Linköping Studies in Behavioural Science No. 170

Enhancing Physics Learning through Instruction, Technical Vocabulary and ICT
A Case of Higher Education in Rwanda

Joseph Rusanganwa

Academic dissertation

Academic dissertation for the Degree of Doctor of Philosophy in Education at Linköping University to be publicly defended on Friday 14 December 2012 at 13.00 in lecture hall I: 101 building I by Joseph Rusanganwa

Abstract

The overarching aim of this thesis is to explore how teaching and learning in tertiary education is performed in times of change both in language policy and learning approaches. The study takes social constructivist and socio-cultural theories as its major points of departure. These theories are combined with cognitive theory of learning with multimedia.

The four studies comprising this thesis are born out of a new situation demanding the mastery of a scientific language in English and new ways of teaching and learning backed with ICT. The studies set out to investigate (i) how students and teachers adapt to a change of medium of instruction (ii) what teachers and students of physics learn when constructing a multimedia vocabulary learning instrument (iii) the impact of two methods of teaching vocabulary on students' test performance and (iv) how teachers reflect on the use of ICT in Physics teaching.

To attain these targets, the study employed a blend of qualitative and quantitative designs to gather relevant data. In three studies, data were gathered from classroom practices in tertiary education. The fourth study included teacher interviews on their experiences with ICT. Findings indicate that the understanding of physics was facilitated by a variation in language use in different classroom spaces, students and teachers' collaborative selection of technical vocabulary and a multimedia tool of technical vocabulary software constructed by two teachers and the researcher. According to the teachers, the quality of physics teaching would be enhanced further by adopting learner-centred teaching methods and the integration of more advanced ICT. The studies show that teachers and students are on their way to develop ICT tools for teaching and learning. Given adequate support, this can pave the way for transforming teaching and allowing for further quality development in innovative and creative ways of learning with ICT.

Keywords: tertiary education; language shift; EFL; physics technical vocabulary; CALL; software encoding; social constructivist theory; cognitive theory of learning with multimedia; ICT tools; transforming learning; Rwanda

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Att förbättra lärande i fysik genom instruktion, ett ökat tekniskt ordförråd och IKT
Ett exempel från högre utbildning i Rwanda

Joseph Rusanganwa

Akademisk avhandling

som för avläggande av filosofie doktorsexamen vid Linköpings universitet kommer att offentligt försvaras i sal I:101, Hus I, Campus Valla, fredagen den 14 december 2012, kl. 13.00.

Abstract

Det övergripande syftet med denna avhandling är att undersöka hur undervisning och lärande inom högre utbildning sker i tider av förändring både inom språkpolicy och inom lärande. Studien tar socialkonstruktivistiska och socio-kulturella teorier som utgångspunkt. Dessa teorier har kombinerats med en kognitiv teori om lärande med multimedia.

Studien består av fyra studier som behandlar den nya situation som uppstått när studenter och lärare behöver bemästra ett vetenskapligt språk på engelska och nya sätt att undervisa och lära med stöd av IKT. Studiernas syfte är att undersöka (i) hur studenter och lärare anpassar sig till ett förändrat undervisningsspråk (ii) vad lärare och studenter inom fysik lär när de konstruerar ett multimedia instrument (iii) utfallet av två olika metoder att lära studenter ett fackspråk inom fysik som det visar sig i olika test (iv) hur lärare reflekterar över användningen av IKT inom ämnesområdet fysik.

För att uppnå dessa mål används en kombination av kvalitativa och kvantitativa metoder. I tre studier samlades data från klassrumspraktiker inom högre utbildning. I den fjärde studien intervjuades lärare om sina erfarenheter med IKT. Resultaten visar att förståelse av fackspråkliga begrepp underlättades av att olika språk användes beroende på avstånd eller närhet till eleverna i klassrummet. Samarbete mellan studenter och lärare i att välja ord och begrepp som skulle användas och mellan lärarna och forskaren i att konstruera ett multimedia-instrument påverkade också lärandet positivt. Enligt de intervjuade lärarna skulle kvaliteten i fysikundervisningen kunna förbättras ytterligare genom att använda elevcentrerade undervisningsmetoder och mer avancerad IKT. Studierna visar att lärare och studenter är på väg att utveckla IKT redskap för undervisning och lärande. Med adekvat stöd kan detta bereda vägen för en transformering av undervisningen och ge utrymme för vidare kvalitetsutveckling genom uppfinningsrika och kreativa sätt att lära med stöd av IKT.

Nyckelord: högre utbildning, förändrad språkpolitik, engelskt fackspråk inom fysik, CALL, konstruktion av mjukvara, socialkonstruktivistisk och kognitiv teori, lärande med multimedia, IKT, transformering av lärande, Rwanda

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DEDICATION

To you my wife Madeleine
To my sons and daughters
and the family

For your understanding, love, moral support and sacrificial patience during my long stay away from home,

This thesis is dedicated.

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ACKNOWLEDGEMENT

Travelling through an unknown terrain you definitely need an experienced guide to help you safely start and complete your journey. Yes! This was a challenging journey through life, both academic and social. Of course it is the end of the beginning but this is a step.

Various people have played major roles accompanying me on this journey. I owe them tribute. I first would like to express my gratitude to Associate Professor Ingrid Andersson my supervisor who guided my studies from the beginning up to this level. Your patience, diligence and tolerance are highly appreciated. I was impressed by your gentle, cordial but firm supervision. I also owe many thanks to Professor Sven Andersson my co-supervisor for his constructive reflections and input in my work. From recruitment to PhD scholarship you have provided constant information on how to manage our studies. As a co-supervisor you proposed documents to consult and provided constructive criticisms to my work which enabled this thesis to be in shape.

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I am pleased with the friendly environment in IBL. The smiling personnel, the cleanliness, the sharing of coffee and conversation, the contribution in symposiums and seminars, the warm and quiet atmosphere all of which boosted my energy to concentrate on my studies and writing tasks.

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Last but not least I would like to express my unfathomable gratitude to my wife Madeleine Uwanyirigira for her patience and understanding during my long absence from home. You courageously took care of the family alone, raising our six children while also doing your university studies. You are a marvellous woman! My children Germain, Revocatus, Livia, Evode, Tekla and Seconde, you have been wise and obedient children. Thank you for your prayers and encouragement. You have been an inspiring spirit behind my completion of my studies. I am proud of you!

Linköping, November 2012

Joseph Rusanganwa

LIST OF ORIGINAL ARTICLES

This thesis is based on the following articles

Article 1: Andersson I. & J. Rusanganwa. (2011). Language and space in a multilingual undergraduate physics classroom in Rwanda. *International Journal of Bilingual Education and Bilingualism, 14*(6) 751-764.

Article 2: Rusanganwa, J. (under review). Developing a Multimedia Instrument for Technical Vocabulary Learning: a Case of EFL Undergraduate Physics Education *Computer Assisted Language Learning.*

Article 3: Rusanganwa, J. (2012). Multimedia as a means to enhance teaching technical vocabulary to physics undergraduates in Rwanda, *English for Specific Purposes*, *32* 36–44.

Article 4: Rusanganwa, J. (under review). University teachers' reflections on the use of ICT in physics teaching, successes and challenges: the case of Higher Education in Rwanda.

INTRODUCTION

The desire of crafting solutions to problems dates back to my early childhood. To enhance child play at pre-school age, I used to wake up at dawn and assembled my friends on the ant-hill near my parents' house to dig out clay from which we made toy cars resembling the white man's who used to visit our village. The car I made was called *penepene* due to the sound it made. The following day the children of the village flocked to my home asking me '*nange uzankorere penepene*' (Me too, make *penepene* for me). The *penepene* cars were made and the play went in full swing. However, I was not satisfied with merely providing play toys. I was also eager to solve other problems. For example our house had no electricity and I thought how to solve this lighting problem. I used to collect castor oil pods, stringed them together and lighted them and wow! there was a light so we could prolong the night telling stories. Also I used to make pair of scissors out of cast pieces of iron to try and cut my friends' hair though it did not work as a normal pair of scissors. The uneasiness to live with an unresolved problem haunted me even when I joined a medical school as an apprentice. I got an inflammation of the ear 'otitis externa' which outwitted doctors' knowledge. After it persisted for more than six months, I felt I should look for a solution. I went to the laboratory and mixed medical potions of anti-fungals, antibiotics and honey and finally I got cured; no inflammation today, 30 years later. In my life I always felt ill-at ease if there was a problem unresolved- I could not hang around with it.

Context and Motivation

The overarching aim of this thesis is to investigate ways in which students can learn technical vocabulary required for the understanding of their physics courses and how teachers can facilitate physics learning with the help of ICT and underlying theories of learning.

The work presented in this PhD thesis is inspired by a study published in a special issue of *Etudes Rwandaises* (Rwandan Studies). The study focused on a problem of students' choice of subject area, that is

'*Causes du Désintérêt des Etudes pour les Sciences Pures au Rwanda* [Reasons for Students' lack of interest in Natural Sciences in Rwanda], by Mureramanzi et al. (2002). When I read it, I asked myself 'why do these students lack interest in the sciences?' At the end of the study, it was pointed out that this really was a problem. The researchers argued that the students did not want to pursue science subjects for two main reasons. First, there was no clear future prospects for science studies in terms of employment and social appreciation. Second, the sciences were perceived as difficult subjects taught using methods that were theoretical rather than practical and in addition inadequate, incoherent and overloaded. One item among their suggestions was to deal with this problem to produce and supply teaching materials adapted to school programmes. For future action they recommended that specific and profound research should be carried out by the government and higher learning institutions to implement their proposed strategies of improving teaching methods and providing needed teaching materials.

Reading through Mureramanzi et al. (2002) longitudinal research study covering the academic years 1981/1982 to 1997/1998, I could spot physics as a subject with the highest failure rate which averaged 26.83% compared with 13.33% of other subjects. This gave me a hint on which subject suffered most and which needed close attention. Through further reading in Graduation Booklets I came across other statistics showing the number of graduates from science subjects for academic years 1999, 2002 and 2004 reproduced below (Table 1).

Table 1. Graduates from natural and applied sciences at NUR.1999, 2002 and 2004

Type of degree obtained	Year of graduation 1999			2002			2004		
	Tot.	Fem.	Male	Tot.	Fem.	Male	Tot.	Fem.	Male
B.Sc Chemistry	3	0	3	0	0	0	4	1	3
B.Sc Pharmacy				17	7	10	3	1	2
B.Sc Physics				4	1	3	2	1	1
B.Sc Applied Maths				1	0	1	6	0	6
B.Sc Computer science				7	1	6	9	2	7
B.Sc Biology				4	0	4	1	0	1
B.Sc Information Technology				20	1	19	0	0	0
B.Sc Electricity and electronics							2	0	2
B.Sc. Civil Engineering							6	0	6
Grand total	3			53			33		

Source: Graduation Booklets 1999, 2002 and 2004

From this reading I was surprised to find a very small number of graduates in the sciences (89 compared to over 2000 from other faculties). Now that I had come to the reality of a problem, what should I do? I did not see employment as a problem to discourage science learning since throughout my academic life I have believed everyone can manage to live a decent life as long as he or she excels in his or her domain. But then, how can science teaching and learning be facilitated so that students don't perceive it as a difficult subject? Apart from the problem of failures in physics there was another problem of very low enrolment of female students in the department of physics. Physics has traditionally been feared as a very difficult and demanding subject to be reserved for a few male students. I thought I should problematize this issue and dispel this myth so that more students including females could join freely.

Now the challenge was how a linguist could give a hand in a science domain. Of course, I had done sciences in my secondary education, but I specialised in languages at university. I reasoned that though I am a language teacher and not a physics teacher, still I could do something to facilitate physics teaching and encourage more female enrolment hence dispelling the myth that physics is an impossible subject to be studied. I felt this strong concern since I am part of the context and stakeholder in higher education hence I have to do something for my community. However, as a researcher, I have tried to avoid falling into the trap of bias. I understand that I should step outside from the role as a teacher and look at what is happening with a researcher's eye.

Between 1997 and 2007 our university espoused a bilingual system where the students were required to take their courses in English and French, both foreign languages in Rwanda. However, my pedagogical knowledge had convinced me that for students to learn a subject in a language they do not master very well would present serious problems to them. These problems, I assumed, would stem from the fact that they were first year, university students who were ill-equipped in languages from high schools to understand materials presented to them. I predicted that listening to lectures presented in English or French would mean a big challenge. Also reading texts full of technical vocabulary abounding in physics would be difficult. I felt these students needed to develop an ability to use domain specific language to describe and explain physics concepts they were learning in French and in English. So, how could I encourage learning physics through these languages? The task of solving problems had already begun once again! Since the students had to understand their course I had to find ways of creating conditions that would facilitate them to acquire a large enough amount of technical vocabulary needed for adequate comprehension of their academic reading in a relatively short period of time.

As we were in the era of ICT (see Rwanda ICT policy, 2005)**,** I had to think of how technology could serve the purpose. I reasoned that ICT would enhance necessary vocabulary learning to facilitate reading text materials found in these two languages. In this process, the students needed to be exposed to carefully selected vocabulary necessary to be learnt for their course requirements. This vocabulary would then be encoded on computer software that would be manipulated to present them and give the required feedback.

Aims and Research Questions

The major concern of this thesis is to present steps taken to find ways of enhancing physics teaching and learning with a focus on language and ICT. First, it aims at showing how students and teachers cope with the abrupt change of language of instruction. Secondly, it aims to understand how students and teachers develop a multimedia instrument using their computer knowledge and theories of social constructivism and multimedia learning to learn physics concepts. Thirdly, the aim is to investigate how this instrument is applied to facilitate physics concepts learning. The fourth aim is to investigate physics teachers' reflections on the integration of ICT in their teaching to facilitate students' comprehension of complex concepts in physics and their visions on how it could be developed further.

