprenticeships, theoretical education was also involved, formally via the workplace and also by attending a local technical college, vocational schools or university while still being paid by the employer often over a period of 4-6 years.*

When learning is systematically organized around a scheme of construction including development and application, then the scheme is referred to as *learning by construction*. A DLE as an effective tool to implement learning by construction, involving both development and application is discussed. In the next section the pillars of Bloom's Taxonomy in balance are discussed.

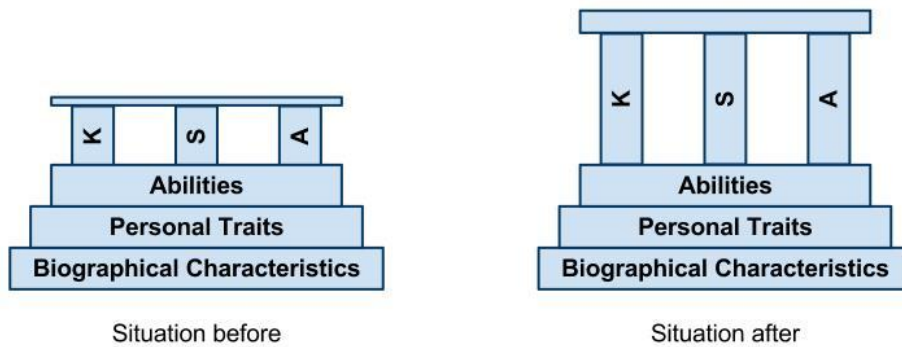
## **1.2 PILLARS IN BALANCE**

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 (Bloom, 1956). The students first learn by imitation such as 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 explained in the next sections.

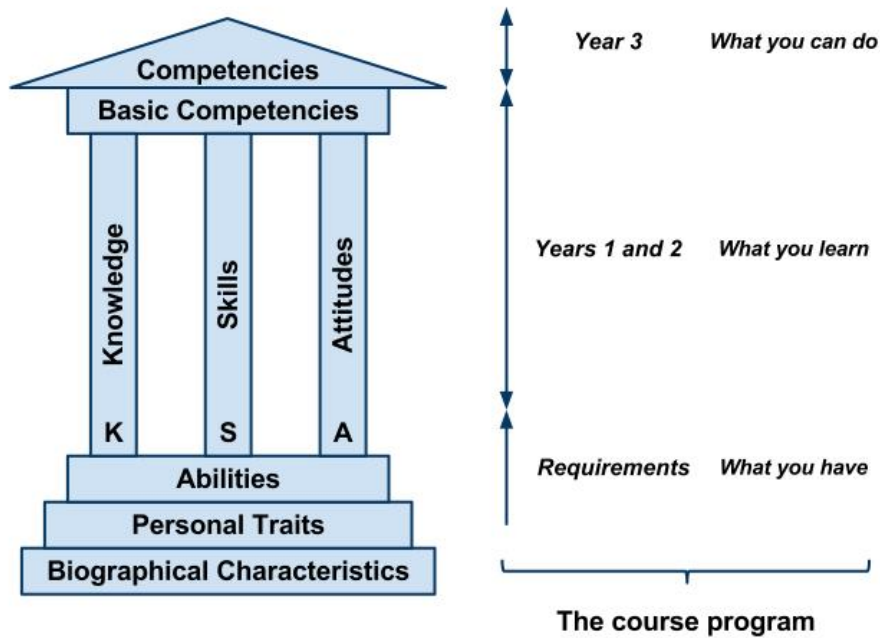
The learning by construction process consists of a number of steps; usually each step will take one school year. At the start of this process, the assumption is that the student has some

required abilities, personal traits, biological characteristics and a few competences and KSA gained from the previous level of education (figure 1.1). When the student enrolls in the course, the KSA and competences increase in a stepwise approach. After completing the final level of education, they gain the general competences because they continuously put KSA into practice, and finally construct a product, hence learning by construction (figure 1.2).



**Figure 1.1: Pillars in Balance**

The authors illustrate the effect of each step using the Competence Architecture Model (Roe, 1999). Each step increases the level in each of the three domains. The authors 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 Figure 1.2.