Based on the situation spanning the period 2009 – 2011, the studies set out to gain knowledge on the following:

- How do lecturers and students in tertiary education adapt to an abrupt change of the medium of instruction?
- What is the learning gained in terms of theory and practice when teachers and students are involved in the construction of their own multimedia instrument?
- What is the impact of two methods of teaching technical vocabulary on student performance in tests of recall and transfer?
- How can ICT integration facilitate physics concepts teaching?

The Targeted Readers of this Thesis

This thesis is a study of how undergraduate physics is learned through language for specific purposes while supported by ICT. The direct beneficiary will be those people involved with university physics teaching and learning. That is, students and teachers of physics. Likewise, as the research questions involved themes such as multilingualism, technical vocabulary and relationship between language and science teaching, the research will be of interest to linguists, language teachers and researchers in English for Specific Purposes.

This thesis also deals with issues related to language and ICT policies in relation to the choice of medium of instruction and the use of technology. The work will therefore be of interest to educational decision makers and curriculum planners. Furthermore, the thesis will be of importance to those who deal with matters of language promotion in relation to official and instructional languages.

According to the researcher, however, this work is first and foremost a contribution to interdisciplinary research between language and physics education. In that way, the thesis provides a theoretical contribution to deepen our understanding of how research can influence practice on content learning through language. It is hoped that earlier research in second language acquisition, theories of social constructivism and cognitive theory of multimedia learning, language learning and ICT will be of interest to both teachers and educational researchers.

A LINGUISTIC HISTORY OF RWANDA

Rwanda is one of few countries in Africa where, in principle, all citizens share a common language, Kinyarwanda (L1). In 1895, Rwanda was colonized by the Germans, becoming part of German East Africa. However, after Germany's defeat in World War I, Belgium was assigned the administration of Rwanda by the League of Nations. During this period, schooling, as we know it today, was introduced for sons of high-ranking people, and French became the medium of instruction, hence a second language (L2). The aim was to train administrative staff to serve in the Belgian colonial administration. After World War II, Belgian rule continued until independence in 1962. During this period, Kinyarwanda was used as the medium of instruction in primary school and French was used from secondary school through to university. When the National University of Rwanda (NUR) opened in 1963, all higher-ranking positions required fluency in French. English (L3) had already been introduced as a foreign language in some secondary schools in the 1960s, but its status was low compared with French.

After the 1994 genocide, many Rwandans returned from exile, some from Anglophone and some from Francophone countries. At the same time, there was a massive investment in higher education. The number of students graduating from NUR increased to 1340 a year in 2000, which is far more than the total number of graduates between 1963 and 1993. All university lecturers were originally French speaking; however, after 1994 an increasing number of lecturers returned from English-speaking countries, and English-speaking foreigners were employed as guest lecturers to replace lecturers who had lost their lives in the genocide. These lecturers could choose to teach in either French or English. Since the university had also started to attract English-speaking students, the university education had to become bilingual in French and English (MINEDUC, 2003). This was carried out already in 1996 when the university realised the problem and established a School of Modern Languages (Ecole Pratique des Langues Modernes, EPLM) in order to make all students bilingual. Gradually, these language courses became compulsory. This was done to help students cope with lecturers who could teach in either French or English.

The content of this thesis is influenced by the bilingual system through to the period of English only as a sole language of instruction but the data presented in it starts in 2009. In October 2008 a decision was taken to change the medium of instruction in Rwandan education to English only (Plaut, 2008) with effect from January 2009. English was to be used from primary upper level (i.e. standard four to six) to tertiary education. The policy was supported by several arguments for the increased status of English, including the fact that Rwanda had become part of the East African Community in 2007 and a candidate member of the Commonwealth since 2007 though full membership was obtained in 2009 (MINEDUC, 2010).

When the government took the decision to change the medium of instruction to English only, all students who wished to enter university had to accept the new language policy, namely the requirement of English proficiency for students who enter Higher Education in Rwanda (2008). The policy stated that all lectures, seminars and practicals e.g in laboratories would be conducted in English, and all oral or written assessment would be in English. Further, English would be the normal language of administration of the university, for both students and staff. Students who enter higher education in Rwanda still have to attend English classes to help them develop proficiency. These classes are intended to provide them with the basic language structures to enable them to develop an understanding of spoken and written English. Classes include reading simple, general and subject-specific texts, writing assignments, academic writing and related requirements in research skills, including paraphrasing, synthesizing, quoting, referencing and note-taking. On entering higher education, students' ability in written and spoken English is tested and they are assigned to one of three broad categories based on their results: advanced (a score of 70% and above), intermediate (50-69.9%) or beginner (Below 50%). Appropriate English courses are provided for students judged to be 'beginners' or 'intermediate'. These courses do not carry credits, but students are reassessed at the end of Level 1 to prove their progress unless they are assigned to the 'advanced' category on the basis of their test results.

It is only when students manage to attain proficiency in English at the advanced level of 70% and above that they are allowed to join faculties. Similarly, all lecturers have to take courses in English to be able to use English as the medium of instruction. In sum, both lecturers and students have to develop their proficiency in English and adjust to a new language culture. The proficiency tests in English are locally done and are designed following Cambridge English Proficiency tests but they are not internationally recognized. The tests are designed in that way because the students use *New Cambridge English Course* books as their class readers. To embrace the new system, teacher-fronted sessions have been reduced and learner-centred activities are encouraged.

Influence of Language of Instruction on Learning

The work presented in this thesis is based on the above described monolingual society with a multilingual education tradition. To my knowledge there are few works on the impact of language of instruction on particularly science subject learning in Rwanda. There are, however, many studies on the impact of languages of instruction in African schools (e.g. Brock-Utne, 2001, Mukama, 2007), language policy and multilingual education (e.g. Samuelson & Freedman, 2010). Most of these studies have suggested using the native languages in primary school (in our case Kinyarwanda) but they have not dealt with using those languages to enhance science learning.

In my opinion, if a native language could be used to disseminate knowledge at any level, it could easily help the learners to understand the content since it is presented in a language in which they feel at ease. According to Mukama (2007), most of the scientific books we come across in African schools have been written by Europeans and Americans in their particular contexts and in their specific languages. The meanings assigned to this literature are primarily embedded in their social realities. Therefore, briefly I could argue that to accurately learn any concept in a foreign language you need to understand the language and the context in which it is embedded. Here I am not arguing that Kinyarwanda is too poor to express ideas. Rather, what I am saying is that languages like Kinyarwanda in our context acts as an auxiliary language to help and to explain complex concepts to the students who would find it difficult to understand them direct from foreign languages. I am aware of some major languages with a high population of speakers like Kiswahili (Rubagumya, 1991) that have been proposed as a medium of instruction but have failed to express scientific and technological issues because they are better grasped when they are expressed in the language of origin. So, students need time to learn and master English over a sequence of years to be able to study in it.

There are factors influencing language choice in favour of English in this work. Some of the factors are the availability of relevant literature in the form of textbooks and journals and the fact that many universities are not sufficient in teaching personnel; hence the need for foreign lecturers. Moreover, students need to be competitive on the job market which entails to prepare them for a world mostly dominated by English. Thus, learners should be urged and helped to learn and master the language in which the learning materials are written, that is English. Being convinced that the targeted learners needed to master science concepts expressed in English as a foreign language, we had to find ways to facilitate learning of the technical language that was a prerequisite to understand their physics courses. Thus the work presented here points to ways that facilitate domain specific language learning and physics concepts understanding through the English language and ICT.

Teaching and Learning in EFL Contexts

Teachers in Rwandan upper primary school up to the higher education are instructed to teach all subjects in English as a medium of instruction. However, English is used in Rwanda not as a second language but as a foreign language (EFL) since apart from classes it is not used in daily transactions. As mentioned above the motivation for using English is both political and economic. Rwanda has to function internationally together with its East African neighbouring countries and as a Commonwealth member country. Moreover, it should be able to establish commercial activities with English speaking countries. Therefore the use of English in Rwandan academic structure is mostly motivated by the need to ‘survive’ in the global competition where Rwanda must seek to trade with other countries and search for knowledge.

Rwanda has not been able to use Kinyarwanda as a medium of instruction in parallel with other languages such as English as it is done in the Nordic countries, Hong Kong, Canada or Netherlands. These countries use their L1 in parallel with English and the learners can benefit from courses given in two languages. In Rwanda, teaching in English is seen as an indispensable choice if we have to prepare students for an academic career. This is true in all subjects whether they be social sciences, natural sciences, engineering, agriculture and medicine where all the course literature has long been published and taught in English as a language of science. First, all text books used are written in English and all the teachers whether visiting or local have to use the same language. Thus, the students have to develop language skills in order to face their studies and expecting to be competitive in the job market.

Importance of Language in Science Learning

Airey (2009) asserts that 'it could be argued that language related problems in disciplinary learning may be *more* acute in L1 – simply because this language is taken for granted and thus learners seldom reflect on the meaning of words or phrases'(p. 17). In Rwanda, the learners are faced with two challenges. First, it is a challenge to understand the language itself and then to understand foreign concepts presented in a foreign language. For instance the concept of a *photon* would be very hard to grasp for learners who are raised in an environment where electricity and light are not concerns of their daily life. The L2 learners will always have problems to understand abstract concepts and how to differentiate between scientific terms and their application in new situations. In a situation like this the increasing demands will be placed on the language to help them construct knowledge and avail it for application (Halliday & Martin, 1993).

So, what is the role of language in science learning? Keys (1999) argues that:

> Science learners have sets of tentative constructions for scientific phenomena that may be continually modified by experiences in the

> classroom. Language is essential for the generative process, because verbal representations are needed to link ideas from long term memory to new information […] Learning science involves extending conceptual structures by generating new meaningful inferences for incoming data and information. (p. 119)

When dealing with scientific assignments one has to follow the steps of analysing problems and setting goals. One has to identify relevant data and determine their meanings so as to construct inferences geared to developing conceptual knowledge structure. All these procedures need language to stimulate reflection for the meanings to be clarified. After this step, one has to make language choice to communicate meanings of the data and construct canons of argument. Language also becomes very important when one has to express the knowledge gained. It is through language that one can state the findings, cite evidence and describe observations (Keys, 1999, p. 121).

Need of Technical Vocabulary in Science Learning

Hyland and Tse (2007) argue that ‘Within each discipline or course, students need to acquire the specialized discourse competencies that will allow them to succeed in their studies and participate as group members’ (pp. 248-9). These competencies should include academic literacy that will strengthen critical thinking and arguments based on theoretical or ideological standpoints. This comes with the assumption that learners are seeking to build a repertoire of specialized academic words in addition to their existing basic or general service vocabulary. However, it has been found that students in the sciences are not well served by general service vocabulary only; hence facing unknown words in the scientific texts they read (Hyland & Tse, 2007). Thus there is a necessity to establish a more specialized and technical vocabulary to serve their field needs. This need is justified by the fact that according to the research, the combined Academic Word List (AWL) and General Service List (GSL) failed to account for 22% of the words in the science corpus, meaning that students would stumble over an unknown item about every five words, making the text incomprehensible (Hyland & Tse, 2007, p. 240).

Technical Vocabulary in Physics Learning in Rwanda

Airey (2009) posits that '[t]here is a critical constellation of semiotic resources that students need to become *fluent in* before they can appropriately experience a given physics concept' (p.107). This is also true in Rwandan context and particularly for the physics context. Usually students who go to university have received a late immersion in language and the subject itself. As said above, the situation in Rwanda expects students to start to be immersed in English late in their final years of primary education. As they continue to secondary education, they are still not well immersed in the English language and still they will have to learn physics as a new subject in a disciplinary language also new to them. As discussed by Airey (2009), this is a kind of '*late immersion* (after grade 7) which may well be associated with *negative effects* on subject knowledge [...] at high school level and above' (p. 26). This negative effect may be related to the demands placed on language due to the increasing levels of abstract knowledge at higher levels of education which students have to adapt to while being taught in a foreign language.

It is argued that even without the added complication of a second language, language problems in physics lectures may be particularly acute due to the experienced complexity and abstractness inherent in learning science. Lemke (1990) argues that learning science critically depends on the ability to understand the disciplinary language in which the knowledge is construed. Moreover, Säljö (2000, as cited in Airey, (2009) sympathizes with the situation by arguing that 'difficulties in student learning are in fact difficulties in handling and understanding highly specialized forms of communication which are not found to any great extent in everyday situations'(p. 27) This depicts the real situation in Rwanda where the scientific forms of communication are only met in the classroom and not in daily life. It is said that students often do not appropriately understand the disciplinary language that they meet in lectures and yet they are bound to use it later in their discipline. As observed by Northedge (2002), it is unfortunate that 'university lecturers' thoughts are so deeply rooted in specialist discourse that they are unaware that the meanings they take for granted are simply not construable from outside the discourse'(p. 256) . It is thus suggested by Hyland and Tse (2007) that teachers should think of helping students to master a specialist vocabulary as an important part of their role hence a list of scientific terms should be made to guide students writing and plan their learning more efficiently (p. 249). They emphasize that teachers need to clearly identify students' target language needs as soon as possible and address them. This will entail introducing and helping students to practice the technical vocabulary of their fields or disciplines. Moreover, teachers should seek to teach the most relevant and useful vocabulary to their students by highlighting which vocabulary should be taught and in which actual situation in the classroom

THEORETICAL FRAMEWORK

Laurillard (2012) argues that teaching is changing and it is no longer a matter of just passing on knowledge to the next generation. Twenty-first century teachers have to keep abreast with research and ever-changing cultural and technological requirements. Since many changes are taking place, teachers also have to work out creative and evidence-based ways of improving what they do. Teachers have to be ready to design and test new ways of teaching, using learning technology to help their students. However, to attain this, the teaching profession needs teachers who are ready to work in collaboration to design effective and innovative ways of teaching.

Furthermore, Laurillard (2012) explains that there has always been a strong relationship between education and technology (p. 17). She believes that technological tools are important drivers of education and that they have the potential to change it albeit unbidden. It is imperative therefore, that teachers and lecturers place themselves in a position where they are empowered with the use of digital technologies, and put them to the proper service of education. They should know what technology has to offer and how it is changing student life. She asserts that ‘knowledge technologies shape *what* is learned by changing *how* it is learned’ (Laurillard, 2012, p. 18).

This thesis is built on the belief that knowledge is both socially and culturally created and that the learners have to develop their own mental models of information to understand concepts presented to them. Learners are expected to actively and profoundly process novel information in order to contextually integrate it with their prior knowledge and promote deep learning. Thus with language as a mediating tool for meaning making in social constructivism (e.g. Vygotsky 1978, 1986) and the use of multimedia in cognitive affective theory (Moreno & Mayer, 2007; Mayer, 2008), this work will explain how learning was enhanced within this thesis.

To begin with, I need to make it clear that these theories are not just there waiting to be picked and applied to the learning situation. They have to be adapted to the context, that is, the environment and the setting where the learning is taking place. Neither do I argue that these theories have no pitfalls. Clearly, most of them are criticised in one way or another. However, despite all these pitfalls, we need to understand each of the theories underlying this work and how they have been applied.

Sociocultural Theory

Sociocultural theory is based on the concept that human activities take place in cultural contexts and are mediated by language and other symbol systems. It emphasizes the interdependence of social and individual processes in the co-construction of knowledge. According to Lantolf (2000) , 'Sociocultural theory holds that specifically human forms of mental activity arise in the interactions we enter into with other members of our culture and with the specific experiences we have with the artefacts produced by our ancestors and by our contemporaries'(p. 79) .

Socio-cultural theory relies most on the Vygotskian concept of mediation as a fundamental notion. The most fundamental concept of socio-cultural theory is that the human mind is mediated predominantly by a process described as the guided construction of knowledge, which is a communication process in which one person helps another to develop their knowledge and understanding (Mercer, 1995).

Referring to Vygotsky's concepts, Ga´nem-Gutie´rrez (2009, p. 323) stresses that human activity is always mediated activity; in the physical world. Instruments, also called artefacts, such as hammers and computers are drawn upon in order to modify the environment and adapt it to our specific circumstances and needs. In effect, he maintains that artefacts are created to satisfy human needs or to achieve certain purposes. Wertsch (2003) expands the possibility of mediating tools to be applied in various sociocultural contexts such as in ICT-based learning environments. As Vygotsky (1978), puts it, the introduction of new signs or tools influences human development through the interplay between people's experiences, actions and motives. These tools back up learning which takes place in specific contexts.

The most important act of mediation dealt with in this work, is the qualitative transformation brought by two artefacts namely language and ICT. According to Bliss and Säljö (1999), language is considered as a psychological tool that permits us to codify the world around us and it is very useful for the purpose of reasoning and communication. Language is a symbolic tool that mediates mental activity. It is considered both a psychological and a cultural tool. In the classroom environment, language allows students to organize their thoughts, map the external world and make sense of it. Furthermore, as a cultural tool, language fulfils the role of communication where learners express their thoughts and receive feedback from their teachers, peers or other people. Language is also used to create conducive conditions under which shared meaning is negotiated and activities are facilitated through learners' interactions. In this dissertation ICT is presented as a mediating tool for teaching and learning.

Constructivism

The cognitive constructivist approach by Piaget emphasizes that 'students construct knowledge by transforming, organizing and re-organizing previous knowledge and information' (Santrock, 2011, p. 333). Vygotsky's social constructivist approach on the other hand emphasizes that students construct knowledge through social interactions with others. The content of this knowledge is influenced by the culture in which the student lives, which includes language, beliefs, and skills. While Piaget emphasizes that teachers should provide support for students to explore and develop understanding, Vygotsky emphasizes that teachers should create many opportunities for students to learn by co-constructing knowledge along with the teacher and with peers. In both models, teachers are expected to serve as facilitators and guides rather than directors and moulders of children's learning.

According to Felix (2002), the constructivist assumption is that learners are active constructors of knowledge who bring their own needs, strategies and styles to learning, and that skills and knowledge are best acquired within realistic contexts and authentic settings, where they are engaged in experiential learning tasks (p. 3). The constructivist theory of learning considers individuals as active agents who engage in the construction of their knowledge by integrating new information into their schema, and by associating and representing it in a meaningful way (Jee, 2010 p. 3). This approach emphasizes authentic and challenging projects that associate teachers, students and experts in the learning community, more closely related to the world outside learning institutions. In an authentic environment, learners assume responsibilities for their own learning. They have to develop meta-cognitive abilities to monitor and direct their own learning and performance. Jee (2010) further argues that when people work collaboratively in an authentic activity, they bring their own framework and perspectives to see a problem from different angles, hence being able to negotiate and generate meanings and solutions through shared understanding.

Social Constructivism

Social constructivism as a branch of constructivism is based on the common theme that '…learning is best understood, stored, and applied when learners develop their own mental model of information' (Vogel-Walcutt et al., 2011, p. 135). In it, the importance of culture and context while constructing reality and knowledge is given primary emphasis. It is based on specific assumptions that to understand and apply models of instruction one should know the premises that underlie them. Social constructivists view learning as a shared and active social process where meaningful learning occurs when individuals are engaged in social activities. It emphasizes social interaction in the construction of new knowledge. Jimoyiannis and Komis (2001), argue that Vygotskian social constructivism, which pays attention to context of knowledge construction, sees ICT as a useful tool mediating among other learners, parents and teachers. The teacher's main role is to provide scaffolds in the learning process, to guide and to coach the student who actively engages in constructing knowledge individually and socially. ICT plays a mediating role, providing informative tools, communication tools, constructive tools, and co-constructive tools (p. 184).

Cognitive Theory of Multimedia Learning

Cognitive Theory of Multimedia Learning deals with building mental representations through selecting, organizing and integrating new information with existing knowledge.

The current part of the literature review is based on the research done by Mayer et al. (2001, 2003, 2005, 2007, and 2008) on the use of

Multimedia in learning. Clark and Mayer's (2003) research clearly demonstrates that under some conditions learners learn better when they are able to hold corresponding visual and verbal representations in their working memory at the same time. They investigate the 'dual coding theory', in which the representation and processing of information concerning verbal and nonverbal materials are handled cognitively by separate subsystems (Clark & Paivio, 1991; Paivio, 1986). In particular, it is shown that phonological and visuo-spatial information is stored in short-term memory by different processes with different resources. Hence, a word encoded in a verbal way will be better recalled if also encoded in a visual form. This is further supported by Mayer et al. (1999) who argue that '… learners are better able to construct mental models when corresponding visual and verbal representations are in working memory at the same time. This situation is created when narration and animation are presented concurrently; and is hindered when the narration and animation are presented successively' (p. 639).

As this theory (dual coding) was proposed to be used in multimedia design, it faced certain criticism. Ayers and Sweller (2005) and Sweller (1999) argued for the *split attention effect* in which inferior learning occurs when one's attention has to be divided between two information sources within one visual modality, for example, between visually presented animation plus simultaneous on-screen text. However, Clark and Mayer (2003) defended it by saying that 'in cases where students have difficulty understanding spoken words or if the pacing of the material is not fast, simultaneous audio and visual information may be experienced as non-redundant and over-loading may be avoided' (Debuse, Hede & Lawley, 2009, p. 749). Kalyuga et al. (1999) further argued that when textual information is presented in auditory form, mental integration with a diagram may not overload working memory because working memory may be effectively expanded by using more than one sensory modality.

Moreno and Mayer (2007) look upon knowledge construction and learning as building mental representations. They maintain that the learner is a sense-maker who works to select, organize and integrate new information with existing knowledge. This is what they call deep learning. Their cognitive-affective theory of learning with media (CATLM; Moreno 2005a) is an expansion of the theory of multimedia learning (Mayer, 2001; Moreno, 2005a) and is based on assumptions that:

(a) Humans have separate channels for processing different information modalities (Baddeley, 1992);

(b) Only few pieces of information can be actively processed at any one time in working memory within each channel (Sweller, 1999);

(c) Meaningful learning occurs when the learner spends conscious effort in cognitive processes such as selecting, organizing and integrating new information with existing knowledge (Mayer & Moreno, 2003);

(d) long-term memory consists of a dynamic, evolving structure which holds both, a memory for past experiences and a memory for general domain knowledge (Tulving, 1977);

(e) Motivational factors mediate learning by increasing or decreasing cognitive engagement (Pintrich, 2003);

(f) Meta-cognitive factors mediate learning by regulating cognitive processes and affect (McGuiness, 1990); and

(g) Differences in learners' prior knowledge and abilities may affect how much is learned with specific media (Kalyuga et al., 2003; Moreno, 2004; Moreno & Durán, 2004).

The following is a cognitive-affective model of learning with media proposed by Moreno and Mayer (2007, p. 314).

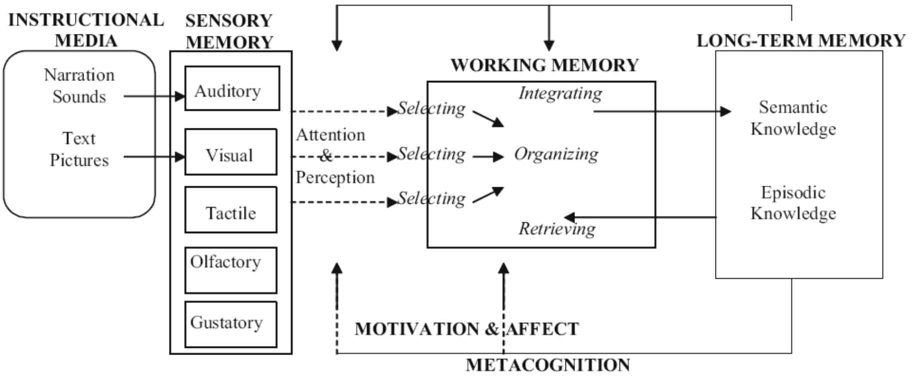

Fig. 1 A cognitive–affective model of learning with media.

The headwords in the above model represent memory stores in the learning process. The *instructional media* are forms of material whether in the form of narrative, sound, text or picture presented to the learner to engineer learning. *Sensory memory* is generally understood to be made up of human five senses; but in psychology it is said to be the part of the memory system which is the initial contact for stimuli. *Working memory* refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning. *Long-term memory* refers to the continuing storage of information. Some information is fairly easy to recall, while other memories are much more difficult to access. Through the process of association and rehearsal, the content of short- term memory can become long-term memory. *Meta-cognition, motivation, and affect* are components of self-regulated learning that interact. These are interactions between trait-like characteristics such as cognitive ability, meta-cognitive knowledge and skills, self-concept, perceptions of control, attitudes, emotions, and motivation in the form of expectancy-value beliefs and goal achievement orientations. *Semantic knowledge* is the memory of meanings, understandings, general knowledge about the world, and factual information. This knowledge is independent of context and personal information since semantic memory enables an individual to know information, including information about self, without having to consciously recall the experiences that underpinned such knowledge. For instance, to know that people live in the society is one part of semantic knowledge that you don’t have to associate to an event that made you to know this fact. *Episodic memory* on the other hand, is the autobiographical memory that individuals possess which contains events, associated emotions, and knowledge around a given context. For example, people can recall their first experience of a hot stove when they touched it and got burnt.

According to the CATLM model in Figure 1, there exist dual (separate) channels where human beings process visual and verbal materials. At the level of sensory memory**,** the verbal explanations presented in the form of spoken or written words combine with non-verbal forms such as pictures and sounds to be processed. For deeper learning to happen the learners are required to select relevant verbal and non-verbal information for further processing in working memory. From this site, the learners organize various representations into a coherent mental model and activate their prior knowledge already stored in long-term memory to be integrated with new information in the working memory and this product is stored in the long-term memory again.

Moreno and Mayer, (2007) maintain that prior knowledge activated by the learner is necessary to partially guide the cognitive processes (as illustrated by the top–down arrows from long term memory to attention, perception, and working memory), and partially by the feedback and instructional methods embedded in the learning environment. As can be seen from the model, learners may also use their meta-cognitive skills to regulate their motivation and cognitive processing during learning. The influence of meta-cognition, motivation, and affect on learning is illustrated by the bottom–up arrows from long-term memory to working memory.

This model is not without criticisms. For instance, it is not clear where the room for social aspects of remembering and learning is placed. It is not indicated how people will interact with each other apart from trying to make sense of ‘boxes’ of auditory and visual channels. Again, the issue of *memory* is not seen with the same lens among scholars. There are those who think that there may be more than two memories while others think there is only one memory. For instance, Pramling and Säljö (in Lieberman 2011 p.