**Figure 1.2: The Final Situation**

In the next section the learning by construction approach is discussed.

**1.3 LEARNING BY CONSTRUCTION**

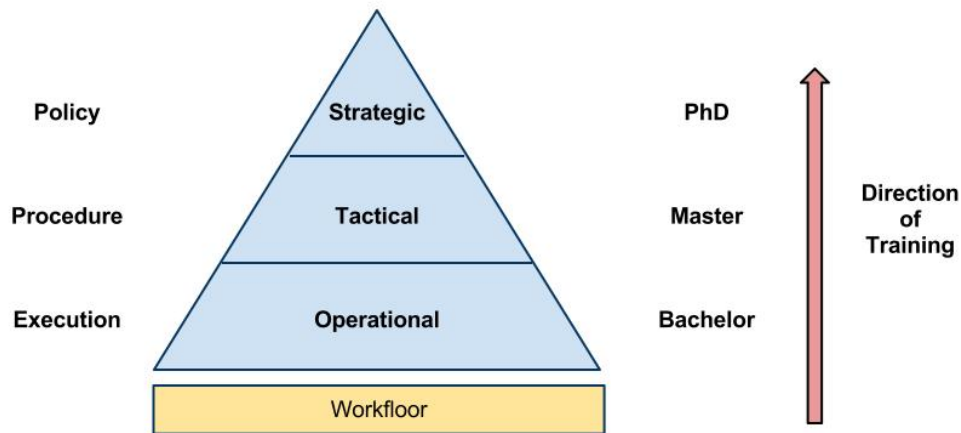
As mentioned before, learning by construction is an apprenticeship model systematically organized around a scheme of construction. Learning by construction is an extension of the learning by building approach that is being applied in a course community outreach project (Weide & Flipsen, 2010). Learning by Building is a method to combine education, research and valorization effectively and is the underlying education philosophy of the educational approach proposed. 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 the changes in the curriculum are made carefully along with adequate planning and support (Barron *et al.*, 1998; Kennisnet, 2010), this approach can be successful. Based on HOCS improvement methods (Bagarukayo & Mbarika, 2008) and Bloom's Taxonomy learning theory, the authors realize the importance of application of knowledge in novel situations. The authors 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. Successful introduction of ICT in a LDC should be based on a proper design to overcome financial and environmental issues (Weide & Flipsen, 2010). The authors propose the introduction of low cost infrastructure to 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. The approach is to set up an educational program with both a theoretical and practical basis. This approach follows Roe's competency development program as described in the competence architecture model, because it encourages building of KSA and competences, which is synonymous with HOCS. HOCS emphasize the ability for students to put knowledge into practice in novel situations and therefore encourages competence building and attainment of KSA which is the aim of Bloom's Taxonomy, in a bid to create a holistic learner. The authors extend the learning by building and Roe's competence models by proposing an approach for the introduction of ICT for HOCS improvement in addition to building capacity and infrastructure.

**1.3.1 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. The authors focus on educational aspects and motivate our educational program from this sustainability principle. Sustainable implementation requires skills at the various academic training levels. At the vocational work floor level students are trained to be well qualified workers.

The PhD, masters and bachelor academic levels correspond with the strategic, tactical and operational managerial levels of the organizational pyramid respectively (figure 1.3). At the bachelor's 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, to describe and optimize processes and the capability 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 Organization for International Cooperation in Higher Education project has been successful at introducing and implementing a model similar to the proposed approach. They initially trained the master's students to strengthen institutional capacity by providing education and training. The masters' holders were later trained in their PhD studies in order to train more students at the home universities.