346), raise queries to the memory model by arguing that if we possessed two memory systems with different properties, then we might expect some variables to affect these systems differently; i.e. there could be functional interference between short term and long term memory. So, they think this matter is more complex to explain than it appears. However, the reasoning given by the founders of the above model is that we have only one memory store which is permanent. They argue that the working memory is *transient* as there are two channels or compartments to handle visual and audio information that can be mutually integrated. Working memory is said to be transient in that few pieces of information can be actively processed at any one time in working memory within each channel. The short term memory is exploited within limited time to process information and stores it in the long-term memory waiting to be retrieved when needed. This model equates learning with information acquisition, something that can be contested by many scholars. However, Moreno and Meyer's suggestions concerning how a multimedia instrument could be developed has been elucidating for my research.

Moreno and Mayer (2007) and Mayer (2008) envisaged potential challenges when learning from multimodal environments. One of them is how to encourage learners to engage in appropriate cognitive processing. It is feared that 'the processing demands may exceed the processing capacity of the cognitive system, a situation we call cognitive overload' (Moreno & Mayer, 2007, p. 315). They argue that this situation may cause *extraneous processing* and *representational holding* that are the 'enemies' of learning.

According to Moreno and Mayer (2007) , *extraneous processing* is defined as 'a cognitive process that is not necessary for making sense of the new information but is instead originated from poorly designing the learning task'(p. 310). A good example is when the text and graphic referring to the same thing are presented on separate pages or computer screens causing the learners to strain their memory to look for the connection between them. *Representational holding* is 'the cognitive processes aimed at holding a mental representation in working memory during the meaning-making process'. An example is when a narration is presented before a corresponding animation forcing the learner to wait for a corresponding illustration in the subsequent animation. Poorly designed learning tasks waste learner's limited processing capacity and any instructional design should reduce extraneous processing and adhere to the *essential processing*. Essential processing is defined as the cognitive processes that are required to mentally select the new information that is represented in working memory. The authors assert that if the designers of a programme manage to reduce these impediments, then the learner's available cognitive resources can be used to engage in *essential and generative processing* activities that aim to maximize learning.

Generative processing is defined as making sense of the new information, such as the processes of mentally organizing the new information into a coherent structure and integrating the new knowledge representations with prior knowledge (Mayer, 2005; Sweller, 1999).

For a multimedia lesson to be effective, it should be based on five principles for reducing extraneous processing; three principles for managing essential processing and two principles for fostering generative processing (Mayer, 2008).

Principles for Reducing Extraneous Processing

The *coherence principle* asserts that 'people learn better when extraneous material is excluded rather than included in a multimedia lesson' (Mayer, 2008, p. 764). According to this principle, inserting extraneous material may force learners to engage in extraneous processing which may exhaust their processing capacity and fail to attend to the material essential for building deep learning outcome.

The *signalling principle* states that 'people learn better from a multimedia lesson when essential words are highlighted' (Mayer, 2008 p. 764). According to the cognitive theory of multimedia learning, signalling can help guide the learner's attention toward the essential material, thereby minimizing the learner's processing of extraneous material. To have a good multimedia presentation, the essential material should be signalled by highlighting it through adding an overview sentence that restates the three main ideas, adding headings for each section in the narration that correspond to the three main ideas in the overview and emphasizing main ideas in the narration by stressing them vocally.

The *redundancy principle* argues that ‘people learn better from animation and narration than from animation, narration, and on-screen text’ (Mayer, 2008 p. 764). The addition of on-screen text creates extraneous processing because the learner tries to reconcile the two incoming verbal streams and must scan between the text at the bottom of the screen and the relevant portion of the animation hence diminishing the cognitive capacity available for deep learning. As proposed by Mayer et al. (1999) and Moreno and Mayer, (2007), deep learning occurs when learners actively construct meaningful mental representations from presented information by selecting relevant information and build coherent connections and integrating the new knowledge with existing knowledge. This is done in working memory and is later transferred into long-term memory.

The *spatial contiguity principle* states that ‘people learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen’ (Mayer, 2008, p. 764). If on the contrary the illustrations and the words are placed far from each other, the reader has to scan between the words at the bottom of the page and the corresponding part of the illustration at the top of the page - thereby creating extraneous processing. There is a need therefore to move an explanatory sentence next to the illustration it describes. The *temporal contiguity principle* argues that ‘people learn better when corresponding narration and animation are presented simultaneously rather than successively’ (Mayer, 2008, p. 765). The narration should be spoken at the same time as the corresponding action is depicted in the animation. According to the cognitive theory of multimedia learning, learners must have corresponding words and images in working memory at the same time in order to make connections between them, so simultaneous presentation should result in better learning than successive presentation.

Three Principles for Managing Essential Processing

Elimination of extraneous processing does not guarantee deep learning. This is because the requirements of essential processing may be too complex and could overwhelm the learner. For instance, if much detailed explanation is needed to simplify the understanding of a certain illustration, the learner's cognitive system is likely to be overloaded by all this essential material. It is very difficult to avoid this explanation because it is needed for the learner to build a coherent mental representation. Therefore three techniques for managing essential processing should be followed. These techniques are *segmenting*, *pre-training*, and *modality principles.*

In segmenting, the continuous presentation should be broken into smaller chunks to help the learner to exhaustively represent each part before moving to the next. This is in line with the *segmenting principle* which states that 'people learn better when a narrated animation is presented in learner-paced segments rather than as a continuous presentation' (Mayer, 2008, p. 764).

Pre-training entails giving a pre-lesson to the learner so that they are aware of what they are learning. For instance when you are giving a multimedia presentation, on how a certain system works the learners would need to know the names of each part, where they are located and their characteristics so that they understand the link which holds between them. Pre-training is intended to manage essential processing during the presentation of narrated animation. The theoretical rationale is that 'learners who are already familiar with the names, locations, and behaviour of each component can devote more of their cognitive capacity to building a cause-and-effect model of the system' (Mayer, 2008, p. 765). This is in line with the pre-training principle which states that 'people learn better from a narrated animation when they already know the names and characteristics of essential components'.

The last technique for managing essential processing is called the *modality principle.* According to this principle 'people learn better from graphics with spoken text rather than graphics with printed text' (Mayer, 2008, p. 765). The theoretical rationale is that when the text is printed on the screen, learners experience *split attention*, that is, when they are looking at the words they cannot look at the animation and vice versa. The incoming essential information can overload the visual channel. According to the cognitive theory of multimedia learning, the solution is to present the words in spoken form, thereby offloading the processing of the words from the visual channel, which is overused, to the verbal channel which is underused.

Two Principles for Fostering Generative Processing

At first sight, one can feel that it is enough to reduce extraneous processing and manage essential processing of a learner so as to free the space for cognitive capacity so that generative processing may take place. However, this does not entail that the learner will engage in generative processing. Therefore, the remaining challenge is to know how to encourage learners to use their processing capacity to engage in generative processing. To do this, one needs to have recourse to the two techniques that foster generative processing namely the multimedia and personalization principles.

According to the *multimedia principle*, people learn better from words and pictures than from words alone. This is in line with the cognitive theory of multimedia learning which states that 'people learn more deeply when they build connections between a verbal representation and a pictorial representation of the same material' (Mayer, 2008 p. 766).

Another technique to foster generative processing is called the *personalization principle* founded on the idea that 'people learn better from a multimedia lesson when words are in conversational style rather than formal style' (Mayer, 2008 p. 766). For instance, instead of saying 'When the blood is pumped from the left auricle to the right ventricle …' you may say 'When *your* blood is pumped from *your* left auricle to *your* right ventricle …'. The theoretical rationale for personalization techniques, such as using conversational style or polite wording, creates a sense of social partnership with the narrator in which learners try harder to make sense of what their conversational partner is saying. The participant feels the sense of belonging to the conversation and not just as an outside addressee.

Language Teaching and Learning

RuÈschoff and Ritter (2001) argue that language learning has often been described as one of the most impressive mental operations of the human mind in view of the complexity of grammatical structures, the size of the mental lexicon, and the multiple functionality learners of any language are confronted with (p. 222). In their view, language learning as well as learning in general should be described as an interactive, dynamic process, in which new knowledge is most fruitfully acquired when learners are placed in a situation where they can explore sources and resources rather than in a context of mere formal instruction.

Language learning and acquisition should be regarded as a process of information gathering and knowledge processing. In such a process, the interaction between knowledge previously acquired and new information gathered leads to the acquisition and even to the production of new knowledge. Learning is an active process in which learners construct new ideas based upon their current and past knowledge. In the following I will focus on vocabulary learning.

Vocabulary Learning

Learning vocabulary is the first and most important step to be taken in language acquisition. Wilkins (1972, p. 111) argues that 'without grammar very little can be conveyed, while without vocabulary nothing can be conveyed'. The importance of learning vocabulary is also supported by Rivers (1983, p. 125) who mentions that 'the acquisition of an adequate vocabulary is essential for successful second language use because without an extensive vocabulary, we will be unable to use the structures and functions we may have learned for comprehensible communication'. In a classroom where students are not comfortable with L2, language learning can be made interactive and interesting with the introduction of appropriate vocabulary learning strategies (Tozcu & Coady, 2004).

Meaning of Vocabulary

Generally defined Lehr et al. (2011, p. 3), vocabulary is the knowledge of words and word meanings. However, since the meaning of vocabulary may be multifaceted depending on the context, it is worthwhile defining vocabulary as the knowledge of words and word meanings in both oral and printed language as well as in productive and receptive forms. In the academic field vocabulary is referred to as the kind of words that students must know to read increasingly demanding text with comprehension.

Importance of Vocabulary

Lehr et al. (2011, p. 6) argue that ‘vocabulary knowledge relates strongly to reading comprehension and overall academic successes’. This relationship seems logical; to get meaning from what they read, students need both a great many words in their vocabularies and the ability to use various strategies to establish the meanings of new words when they encounter them. This particular relationship between vocabulary knowledge and reading comprehension seems clear. But vocabulary knowledge contributes to reading success in other important ways that are perhaps less obvious. For beginning readers, evidence indicates a link between word knowledge and phonological awareness Young children who have a large number of words in their oral language may more easily analyze the representation of the individual sounds of those words. In addition, vocabulary knowledge helps beginning readers decode, or map spoken sounds to words in print. If children meet printed words also existing in their oral vocabulary, they can more easily and quickly sound out, read, and understand them, as well as comprehend what they are reading. If the words are not in children’s oral vocabulary, they have trouble reading the words and their comprehension is hindered (National Reading Panel, 2000). Thus, an extensive vocabulary is the bridge between the word-level processes of phonics and the cognitive processes of comprehension. In terms of vocabulary development, good readers read more, become better readers, and learn more words; poor readers read less and learn fewer words.

Vocabulary plays a fundamental role in the comprehension and production of language. Ma and Kelly (2006) show the importance of vocabulary as a central pillar in language learning and overall comprehension. They emphasize that vocabulary knowledge is the best predictor of success in listening as well as reading comprehension. Tozcu and Coady (2004, p. 477) suggest that a large recognition vocabulary allows for ‘skilful language use’ that is, effective reading will increase vocabulary knowledge because the reader will be able to guess the new vocabulary from context. Also Nation (1993, p. 118) claims that ‘the focus of teaching initially needs to be on increasing the size of the learner’s recognition vocabulary'. According to Nation (1993), if learners know the most frequent 1,000 words in English which includes words like '*put, end, difficult, come,* and *material,*' then they will be able to understand 75% of all the words on a typical page. However, this claim seems not to reflect the reality on the ground since most frequent words are also the most complex. Just a look at the number of entries in a dictionary indicates this. An additional problem is that the rarer words are often the words that carry more meaning. Laufer acknowledges the importance of vocabulary size in reading. Laufer (1989, 1992) claims that learners whose vocabulary size enables them to recognize more than 95% of the words in a text are capable of reaching a reasonable level of comprehension for that text, for example, 55% and above.

There is a strong relationship between vocabulary knowledge and reading skill. Thus, those having more vocabulary knowledge are better able to comprehend. As a matter of fact, causal connections were found between vocabulary knowledge and reading comprehension in various research studies. Coady (1993) claims that there are some 2,000 words that account for almost 80% of the running words in an average text, and that these words therefore occur frequently enough to justify significant commitments of instructional or learning time (pp. 15–16).

Kinds of Vocabulary

According to Nation (2001, p. 11–12), there are four kinds of vocabulary in a text: high frequency words, academic vocabulary, technical vocabulary, and low frequency words. High frequency words are the most frequent 2,000 words of English. West (1953) calls these words a general service vocabulary because they are of use (or service) in most general texts. For learners with academic goals, the 570 word family Academic Word List by Coxhead (2000), the second kind of vocabulary, is like a specialized extension of high frequency words. Academic vocabulary is common to a wide range of academic fields but it is not what is known as high frequency vocabulary and it is not technical in that it is not typically associated with just one field. Technical vocabulary, the third kind of vocabulary, is largely used by people working in a specialised field. The fourth kind of vocabulary consists of all remaining words of English, the low frequency words.

Academic Vocabulary

What is academic vocabulary? Contrary to the belief that academic vocabulary is more difficult than general English, academic vocabulary is not necessarily 'difficult vocabulary' - using academic words is in fact equated to finding appropriate language to fit a certain scientific domain. According to Hyland and Tse, (2007, p. 235), the term is used to refer to ‘items which are reasonably frequent in a wide range of academic genres but are relatively uncommon in other kinds of texts’.

The importance of academic vocabulary is very well known. It is argued by Hyland and Tse (2007, p. 236) that:

> …first year undergraduate students are said to find an academic vocabulary a particularly challenging aspect of their learning. This aspect of their learning is challenging because although technical vocabulary is central to students’ specialized areas, general academic vocabulary serves a largely supportive role and the words are not likely to be glossed by the content teacher. So, the teachers need to identify students’ target language needs as clearly as possible and address them as well as they can, and part of the work will involve introducing, making salient, and practicing the specialized vocabulary of their fields or disciplines.

The 570 words on the Academic Word List are all thought to be important for students preparing for academic study. If they study these words and try to use them actively, it would help them to use English vocabulary more successfully, regardless of their study discipline. All academic representations shape and manipulate language for disciplinary purposes, often refashioning everyday terms so that words take on more specific meanings (Hyland &Tse, 2007).

Technical Vocabulary

Chung and Nation (2004) explain that technical vocabulary is referred to by a variety of labels such as ‘terminological words’ (also ‘terms’ and ‘terminology’, Bečka, 1972), ‘specialised lexis’ (Baker, 1988), ‘technical terms’ (Yang, 1986), ‘specialist vocabulary’ (Kennedy and Bolitho, 1984), and ‘technical words’ (Farrell, 1990). In the discipline of terminology, ‘terminological units’ (Cabre, 1999, p. 81; Desmet & Boutayeb, 1994), 'terms', 'technical terms', or 'terminology' are used in the sense of 'technical vocabulary'.

Chung & Nation (2004) emphasize that technical vocabulary is subject related, occurs in a specialist domain, and is part of a system of subject knowledge. The meanings of technical terms are closely associated with a particular subject area. The best way to determine this for any word is to use a rating scale that classifies words according to how closely related they are to a particular subject area (Baker, 1988; Farrell, 1990; Sutarsyah et al., 1994).

Implicit and Explicit Learning of Vocabulary

It is argued that vocabulary should be learned implicitly as well as explicitly; learners need to be trained to become good learners, e.g. by being instructed in useful learning strategies, to enable them to learn vocabulary more efficiently and effectively.

The Implicit Learning of Vocabulary

The basic assumption of the implicit learning paradigm is that words can be acquired naturally through repeated exposure in various language contexts with reading as the major source of input, a notion that is strongly supported by findings in respect of L1 vocabulary acquisition. Several studies support the implicit learning paradigm. Krashen's input hypothesis (1989, 1993) postulates that vocabulary can be acquired by reading as long as the input is comprehensible to the learner. Nagy, Herman, and Anderson (1985) hold the view that children acquire most L1 words through reading and that they do so incidentally. In the same vein, Sternberg (1987, p. 89), relying on studies in L1 acquisition, claims that 'most vocabulary is learned from context' by contextual guessing, although whether this process can take place successfully or not depends on several 'moderating variables' (pp. 92 – 94), such as the density of unknown words; the learner may be overwhelmed by a large number of unknown words with the result that no learning takes place.

The Explicit Learning of Vocabulary

Authors who adhere to the explicit learning paradigm argue that vocabulary and vocabulary learning strategies should be learned or taught explicitly so that learning can be more efficient. They agree with upholders of incidental learning that context is the main source for acquiring vocabulary, but they claim that learners need some extra help to build up an adequate vocabulary and to acquire strategies necessary to cope with the vast reading context (see Coady, 1997). There are two main approaches in respect of the explicit learning paradigm: explicit instruction and strategy instruction.

Authors who favour explicit instruction argue that learners should be taught vocabulary explicitly by using various means including direct memorization techniques (Coady, 1993; Nation, 1990, 2001). Here the concern is mainly with low level learners who do not have enough vocabulary to read extensively. Nation (2001) suggests that high frequency (2,000 word level) and low frequency vocabulary should be treated differently. High frequency words have a high coverage (80%) of text and should be mastered as soon as possible. This can be achieved by direct teaching (teacher explanation, peer teaching), direct learning (using word cards, consulting dictionaries), incidental learning (contextual guessing, communicative activities) and planned encounters with the words (graded reading, vocabulary exercises). As for the low frequency words, teachers should train learners to use strategies such as contextual guessing, dictionary use, memory techniques and vocabulary cards to cope with these words and to enlarge their vocabulary. According to Laufer (1997, p. 23), learners should master a basic vocabulary of 3,000 word families to be able to use the 'high level processing strategies' needed to comprehend a general text. Empirical studies by Paribakht and Wesche (1997) show that reading plus explicit vocabulary training enables learners to learn vocabulary both quantitatively and qualitatively better than by simply relying on context alone.

Importance of Explicit Vocabulary Learning

According to Ellis (1995), recognition and production of words in both their oral and written forms occur through implicit learning and are a function of frequency and context. Grasping all meanings of a given word requires conscious learning along with more in-depth strategies such as semantic mapping and imagery, which are mnemonic techniques related to explicit learning. In-depth knowledge of a word requires conscious learning of its spelling, pronunciation, syntactic properties and relationships to other words in the semantic network.

Coady (1997, p. 279) advocates direct memorization of highly frequent vocabulary items so that automaticity in word recognition can be achieved. He emphasizes explicit teaching of words at the early stages of acquisition. At the later stages, however, vocabulary learning will be inferred from the context.

Discussing the incidental L2 vocabulary acquisition, Duquette, Renee and Laurier (1998) argue that the main problem with incidental L2 vocabulary acquisition seems to be attributable to three sources. First, incidental learning inevitably involves a great deal of contextual guessing of the unknown words. Context alone does not always facilitate meaning transfer; in some cases even educated adults cannot infer the meaning of L1 words in context. Second, as a consequence, the learning rate is very low. According to Nation (1990), 5 to 16 exposures are needed to fully acquire a word. This is implicitly supported by Nagy et al. (1985) who reported a 5%–15% probability of a word being learned at first exposure; similarly, Knight (1994) demonstrated a learning rate of 5%– 21% from her studies, also for one exposure. Third, the vocabulary acquired through incidental learning is mainly for recognition and hardly at all for production. This is due to the nature of incidental learning: the main language activity is reading where the focus is on meaning and content and only limited attention is paid to the lexical and syntactic features of the new words. The quality and quantity of lexical processing in incidental learning is simply insufficient to enable the learner to grasp the precise meanings and correct usage of words that will lead to correct production (p. 5).

Ma and Kelly (2006) posit that ‘the greatest difficulty in acquiring a word in the initial stages is to link the form and the meaning in memory’ (p. 18). This is particularly true in respect of an unrelated language and is the initial driving force behind the keyword method (Atkinson & Raugh, 1975). It would seem that the explicit learning paradigm is best summarized as a ‘mixed approach’, to use Coady’s words (1993, p. 17). Supporters of this paradigm combine a whole variety of activities, including explicit vocabulary instruction, vocabulary exercises, vocabulary learning strategies, and extensive reading.

Multimedia and Computer Assisted Language Learning (CALL)

The use of information and communication technology (ICT) is becoming an integral part of education in many parts of the globe (Adeyemo, 2010). Tasouris (2009) sees the use of ICT as a tool that facilitates teaching and learning practices and which improves communication between students and teachers. He further claims that the use of ICT can give the students additional opportunities for the investigation of the relationships between concepts and ideas. This assertion agrees with Adeyemo (2010)'s position that the use of ICT in teaching is a relevant and functional way of providing education to learners that will assist them with the required ICT skills also needed for the world of work (e.g. Mutwarasibo, Ruterana, Andersson, 2012). He further argues that most experts in the field of education agree that, when properly used, information and communication technology holds great promise to improve teaching and aid learning in addition to shaping work force opportunities (Adeyemo, 2010). Indeed ICT has become an integral and accepted part of everyday life for many people.

But what is the ICT?

Adeyemo, (2010) defines Information and Communication Technology (ICT) as the use of technology in managing and processing information with the use of electronic computer systems and computer software to convert, store, protect, process, transmit and retrieve information.

Second Level Support Service (SLSS), (2008) contends that the use of ICT in appropriate contexts in education can add value in teaching and learning, by enhancing the effectiveness of learning, or by adding a dimension to learning that was not previously available. ICT is also seen as a significant motivational factor in students' learning and can support their engagement with collaborative learning. Also, according to Muhirwe (2012) the increasing importance of ICT, which is expected to continue, will make ICT literacy become a functional requirement in students' lives to scaffold their learning and enhance international communication.

Multimedia

To facilitate learning, Mayer (2003) argues that by combining pictures with words in multimedia designed in ways that are consistent with human learning, we will be able to foster deeper learning in students than from traditional verbal-only messages. But what is multimedia?

Ma and Kelly (2006) posit that 'as the name suggests, multimedia means an assemblage of various media such as text, sound, video, animation and picture, tied together in a framework of sequence and interaction'(p. 24). The importance of multimedia is stressed by Nesselhauf and Tschichold (2002) saying that:

> all the possibilities offered by multimedia Computer Assisted Language Learning (CALL) can be put to a useful purpose: pictures can illustrate vocabulary items; sounds can accompany the written words and expressions and give a model pronunciation for the examples; and sound can also be used to give acoustic feedback to the learner. (p. 251)

Moreno and Mayer (2007) discussing the role of multimedia posit that 'according to the multimedia principle, student understanding can be enhanced by the addition of non-verbal knowledge representations to verbal explanations (p. 310). Ma and Kelly (2006) assert that 'In a multimedia environment it is possible to repeat words, rules and lessons at will, and to adopt a mixed approach: implicit through the use of oral and written texts, and explicit through the availability of on-line dictionaries, aids and exercises' (p. 310). Multimedia offers still images, animation, sound and written text and focuses on listening comprehension, vocabulary acquisition and developing learning awareness.

Using Multimedia and CALL

Iheanacho, (1997) has a detailed account of CALL and English language teaching. He explains that CALL has important potential for English language teaching. If used properly with clear educational objectives, CALL can interest and motivate learners of English. CALL can increase information access to the learner, provide flexibility to instruction and thereby better serve the individual's learning pace, cognitive style and learning strategies. CALL allows learners to control their own learning process and progress. Using effective and suitable software applications, CALL can provide communicative meaningful language learning environments. Good quality and well-designed CALL software can offer a balance of controlled practice and free communicative expression to the learners, including immediate feedback.

However, despite greater user-friendliness, and effectiveness of multimedia, some software designs were criticized for the lack of originality and context, being too artificial and having no consistency. It has been noted that designers seem not to base their software on language theories, and some designers lacked linguistic background causing some words to be inaccurately presented. Ma and Kelly (2006) underscore the fact that some CALL programs lack a pedagogical basis. Sometimes the CALL projects are not preceded by solid research. They are particularly vulnerable when it comes to the issue of users' needs being addressed. They do not consider the background information, such as the age, sex, cultural background, other foreign language knowledge, computer knowledge and so on, of those users for whom the programs are intended. Therefore, given their general lack of research basis as well as the comparatively small amount of time and space devoted to vocabulary learning, the quality of the vocabulary learning resulting from the utilization of these programs is often disappointing.

Discussion on the Theories Used

The above theories are presented to give an insight into how they can be applied in general. It is upon the users to see if they are relevant to their context and how they can fit them in. So, the theories are not just there ready to be applied as they are. They have to be adapted to the context such as the environment and the setting where the learning is taking place. Neither should we think that these theories are without pitfalls. Clearly most of them are criticised in one way or another. For instance, constructivism claims to see learning as an autonomous process, to be regulated by the learner's expectations, goals, existing schemata and intentions (RuÈschoff & Ritter, 2001 p. 224). But from a socio-cultural perspective it is argued that learning takes place in the society with learners supporting each other in their learning. Doolittle (1999) argues that the ‘truth is not to be found inside the head of an individual, it is born between people collectively searching for truth, in the process of their dialogic interaction’ (p. 4). Furthermore, Vogel-Walcutt et al. (2011) argue that constructivist approaches fail to consider efficiency in learning and human cognitive architecture. Contrary to limited capacity assumptions (Moreno & Mayer, 2003), constructivist theory encourages the learners to continue acquiring whatever is presented to them hence the risk of overloading the cognitive capacity. Likewise a cognitive affective model of learning with media cannot be applied wholesale without locating the information needs of the learners. There should be explanations on how the sensory memories work and how information would be processed, stored and retrieved. For example in this model, there appears to be no obvious room for social aspects of learning and remembering. Also in the case of developing and applying multimedia in this thesis, only two sensory memories (visual and auditory) were applicable while in the model we have five sensory memories. There was no room where tactile, olfactory and gustatory sensory memories could be applied. Hence, there is no obvious ‘box’ that shows social aspects of the model. It is just inferred that the information would be remembered by retrieving it from long term memory and that a social aspect of it is seen when people pass information to each other through visual and auditory channels. However, despite functional gaps, these theories are depicted to guide the construction of the multimedia part of this thesis.

Under social constructivism (Vygotsky, 1978; Mercer, 1995; Wertsch, 2003) the participants work together to construct their knowledge. Learning is seen as a meaningful, shared and active social process that occurs when learners are engaged in activities and assume responsibilities for their own learning. This learning needs psychological and physical tools such as language and ICT to mediate it. We need to modify the environment and adapt it to our specific circumstances which need using these tools. Taking into consideration that we need to create a mediating tool to help us understand and retain some concepts, we turn to psychological tools such as language to explain how memory works. If we need to retain the learned concepts then we can choose to record those concepts in two channels of image and sound. So, we will need a cognitive affective model of learning with multimedia (Mayer, 2003, 2005, 2008; Moreno 2005, 2007) to help us encode the needed concepts on the computer as a physical mediating tool. The next step will be to present the concepts to the learners so that they store and remember them for a long time. To do this the learners are given opportunity to manipulate ideas, generate new ways of looking at the phenomena, test hypothesis and interpret what they learn based on their preconceptions. At this stage, they can acquire new knowledge or modify the existing one.