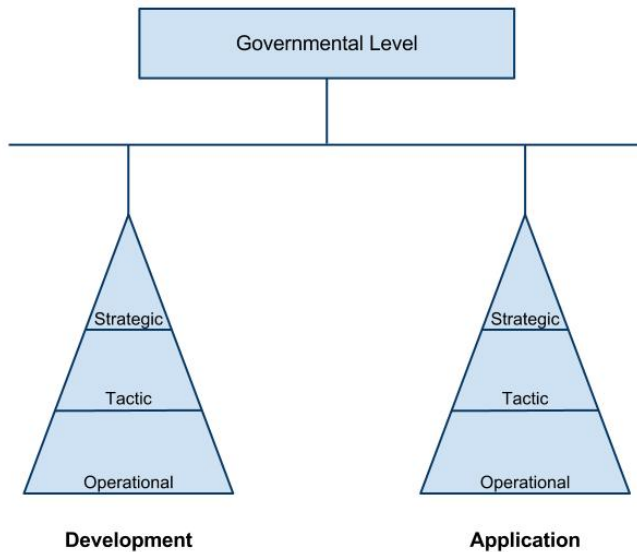


**Figure 1.3: Managerial Levels and Capacity Building**

A topic-directed educational approach as a training program involving capacity building at all these levels is seen. Using the learning by construction approach leads to learning at all levels. Suppose the authors would set up this topic-directed approach to introduce ICT in a LDC. Then the results from the construction will lead to strengthening the ICT infrastructure. The improved infrastructure can only be effective when also 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. The illustration is in figure 1.4.

Applying this in our example of ICT infrastructure introduction, starting with two educational programs is proposed. 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.



**Figure 1.4: The Structure**

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 Bloom's Taxonomy 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, whereby a product is developed 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; and can record videos of classes to be posted on the Digital Learning Environment (DLE) to enhance the learning process. The students can do recording of videos as part time jobs, especially those that have covered the course unit before, since they will know the difficult areas to concentrate on when recording. 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 therefore 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 the implementation steps in the Digital Learning Environment (DLE) –case are discussed.

## **1.4 THE ROLE OF THE DIGITAL LEARNING ENVIRONMENT**

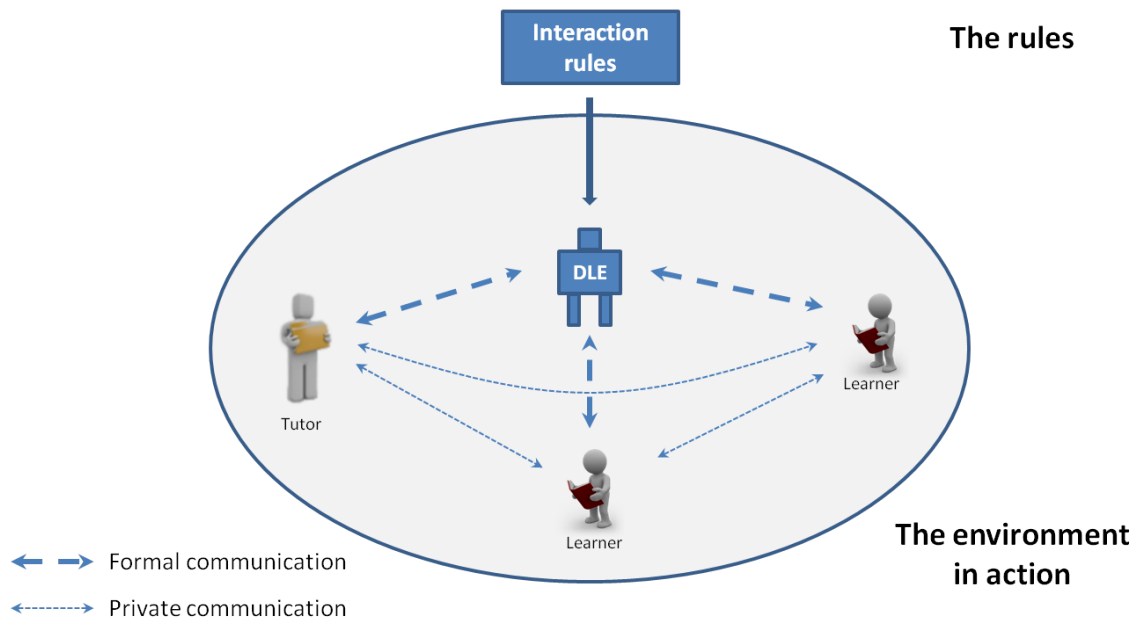
In this section the process of introducing ICT hand in hand with education is further elaborated. The DLE has functions both at the low level for supporting administration and at the high level for learning. The DLE as a knowledge management center has processes related to the specific knowledge maintenance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

In this section the focus is on the low cost production of the DLE. The DLE development costs should be low by the use of open source software like in the case of Moodle. The authors emphasize development with reasonably low investments. 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.

### **1.4.1 As a Tool to Be Used**

The DLE will be used as a support tool for learning as described in the methodological framework section (Bagarukayo *et al.*, 2011a). The authors also noted that students can attain HOCS 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 (Bagarukayo *et al.*, 2011a). 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.



**Figure 1.5: The DLE Environment**

The students and tutors exchange information via the DLE's interaction rules discussed (Bagarukayo and Weide, 2012a). 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.

#### 1.4.2 Designing Learning Material for HOCS Improvement

In the approach the authors introduce the concept of designing content and software for HOCS improvement based on the HOCS improvement requirements. These requirements include 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 multimedia 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 makes up the DLE. Each student or class will be required to construct a module that will contribute to the 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.



The students create content that takes into account the functionalities for HOCS improvement discussed (Bagarukayo *et al.*, 2007). The functionalities in the DLE will test for HOCS improvement. The authors 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 for improving HOCS. The approach tests for actual HOCS improvement with respect to the learning profile used during the learning process. 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.

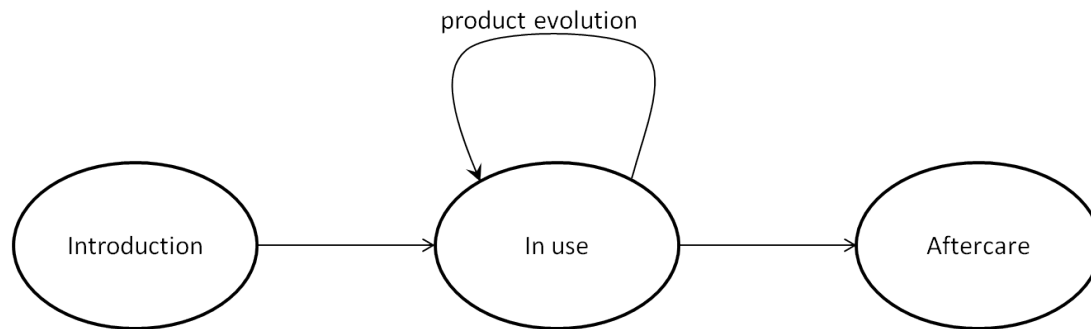
### **1.4.3 As a Product to be Constructed**

Besides using the DLE to facilitate the learning process, the DLE is also the product resulting from learning by construction. Since the intention is to develop a product, module or functionality, the authors elaborate on the principles of product development as they are used in practise. The authors will first discuss a most general product development approach. In particular the authors describe the so-called epicycle for the product lifecycle, and interpret it in the context of our educational program. The authors will see how this cycle is easily related to a learning cycle. The authors propose this learning cycle as the basis for the learning by construction steps as described in section 1.2.

#### **1.4.3.1 The Product Life Cycle**

The product life cycle (Figure 1.7) starts when the product is introduced, usually after its first development phase (Vlietstra, 2003). In the next phase 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, the authors focus on the product evolution step. Figure 1.7 gives a simple most generic view on this evolution step, referred to as the PL cycle.

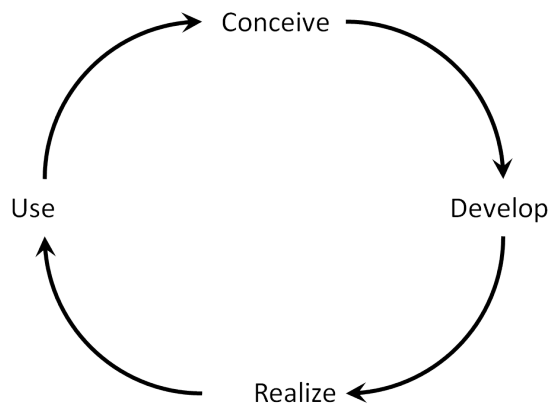
For a product to be developed there is need for data, technology, methods, tools, processes and people. The authors focus on the importance of the knowledge centre and do not consider the commercial concepts.