Theory, Method, Focus and Technology in CALL

Ma and Kelly (2006) argue that ‘it is commonly agreed that a sound theoretical underpinning is vital to ensure the quality of a CALL program’ (p. 21). The quality of a CALL program is determined by the methodology behind it rather than the computer technology itself. The overall approach to the design of the program and the underlying theoretical principles are very important aspects. Also language learning theory, that is, the program designer’s assumptions about the nature of language, language learning and the process of learning should be taken into account. What specific language learning theory to choose depends on what language knowledge aspects or skills the CALL program would like to focus on. In CALL programs for vocabulary learning, learning theories or research findings specific to vocabulary learning should be considered first. The selection of a specific or general language learning theory will serve as a guide in the selection of the technologies to be used (Ma &Kelly, 2006).

In my opinion, CALL programmes can be said to be efficient when they help teachers and learners to achieve their objective of the intended learning in a short period of time. The outcome needs to be measurable to ascertain its efficiency in teaching and learning. However, CALL like any other new technologies, will never replace the teacher. CALL is not a magic solution to language teaching. The effectiveness of CALL relies on how

CALL is utilized to meet language learning goals for learners' preferences in specific educational settings.

METHODOLOGY AND DESIGN

Research Design

The overarching aim of this thesis is to investigate ways in which students can learn technical vocabulary required for the understanding of their physics courses and how teachers can facilitate this exercise with the help of ICT and underlying theories of learning.

The research design is built with the overarching aim of the study in mind. Here, a blend of *qualitative and quantitative* designs is employed as the presented research questions concern both social realities and the construction and outcomes of a pedagogical instrument new to the context. The majority of the qualitative data were analysed *inductively*, that is, we reviewed and re-read transcripts of the data to find patterns or themes appearing in the work procedures or expressed in interviews which only later were related to theories. However, when constructing a multimedia instrument we also worked *deductively* following theories of multimedia construction suggested by Mayer (2008) and others in the same paradigm. This is in line with quantitative research methods which incorporates a natural science model of the research process which emphasizes quantification in the collection and analysis of data (Bryman 2004). This method was used in our quasi-experiment research to determine the potential of the instrument to facilitate teaching and retention of technical vocabulary in study III. We say that this was a quasi-experimental because all variables such as various factors contributing to the observed results were not controlled. This strategy helped us to measure and correlate students' performance with the type of teaching method, the duration of teaching and the differences in test results.

The works in this thesis present variations existing between the groups the researcher worked with, thus allowing the gathered data to be expressed in statistical terms such as Cohen's levels of significance, and qualitative expressions of frequencies like most of, few, often etc.

According to Silverman (2001) and Bryman (2008), data gathering methods are influenced by the research topic and the problems that are investigated. Video recording is an effective method to capture both visual and audio information required when investigating different processes. Also, Akbaba-Altun (2011) argues that the semi-structured interview technique which is also called a standardized open-ended interview is useful. It has the basic characteristics that questions are prepared beforehand. Abuhmaid (2011) argues that semi-structured interviews are capable to gauge multiple responses from various angles and different perspectives at any issue of concern. Furthermore, if there is any issue needing clarification, the researcher can still ask more questions to straighten out understanding.

Participants and Setting

Undergraduate students from a first year physics cohort were invited to participate in this study. The major determinant of participation was the participants' willingness to take part in the study and avail time for the task. This kind of participant selection fits the criteria of convenience sampling.

According to Bryman (2008) convenience sampling involves 'selecting the sample by including participants who are readily available and who meet the study criteria' (p.183). Throughout my research therefore, only those students and teachers who were found in the classroom and agreed to be video recorded were included. Also those students who agreed to take part in selecting technical vocabulary and encoding them were involved. It was the same for those students who accepted to undergo the process of learning the selected concepts, and who were able to consistently take the course and tests in the two different groups. Finally, those university teachers who were ready to devote their time to answer the interview questions were included. The only disadvantage with this sampling is that one may end up having few participants to an extent that the findings may not be claimed to be representative or generalizable.

As said above, the choice of participants and setting were determined by the context of the study and overarching aim of the thesis. This study required full participation of the researcher, teachers and the students as stakeholders. All the studies constituting this thesis were done in university environments though in different places. The outcome of this selection is that a total sample of 169 participants was involved. In the first study of classroom video recordings there were 43 undergraduate first year students together with their teacher, the second study that dealt with selecting technical vocabulary involved 82 students together with their two teachers and the researcher; the third study analysing test results involved 32 undergraduate first year students and the fourth which is the final involved 12 university teachers (see Table 2). As for the age of participants, the participating students were aged between 20–23 years while the teachers were aged between 40 and 68, all male and teaching physics. All the universities were found in urban areas with one university in a big city.

Table 2. Overview of methods, participants and settings

Studies	Instruments and date	Participants	Number of participants		
			Male	Female	Total
I	Video observation (2009)	Undergraduate first year university students and 1 teacher	35	8	43
II	List of vocabulary/concepts, computer programmes (2009)	Undergraduate first year university students and 2 teachers and the researcher	68	14	82
III	Class tests (2009)	Undergraduate first year university students	29	3	32
IV	Interview (2011)	Teachers of physics from 3 universities in Rwanda	12	0	12
Total			144	25	169

Ethical Considerations

Ethical considerations underlying the four studies making up this thesis have been discussed in each article but they are being referred to in general under this section. Throughout the processes of data collection using video recording, vocabulary list writing, class teaching and testing and interviews, ethical considerations were respected. Bryman (2008) stresses the importance of confidentiality, respect for privacy and informed consent. He emphasizes that care needs to be taken when findings are being published to ensure that individuals are not identified or identifiable. One of the suggestions to adhere to this end is '… storing the list of participants and their identifier codes separately in a locked cabinet' and '… ensuring transcripts do not include participants' names' (Bryman, 2008, p. 120). Another important aspect of ethical considerations is the informed consent. Bryman (2008) points out that '… prospective research participants should be given as much information as might be needed to make an informed decision about whether or not they wish to participate in a study … [and they] should be fully informed about the research process'(p. 121). Furthermore the researcher should clarify the rights of the participants. 'They should be aware of their entitlement to refuse to participate or answer questions at any stage for whatever reason and to withdraw data just supplied'. (Bryman, 2008, p. 121). Although this research did not present any potential jeopardy to the participants' well being, the researcher had to make sure that the ethical conduct of research is respected.

The students and teachers in different universities were informed about the researcher and his affiliation, what kind of research he was doing, why it was carried out and what procedures would be followed and how the data would be used. They were told that the results were only to be used for the purpose of research which is enhancing physics learning through instruction, technical vocabulary and ICT at university. Since the participants were reminded that participation was entirely voluntary, they had the liberty to participate or not. The fruit of this freedom showed up in the third study when only 32 out of 63 students qualified to be included in the findings by fulfilling the criteria of attending all the classes and participating in the two tests. The rest chose to withdraw from consistent attendance and doing the tests.

As emphasized by Bryman (2008), the researcher must ensure that the security, privacy and confidentiality of the participants are respected. To respect this requirement, the code and relating transcript were kept without names. The settings where the research was carried out were reported as A, B and C. Whenever it was necessary, the sex, age and affiliation of the participants were kept with the transcripts but again making sure that the participants would not be exposed.

Data Gathering Procedures and Analyses

The empirical data were drawn from the analysis of video recordings, observations, vocabulary list constructions, test results, and interviews. Here, the research procedures and how findings were reached are clarified in order to be open to the judgement of other scholars.

In the first study video recordings were used to investigate how a teacher supports a group of students to learn physics technical vocabulary in

English in order to help them to cope with the change of language of instruction. One such teaching event consisted of a 90 minute recording from a classroom where a traditional teaching method was selected for inductive analysis. This event is representative for how teaching used to be performed.

The second study looked into how a multimedia instrument for technical vocabulary learning was developed. Both students and teachers participated in a careful selection of eighty one concepts found in students' course notes and considered to be important for the understanding of a course on Electricity. Eighty-one video clips, emanating from technical word lists were encoded following principles suggested by Moreno and Meyer (2007).

In the third study, teaching using the MAVL instrument was compared with teaching using traditional methods. Two tests were constructed to see the outcome in terms of technical vocabulary recall in the middle and at the end of the taught module to see the potential impact of the multimedia instrument. The results from this quasi-experimental study were subjected to quantitative analyses.

The fourth study investigates twelve university teachers' reflections about their current use of ICT as a tool to facilitate physics teaching and helping teachers to create materials that would simplify concept understanding. Twelve interviews lasting between 50 and 70 minutes were recorded, transcribed verbatim, and analyzed.

Data Analysis

While analyzing qualitative data I used both coding and thematic analysis processes to simplify the understanding of my data. According to Bryman (2008), the coding should help the researcher to understand the general categories 'surfacing' in the data, what they represent, the topic and question(s) suggested and the answer(s) implied. The data should indicate what type of event is going on, what the participants say they are doing, and what you see they are doing.

Since I also used interviews which I administered to teachers from three universities, transcription was immediately done each time as soon as I finished interviewing teachers from one university before moving to the next.

Bryman (2008) suggests ‘outlin[ing] connections between concepts and categories you are developing’ and to consider in more detail ‘how they relate to the existing literature’ (p. 552), and see if they confirm the data produced by your participants. During this period, the researcher has to familiarize him/herself with the data and identify themes and subthemes that emerge by reading and re-reading the transcripts of the data (Bryman, 2008, p. 554).

The first stage following my data gathering involved familiarization with the data i.e. watching and listening to audio and video materials several times, reading and re-reading the collected lists of vocabulary, reading and re-reading the test results, listening to and transcribing the interviews, all of which aimed at establishing common patterns found in the collected data. The next stage was to select representative examples or utterances indicating the variations in ways physics teaching and learning were enhanced. The third stage entailed categorizing the concepts and spotting important themes and sub-themes found in all collected data as suggested by Braun and Clarke (2006). The fourth stage was to establish a coding system that would be employed to analyze the findings. Through the collected data I selected utterances, test questions or answers and responses that would illustrate the argument being put forward. The final stage was to interpret the data based on the underlying theories or conceptual framework. This is in line with Bryman (2008) who emphasizes that ‘… your findings acquire significance in our intellectual community only when you have reflected on, interpreted and theorized your data. You are not there as a mere mouthpiece’ (p. 554). Indeed, I had to contribute my input by reflecting and relating my data to the theories so as to gain a correct interpretation of how it corresponds to the research questions. However, a leading principle was to let the data speak for themselves without ‘bending’ them to support my expectations.

Hence, the selection of quotations was based on information gauged from the participants’ activities, the administered tests, and participants’ responses, which facilitated the understanding of the problem in question. For instance, observations on the use of classroom space and language used by the teacher including code- switching and how code mixing influenced their questions were tendered as examples. There were also some snippets by students and teachers commenting on the effect of the experienced method of teaching, quotations from theories used, sample questions of the tests, quoted literature reviews and evidence from experiments. In this respect, more quotations were used in study III and IV where participants give accounts of what they do in their activities. The quotations were purposely selected as best exemplars to demonstrate variation and how the arguments were made in relation to the topic in all 4 studies.

Quality Considerations

As emphasized by Bryman (2008), the quality of qualitative research is often judged against the measures of transparency and coherence, impact and importance and sensitivity to content and commitment. Any research carried out must consider ethical issues, theoretical positions and should contribute something useful to the existing knowledge. Evaluation of such studies will be based on the sample composition, the choice of the method(s) and relevance of research questions. The credibility of the study is secured when the findings and conclusions tally well with the empirical data and these have significance to the theory and the community they purport to serve. For this reason, my research made a point of presenting quotations taken from respondents' views or the empirical data from experiments to make part of discussions and conclusions, as Patton (2003) emphasizes that a rich, credible and clear description is required so that whoever wants to make their judgment and own interpretations may do so. Thus in my studies, any claim or argument made is supported by evidence from the empirical data.

As regards the validity of a qualitative research, the results were examined to test if they are plausible and credible. For example the data gathered from different contexts were examined to establish their truth or faithfulness. The plausibility of the findings was measured against the existing state of knowledge and its agreement with the underlying theory. The researcher's judgment should also be credible. That is, it should be accurate given the context of the study and the nature of the problem. To respect this requirement, the findings were discussed following good practice such as sticking to methods, theories and empirical data irrespective of the research method used.

Above all, in order to attest for the strength and validity of my study, all the four articles in this work have been submitted to be peer reviewed by the research community in higher education seminars, symposiums, and have been presented in international conferences where the members of the same discipline may contribute to the researcher's work (Bryman, 2008). This is a clear sign of credibility where the work is reviewed and critiqued by other researchers during the research process.

The following is the list of papers showing the titles, the name of the conference, the place and date they were presented:

(i) Language and social space in a Multilingual Undergraduate Physics Classroom. Paper presented at EARLI Special Interest Group 10 and 21, *Moving through cultures of learning*. Utrecht, September 2 and 3, 2010.

(ii) Developing multimedia instrument for technical vocabulary in tertiary physics education in Rwanda. PhD symposium 27/01/2011, Linköping; Linköping University

(iii) Multimedia as a means to enhance teaching technical vocabulary to physics undergraduates in Rwanda, Euro CALLNottingham 2011, U.K 31/8-3/9, 2011- THE CALL TRIANGLE: Student, teacher and Institution

(iv) University teachers' reflections on the use of ICT in physics teaching, successes and challenges: the case of Higher Education in Rwanda. Rwanda International Conference on Technology in Education: *'Enhance learning through technology*'- Kigali Serena Hotel 5-7 September 2012.