**Figure 1.6: The Product Life Cycle**

The various stages of the development process are: (1) conceive, (2) develop, (3) realize and (4) use (figure 1.8). For our purposes the authors will see this as:

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



**Figure 1.7: The PLM Cycle**

The stages of the process phase of the Product Lifecycle Management (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

The authors elaborate on these stages further in the next subsection.

### 1.4.3.2 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 1.9, the authors 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

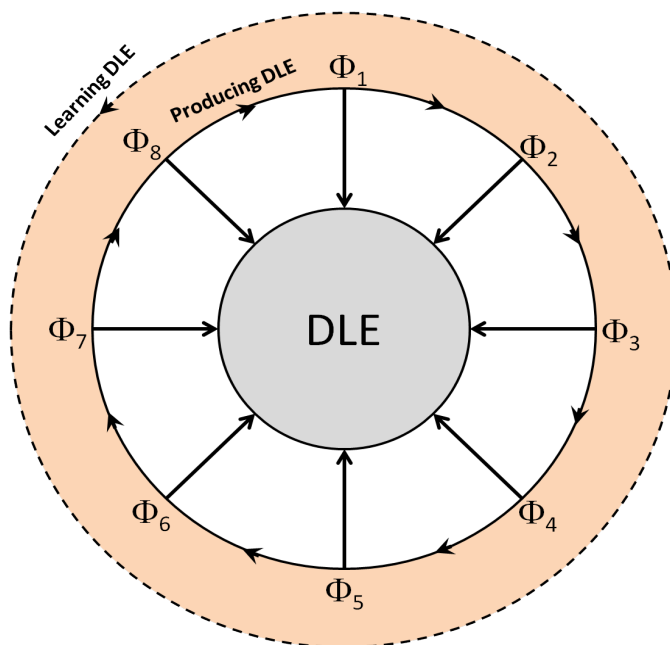


Figure 1.8: The DLE epicycle

The authors 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 ( $\Phi_2$ ), which is made up of standards and best practices, and resources allocation ( $\Phi_3$ ) which is made up 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 ( $\Phi_4$ ), technical design ( $\Phi_1$ ) and design analysis phases ( $\Phi_6$ ). 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 ( $\Phi_7$ ) 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 ( $\Phi_6$ ). 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.

#### 1.4.3.3 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 the authors 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 Blooms Taxonomy in balance. The learning steps are summarized in Table 1.1 as follows:

In the learning cycle the student starts with supporting the use, stage  $\Phi_8$ . 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 evaluate level the cognitive domain, receiving and responding level in the affective domain, and imitation and naturalisation level in the psychomotor domain.

In the next step, stage  $\Phi_7$ , 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 the create, characterizing and articulation levels of the domains and therefore can create a product or functionality.

Using this knowledge, the learner then during stage  $\Phi_6$ , 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 evaluating, organising and precision levels of the domains.

The learner will then, during stage  $\Phi_5$ , 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 level of the cognitive domain.

Equipped with this knowledge, the learner enters stage  $\Phi_4$ , where a functional design is derived from a requirements specification. During this stage, the learner will experience what makes good requirements specification. At this level, the learner is supposed to work at the application and valuing levels of the learning domains.

The next learning step involves stage  $\Phi_3$ . The learner is contributing in this phase 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  $\Phi_2$ , 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  $\Phi_1$ . The learner is at the remembering level of the cognitive domain, 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 1.1: Keeping the Pillars in Balance**

Stage	Cognitive domain	Affective domain	Psychomotor domain
$\Phi_8$	Evaluate	Receiving and responding	Imitation and Naturalization
$\Phi_7$	Create	Characterizing	Articulation
$\Phi_6$	Evaluate	Organising	Precision
$\Phi_1$	Analyze		
$\Phi_4$	Apply	Valuing	
$\Phi_3$	Apply	Responding	Manipulation
$\Phi_2$	Understand	Receiving	Imitation
$\Phi_1$	Remember	Characterizing	Naturalization

The next section presents the organizational structure and curriculum of the ICT education program.