The last aspect to bring up here deals with the potential transferability of the findings in this study. According to Bryman (2008) transferability refers to whether the findings apply to other contexts or whether they hold in some other context or in the same context at some other time. But he argues that in social research methods in the social sciences replication is not common. This is true because one cannot expect to find exactly the same necessary conditions and the same context everywhere. It is safe to say that it is possible for the same research to be carried out in similar situations. For example, the developing of a multimedia instrument can be done in any environment where there is a need to learn technical vocabulary. What can be different might be the discipline and the corpus dealt with. Also, the application of the instrument to an intervention group versus a control group would be done in other settings though no one can guarantee similar results. Therefore, the main concern should not be the exactitude of the conditions and the settings but seeing whether the findings could be applicable in other contexts.

SUMMARIES OF THE ARTICLES

Introduction

The current section is made up of summaries of the four studies that constitute this thesis. I start by an introduction to show how they are related and how they contribute to the theme of the research, that is, to enhance higher education physics learning through instruction, technical vocabulary and ICT. Although the studies have been done within different perspectives, different settings, different methods and varying samples of participants, all of them aim to investigate ways that are appropriate to enhance physics teaching and learning.

To be able to change the collective student belief that physics is reserved for the only few, very clever male students, the four studies of this thesis strive to find a solution to the problem of failure and of fearing physics subject. It is assumed that any subject that is taught using appropriate methodology, backed by necessary tools of basic scientific language and technologies will be facilitated to learn. This assumption is based on other scholars' results (e. g. Adeyemo 2010; Barton 2005; Haydn & Barton 2007; Chandra & Watters 2012; Hennessy et al., 2007; Jimoyiannis &. Komis 2001; Tasouris 2009) showing that physics can become more accessible to both female and male students when active participation and more opportunities for interaction and discussions backed with ICT are involved.

The first study emerged at the crucial moment when the language of education in Rwanda was changing from French to English. The researcher was concerned to see how the potential negative impact of this transition would be attenuated to limit negative effects in the context of science learning through foreign languages in tertiary education. There was a need to investigate how a lecturer and his students adapted to the change of language of instruction using all their common languages to make sure that the content of the lessons were understood Based on the findings, it was found that the student participants tried to access knowledge from their lessons while at the same time respecting the language policy. By analyzing the recorded videos, we could see how the teacher adapted different languages to different spaces of the classroom which we named *official, semi official* and *personal,* with the aim of helping the learners to understand the target lesson.

The second study concerns developing an instrument for technical vocabulary learning. The study describes how a multimedia assisted vocabulary learning (MAVL) instrument was constructed. Both students and teachers were involved in a process of selecting technical vocabulary relevant for the learning of electricity terms. After this cooperative work, the participating teachers and the researcher encoded the selected concepts on the computer in the form of video clips based on the principles of multimedia design by Mayer 2008. A total of 81 video clips were saved on the computer, CDs and memory sticks ready for use.

The third study shows how the created MAVL instrument was applied in a one-computer classroom in an environment where textbooks and multiple computers were not available to teach technical vocabulary to undergraduate physics students at one university in Rwanda. To find out the possible strength of the instrument, two methods of vocabulary teaching were devised. One was intended to use the MAVL instrument based on theories of cognitive load and multimedia learning and the other used a traditional chalk and talk method to teach the same concepts. Both groups were given the same test after 4 weeks. The results showed that the group of students who were exposed to computer-mediated multimedia performed better on the recall of the concepts than those in the control (traditional) group. Overall, the study indicated that multimedia can be used as a means to enhance teaching technical vocabulary to physics undergraduates in Rwanda.

Seeing that ICT had potentials to support teachers and students in their teaching and learning my next queries concerned in what ways teachers claimed that ICT was integrated in current physics education at tertiary level. Hence, the fourth study reports responses elicited from university physics teachers who were interviewed on the integration of ICT in their teaching. The teachers reported how they used ICT, the problems they encountered and what they proposed to solve them. Overall, when compared to the standard levels of ICT, one can infer that the teachers were still using it at a basic level to enhance their traditional teaching in a modified way. However, they showed eagerness to improve their teaching if more training in ICT was offered.

Summaries of Articles Constituting the Thesis

Article 1

Language and space in a multilingual undergraduate physics classroom in Rwanda, *International Journal of Bilingual Education and Bilingualism, 14*(6) 751-764.

Ingrid Andersson &Joseph Rusanganwa, Behavioural Sciences and Learning Department, Linköping University, Linköping, Sweden

Aim

This study was conducted in 2009 just after the introduction of English as a sole language of instruction. The aim was to examine how a lecturer and a group of students adjust to the change of language of instruction from a bilingual to a monolingual context. The research set out to find answers to the following questions. 1. How does the teacher align with students during a teaching event? 2. How are languages used during the teaching event? 3. How does the use of English, French and Kinyarwanda relate to classroom space? Theoretically we take a social constructivist perspective as a point of departure.

Method

Video recording was used as a tool to gather data from a lesson where Physics technical vocabulary and concepts were introduced. One teacher and 43 students participated. The first data analysis was inductive and we started by looking carefully at the video in order to find patterns of language use. We realized that the teacher changed position during the whole session and that his movements followed a pattern. Thereafter we employed a mixed method that dealt both with quantitative and qualitative designs since we had to verify what we first had seen by calculating the time the lecturer changed positions, the minutes he spent talking in each language and the effects it produced. The moments of code-switching in different classroom spaces were calculated.

Results

According to this study, the lecturer appeared to use space in the classroom to make his subject understood throughout his teaching. Another means was to use code switching from English, Kinyarwanda and French to make the course manageable. Additionally, it was found that the teacher used all the languages in different spaces of the classroom to help the students understand the subject. The spaces which we called *official*, *semi-official* and *personal* were used together with different languages to make the learners feel at ease while learning and by motivating them to participate. The overall picture of the lecturer’s movement is that the personal space is the most important where most teaching is done. It was observed that code-switching was mainly used in the semi-official and the personal space where the lecturer and students switched to French and Kinyarwanda to straighten out misunderstandings. Another observation is that the official space is used to the same degree at the beginning and at the end of the lesson. In sum, it was observed that the lecturer utilised all common languages while teaching and this increased the learners’ understanding. This agrees with studies showing that the use of multiple languages as tools for mediating knowledge has both social and cognitive benefits, as learner confidence and participation increase (Airey 2009; Lantolf 2000; Vygotsky 1978).

Discussion

The results from this study show that the participants are aspiring to become proficient bi- or multilingual students through their technical vocabulary lesson. Three languages, English, French and Kinyarwanda, are in daily use as academic tools and social resources. Code switching is used to supply the learners with appropriate words so as to understand their course. The lecturer also exploited various positions in the classroom as spaces to deliver the knowledge required by the students. Through watching the video we noted that the lecturer attended to signals of confusion and tried to support students’ understanding by all means, even if that meant using languages that are not formally accepted. He seemed to be empathetic to students’ needs, a patient listener and sensitive to their language problems. From this study, it is inferred that code switching can be exploited for students’ understanding (Martin- Jones and Saxena 2003; Van Lier 2004). It appears to be an important asset in the learning process and has to be resorted to when it comes to meaning making and co-construction of knowledge.

Article 2

Developing a Multimedia Instrument for Technical Vocabulary Learning: a Case of EFL Undergraduate Physics Education *Computer Assisted Language Learning,* (under review).

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Aim

This study intended to gain knowledge on how a multimedia assisted vocabulary learning (MAVL) instrument could be constructed to be used in a context of a one-computer classroom. Many studies have been conducted in the field of multimedia development and application (Chanier & Selva, 1998; Colpaert, 2006-2010; Chun et al., 1996-2010; Devi, 2010; Duquette & Renié, 1998; Ma & Kelly, 2006; Mayer et al., 1993-2008). Most of these studies applied multimedia in L1 and in a rich virtual learning environment where computers are easily accessible. However, this study was done to investigate the process of constructing a multimedia tool to support students' learning of L2 vocabulary in physics specifically within the electricity domain in an environment where only one computer was available for a whole class. The research questions guiding this study were: 1. What characterizes students' and teachers' selection of vocabulary to be included in a MAVL instrument? 2. How are the words encoded? 3. What knowledge do the participants gain from being involved in the construction?

Method

The researcher collaborated with a group of 82 students and their two teachers to select technical terms or concepts that were needed to be learned to understand students' electricity course. The selection of these terms was based on the following criteria: *repeatability, transportability, structural and contextual analysability* proposed by Fisher et al. (2009). A thematic coding method was used to categorise the selected terms respecting *cognitive load* limitations. The terms and concepts were encoded in the form of video clips based on the requirements of multimedia learning by Mayer (2008).

Results

The stakeholders (i.e. students, teachers and the researcher) agreed to trim down the number of the selected vocabulary to 81 concepts which would be manageable to be taught. The selected technical vocabulary yielded three categories namely *everyday, basic* and *advanced* technical vocabulary. Some difficulties were experienced. Some of the terms were found in the form of collocations or as compound words making it difficult to find their pronunciation in online dictionaries. To solve the problem, we decided to record our own voices even if they did not sound exactly like those of native English speakers. These voices were finally encoded on the computer as video clips following the principles for designing effective multimedia lessons (Mayer, 2008).

Discussion

The final product of the MAVL instrument attests to the capability of stakeholders to create their own mediating tools (Wertsch, 2003). This tool intended to facilitate technical vocabulary learning. In line with the social constructivist perspective, cooperation among the participants during the selection process was an important aspect. Also, the construction of the instrument agreed with the participants' needs and interest and they were used to working in groups during their laboratory experiments. Hence, it was possible for them to be actively involved in completing this academic task (Kan, 2011) as it was familiar to them. The criteria of vocabulary selection proposed by Fisher et al. (2009) were adhered to. By following these criteria relevant terms and concepts were selected. Furthermore, Mayer (2008) argues that for deep learning to happen, principles for multimedia design must be followed in order to help the learner to retain the learned material for a long time.

The pedagogical implications of this study are that the construction of the instrument helped the stakeholders to obtain ICT knowledge during tool construction. Also it attests to the notion that research can influence practice. Theories of social constructivism guided the cooperative segment, and a cognitive theory of multimedia learning pointed to the value to approach vocabulary learning drawing on sensory memory as well as affect and meta-cognition.

Article 3

Rusanganwa, J. (2012) Multimedia as a means to enhance teaching technical vocabulary to physics undergraduates in Rwanda, *English for Specific Purposes 32* 36–44.

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Aim

Based on the belief that a computer assisted language learning (CALL) instrument could facilitate the learning of technical vocabulary (e.g. Chanier & Selva, 1998; Duquette & Renié, 1998; Ma & Kelly, 2006; Tozcu & Coady, 2004), the recently created multimedia instrument (MAVL) was applied to compare its effect against a control group that did not use it. The exercise intended to explore learning in a one-computer classroom in an environment where textbooks and multiple computers are not available. The students involved in this study needed to master technical vocabulary in their electricity course. The aim was to see the impact of two methods of teaching technical vocabulary on student performance in tests of recall and transfer.

Method

Two groups of students called *multimedia* and *traditional* were created to investigate the possibility of learning technical vocabulary and be able to recall it after 4 weeks. The multimedia group (N=13) used computer mediated multimedia to present technical vocabulary on-screen. The traditional group (N=19) received blackboard presentations employing traditional methods to help students internalize the same vocabulary. The training for each group took 24 hours (eight three-hour sessions) spread over 4 weeks. The tests were set to measure the students' performance in recall and transfer. Post-test scores of the two groups were compared using t-test and ANOVA.

Results

A two-tailed t-test showed that the two groups did not differ significantly on Test 1, t (30) = .379, p = 707. However, a two-tailed t-test showed that the two groups differed significantly on Test 2, t(30) = 2.633, p = .013.

To compare the outcome of the two teaching procedures, an ANOVA was performed as a between-subject variable and the test occasion as a within-subject factor. The ANOVA revealed no main effect of group, F (1.30) = 1.32, p > .05. However, there was a main effect of time, F (1.30) = 34.5, p < .001. The results show that the effect of multimedia on the recall of the concepts taught is large (Cohen's d 0.95).

Discussion

The findings from this quasi-experimental study indicated that the created multimedia instrument had the potential to teach and help retention of technical vocabulary (Mayer, 2008; Moreno & Mayer, 2007; Sydorenko, 2010). Chun et al. (1996) suggest that people remember images better than words, and that words are easily remembered if they are associated with images. According to *dual coding theory* (Paivio, 1986, 1991, 2007) the combination of imagery and verbal information may have helped the participants to engage in *essential and generative processing* which facilitated the storing of learned materials in long term memory. The group that used the traditional method also indicated improvement in the recall of terms but it did not hold for a long time. In brief, this study gives us insights into the outcomes of vocabulary teaching in a traditional and a one-computer classroom, respectively. It emphasizes the potential of the multimedia method to facilitate recall of technical vocabulary. One remark to be made is that with so few participants, we cannot generalize our findings.

Article 4

University teachers' reflections on the use of ICT in physics teaching, successes and challenges: the case of Higher Education in Rwanda (under review)

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Aim

This study intended to investigate the integration of ICT in physics teaching in Rwandan higher education and point out further potential applications of it in facilitating physics learning. Shieh (2012) argues that university students studying introductory physics courses under Technology Enabled Active Learning (TEAL) achieved higher learning gains than those studying in traditional classrooms. It is evident that nowadays physics students should be given opportunities to manipulate ideas, generate and test hypothesis, interpret what they learn based on their preconceptions, which may contradict scientific concepts that are canonical in physics (Chandra & Watters, 2012). The investigation was intended to elicit accounts on the access of ICT, integration of ICT in teaching and the challenges faced.