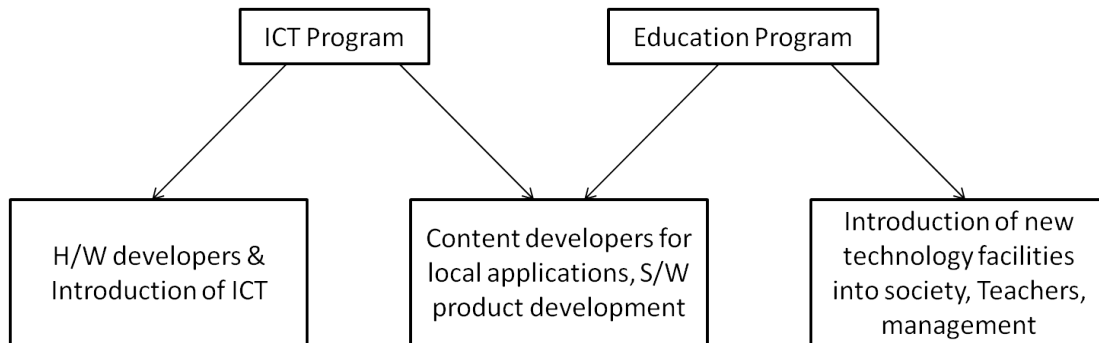
### 1.5 LEARNING BY CONSTRUCTION IN A LOW INFRASTRUCTURE SITUATION

In this section the authors describe a way to introduce learning by construction in a low infrastructure situation. The authors focus on 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). The assumption is 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 (Kennisset, 2010). As noted in (Bagarukayo and Weide, 2012a) 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. The institution will also start with some initial teachers. Guided by these teachers, the initial learners can make the first installation, after which they start with stage  $\Phi_8$  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 the authors 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.



**Figure 1.9: 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 Blooms 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, the authors 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:

*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*

## **1.6 CONCLUSIONS**

The authors validate our approach by using data and by construction as the authors elaborate in this section. The architecture is complex- learners and teachers have to learn the new interaction rules and learners should also be constructors of the new infrastructure (Roe, 1999). Experiments on the impact of technology on learning described in (Bagarukayo *et al.*, 2011b; 2012b) were done initially and are used to support restricted parts of the new approach. Therefore in this paper there are relations with the experiments above. The methodology framework is a reflection of what people think the methodology should cover. The authors show that the proposed approach satisfies the methodological requirements.

### **1.6.1 Validation by Data**

This was done in two ways, the data being used to predict that it can work or prove that it works. In both cases the authors fit the system to the real world situation. In our case using multimedia, HOCS was improved because students' HOCS and knowledge gain increased, which is proven in the results described (Bagarukayo *et al.*, 2012b). The proof includes Learner profile, HOCS promoting teaching and assessment strategies for actual HOCS improvement and multimedia instructional content design as HOCS improvement Requirements discussed. The results also note that the DLE impacts the learning process positively, since there was increase in use of



materials, students and course numbers. The DLE also increased the motivation and interest of the students. The authors believe that with more interaction, collaboration and cooperation, HOCS improvement can be enhanced with the DLE as results show (Bagarukayo *et al.*, 2011b). This is proven by an example; the impact of videos on learning was positive due to the benefits highlighted; 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 (Bagarukayo *et al.*, 2011b). 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.

### 1.6.2 Validation by Argument

The authors' show that the approach is inherently sound by arguing that it works also referred to as the proof of concept. During the theoretical proof, the authors 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.

### 1.6.3 Validation by Construction

It was found that the approach is realistic by showing how it can be introduced / built. The introduction may start from a working situation, but the authors show how the system can be introduced by starting from a low infrastructure situation. The authors set up a framework for the complex system architecture. The authors 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.

### 1.6.4 Summarizing

Experiments were done (Bagarukayo *et al.*, 2012 b) and described to test particular aspects that play an important role in the learning by construction approach. The authors argued the validity of the proposed approach. In section 1.1 the authors have shown that the Learning by Construction approach can gradually (and effectively) be introduced in a low infrastructure environment and believe it can build capacity and infrastructure.

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