Method

Interviews were used as a research tool in this study. A total of 12 male university physics teachers from three major universities in Rwanda participated in this study in 2011. The study elicited views from the participants on the use of ICT in physics teaching, how they used it to create learning materials, the training they received and the challenges they faced. These interviews were audio recorded and later transcribed verbatim and coded for further analysis. During analysis, thematic coding was developed. Data were analysed both quantitatively and qualitatively by attaching numerical and qualitative values to the findings.

Results

According to this study, ICT was found to be used to search for information. It was also used to create course note slides for classroom projection. Compared to the modelling approach (Peeraer & van Petegem (2012), it was inferred that the use of ICT in Rwanda is at the embryonic level type I where it is applied to enhance traditional ways of teaching on its way to professional improvement. On the part of a government's report (2010), the level of ICT use is pitched at a technology literacy level or applying stage heading to knowledge deepening. Some problems hindering creative exploitation of ICT were also pointed out. Lack of training, lack of funds and lack of the maintenance of the equipment were reported. Also power cut and low internet capacity were mentioned to impede ICT integration. Suggestions for improvement such as more workshops and follow-up sessions were mentioned.

Discussion

When examined against the ambitious target of ICT use stated in Rwanda vision 2020, the current use needs to move to the stage where it can guide learners through complex problem solving and manage a dynamic learning environment, that is, to the transformative stage of knowledge production (MINEDUC, 2010). Thus, more training in ICT to simplify and modify classical physics teaching is needed. Also ICT tools such as simulation, virtual programs, interactive technologies and authoring tools need to be exploited. To do that, those teachers who seem to be spearheads have to be identified, given more training and be asked to train others. This task is in the hands of government, institutions and educational partners (Hooker, 2009).

As we have seen before, the higher education in Rwanda has been undergoing rapid reforms in education processes and language which entailed students and teachers to adapt to the situation. In response to the Bologna Process, the teacher-fronted sessions have been reduced and learner-centred activities are encouraged. Additionally, a new language policy has been introduced where English is used as a sole medium of instruction. At the initial stage, affordable practices such as code switching are employed to facilitate students' learning of their course content while giving them time to learn a new language of instruction starting with technical vocabulary underlying their course. Mastery of scientific language is very important since they need it when they are explaining what they are doing either orally or in writing.

Learning of technical vocabulary can be explicitly facilitated by intensive teaching and extensive reading. However, in the case of Rwanda where access to books and online materials is difficult, there is a need of constructing own learning material using multimedia. This is what was done in the second study where MAVL was created. The results of its application shown by the class tests in the third study indicated that the multimedia instrument has a potential to be used as a means to enhance the teaching of technical vocabulary to physics undergraduates in Rwanda. This will be a useful database for universities which can be consulted whenever needed.

In the fourth study, the accounts of twelve university physics teachers were investigated. In their responses they indicate that they are striving to facilitate physics learning through the aid of ICT and good practices.

To conclude then, the issue of language of instruction appears to be very sensitive and the need for technical vocabulary to understand science subjects should be taken seriously. All the studies converge to make a point that physics learning can be facilitated by establishing a database for technical vocabulary and by adopting new ways of physics teaching employing affordances provided by ICT.

CONCLUDING DISCUSSION

Introduction

The aim of the current thesis was to investigate ways of enhancing physics learning. After working on the different studies constituting this thesis, I came to have a better understanding of the width and breadth of the problem of my research. I have been able to investigate the need for adaptation to the newly introduced language policy, the need to create an instrument to facilitate technical language learning, new methods of teaching physics starting with technical vocabulary and how new ways of active participation using strategies that involve more opportunities for interaction and discussions could be encouraged.

Chandra and Watters (2012) in their study report that physics teachers were criticised for not showing the details of how problems were solved on the blackboard (p. 631). Therefore the teachers were advised to re-think their pedagogical approaches by applying ICT tools since the literature suggests that pedagogical shifts driven by ICT can enrich the learning environment. For example Chandra and Watters (2012) support the view by Wieman and Perkins (2005) who argue that 'education research, careful measurement, and new technology make it possible to guide most students safely along the path towards a true understanding and appreciation of physics' (p. 40).

As explained above, this study was driven by the need to facilitate physics learning starting with the technical language underlying it. In the literature (Chandra & Watters, 2012; Jimoyiannis & Komis, 2001; Schauer et al., 2008; Tasouris 2009) physics is viewed as a subject that is demanding, theoretical, abstract, and labour intensive, which requires understanding abstract ideas. Moreover, educational practices such as chalk and talk lessons are viewed as slow, and students prefer active participation using strategies that involve more opportunities for interaction and discussions. All this will be possible when the learners have a language through which they can share their views and understanding.

Since the studies of this thesis started in 2009 at the time when English was newly introduced as the sole medium of instruction, the students and teachers who were familiar with the French system of learning had to adapt to the new situation. They had to use the little knowledge of English they had and try to switch from English to French and even Kinyarwanda as a strategy to share and construct knowledge.

As the teaching started to gain momentum, a new need to master physics technical vocabulary in English was felt. It became difficult to understand physics concepts by using the little knowledge of English students had learned from their General English. Obviously, they did one year English language preparation but that was not enough to enable them to plunge into the subject in depth. This then, warranted the need to focus on technical vocabulary learning, because as Wilkins (1972) argues 'without grammar very little can be conveyed, while without vocabulary nothing can be conveyed' (p. 111).

Clearly, these students needed wide reading and writing experiences on various aspects to accumulate enough vocabulary. So, they needed some extra help to build up an adequate vocabulary and to acquire strategies necessary to cope with the vast reading context (Coady, 1997). But in addition to extensive reading, solid science literacy instruction requires attention to scientific vocabulary (Fisher et al., 2009). In addition to the existing basic or general service vocabulary that is common to many academic disciplines, teachers and learners of science seek to build a repertoire of specialized academic words to better handle their studies (Hyland &Tse, 2007).

Coping with a New Language of Instruction

Through the lens of social cultural theory we observed the effect of an abrupt change in language policy and how the stakeholders react to adapt to the situation. It is from this situation that the need of mastering the language of instruction becomes evident.

As I have emphasized from the beginning, the teachers and students of physics have to master the language of the subject in order to function in it. Lemke (1990) points out, that learning science critically depends on the ability to understand the disciplinary language in which knowledge is construed. The first study acknowledges that Rwanda has adopted English as a medium of instruction for clear socio-political reasons. The advantage of this choice has been widely explained, including international co-operation on the political, commercial, social and cultural levels. But in addition, for Rwandan universities there is a need to access scientific knowledge mostly presented in English language. In order to attain this knowledge the students and teachers need to work hard to acquire the language of their domain, in this case English language for physics. However, as this policy was starting to be applied, the teacher has to find ways to make his subject understood throughout his teaching. One way was to use code-switching from English, Kinyarwanda and French to make the course manageable. This agrees with studies showing that the use of multiple languages as tools for mediating knowledge has both social and cognitive benefits, as learner confidence and participation increase (Airey 2009; Lantolf, 2000; Vygotsky, 1978). We also discovered that the different languages were used in certain spaces of the classroom probably representing the participants comfort zones for language use.

Learning through Cooperative Construction of a Multimedia Instrument

Through theories of social constructivism and learning with multimedia we encouraged co-operation among teachers and students to construct their own multimedia learning instrument using the material available (Study II). Cooperation among students helped them to share ideas and complete their task to select vocabulary. This gave them confidence that they could contribute and work independently in small groups. While selecting vocabulary, they also had the opportunity to practice pronouncing them. Obviously, this created excellent opportunities for students to use language, talk about language, and engage in problem solving with the help of their group members. As science students are used to working in groups while executing science experiments in the laboratory, the ability to work cooperatively was already present and this simplified the work. For teachers, they learned that students could be resources in the process of selecting what new vocabulary they needed.

Furthermore, we understood that the number of technical vocabulary needed to be taught had to be limited due to the time available in the course of four weeks. We therefore had to find strategies that would help us to select relevant vocabulary for our learners following criteria laid down by Fisher et al. (2009). According to these criteria, the selected vocabulary needed to be representative of other concepts in the course notes, the ability to appear several times in all chapters, to be extended to other tasks such as reading and writing, the possibility to be used and retrieved in the context and also the facility to be assimilated by the cognitive capacity of the learners.

In addition to the cooperation among the stakeholders, the presence of a computer helped in the construction of the multimedia instrument. Computers play significant roles in the preparation of learning material using multimedia that provide scope for explaining, demonstrating and illustrating ideas in the target language for the benefit of language learners. Materials prepared in multimedia can be presented in the form of text, graphics, audio and video and all of them can be integrated with the four skills of listening, speaking, reading and writing especially interesting for language teachers.

When preparing the MAVL instrument we relied on research-based theories to enlighten us on how to accomplish this activity. Respecting principles in multimedia learning, we constructed our clips following the *coherence principle.* We made sure the clips were simple, well-spaced, focused and only showing intended concepts to reduce processing demands and maximize successful encoding in long-term memory. By respecting *spatial* and *temporal contiguity principles,* we placed the images and the terms describing them near one another on the same screen along with their pronunciation at the same time as the corresponding image is depicted.

Being aware that the students might be learning these technical vocabularies for the first time in English, we used the *pre-training principle* to prepare them to learn more complex terms. To do this, we included basic electricity vocabulary such as *wire, charge, current, rod, sphere, conduction, repel* in the first clips to be taught before teaching subsequent complex concepts. It is evident that some principles were used more than others depending on the effect we wanted to produce in our students. Since we wanted them to retain the technical vocabulary for a long time we stressed those principles that were directly involved.

So, after having selected and depicted a manageable corpus we started teaching it following explicit vocabulary instruction and vocabulary learning strategies (Coady, 1993).

Comparing two Vocabulary Teaching Methods

In the third study we needed to know the impact on student performance in tests of recall and transfer. . We compared a traditional method and the multimedia method of vocabulary learning and both methods had a group of students attached to it. The results of the tests indicate that the group that used multimedia exploited the advantages it offered. For instance, the learners were able to suggest repetition of the terms whenever needed. By repeating the terms more than once (Nation, 1990), it was possible to internalize them in the long term memory (Moreno & Mayer, 2007).

However, this was not possible for the traditional group where once the chalkboard is cleaned the students could not see the words they were learning. Also, as the students in the traditional method were busy writing notes, they could not give full attention to the teacher's explanations hence missing important information. For the multimedia method group, it was easy to give full attention to the well-spaced clips presented in manageable chunks. However, students in the other group seemed to experience difficulties scanning through many concepts on the board causing them the effect of *split-attention* (Kalyuga, Chandler & Sweller, 1999) and reducing their possibilities of internalizing the words.

Teachers' Reflections on the Potential of ICT

The potential of ICT to facilitate physics teaching in higher education is reflected in the fourth study from the results of interviews that were administered to 12 physics teachers belonging to three different universities in the country. In the interviews, it was noted that ICT was helping them to modify their teaching. They reported that they used ICT to search for information from the web and present their course notes on the screen to their students. However, there is still a gap. Searching for information and presenting course notes do not meet the new demands of physics teaching. The level where they are is labelled Type I application in a *modelling approach* that simply makes it easier, quicker, or more convenient to continue teaching or learning in traditional ways (Peeraer & van Petegem, 2012). This level is also labelled the technology literacy stage (i.e. *applying*) by (MINEDUC, 2010 p. 21) for its tendency to be used for information search and material presentation. The question remains how these teachers upgrade their knowledge to be at the required level to manage teaching of complex concepts in physics.

In the literature (Chandra & Watters, 2012; Jimoyiannis & Komis, 2001; Mureramanzi et al., 2002; Schauer et al., 2008; Tasouris, 2009), physics is still viewed as a demanding subject that requires an understanding of abstract ideas. Unfortunately, there still exists a classical way of *lecture–seminar–laboratory exercises* performed by the teacher in front of the class based on the idea of the accumulation of basic models and laws in teaching physics (Schauer et al. (2008). Yet most important for learning is that students are actively participating and discuss their understanding. Moreover, the teacher is central as a facilitator ready to explain and challenge students with questions and new scientific knowledge. This is necessary according to social constructivist theory which is the foundation of this thesis. From the challenging situation of these new demands, physics teachers, helped by new pedagogies, need to re-think their pedagogical approaches aided by new technological affordances. In study IV most of the participants seemed to be aware of a vast array of technological applications ranging from spread-sheets, computer-based laboratories, simulations, exploratory environments, educational software design, development and evaluation just to name the few, whose strengths need to be explored and exploited.

Contribution of the Thesis

This thesis adds to the existing literature and knowledge on the necessity of technical vocabulary and how the lack of it may affect the understanding of physics phenomena. From Hyland and Tse (2007) we have seen that even with Academic Word List (AWL) and General Service List (GSL) accounting for 22% of the words in the science corpus, the students would still stumble over an unknown item about every five words, making the text incomprehensible (p. 240). Therefore the students in the present study were introduced to specialized vocabulary in the field of physics so as to succeed in their studies and participate as group members in their domain. It is felt that teachers have to make sure that students understand the most relevant and useful vocabulary appearing in their courses. One way to do this is to analyse the corpus of the required academic vocabulary and make it available to their students. Also, apart from selecting and teaching the vocabulary through multimedia, teachers have to provide students with tasks that allow them to apply what they have learned to new situations such as in peer conversations and writing.

With this solid foundation the students will be able to advance and learn even more complex physics concepts which hopefully will be facilitated through the use of ICT. Clearly, this is not just an easy task since it needs strong collaboration between all stakeholders namely students, teachers and the institution to make sure that conducive conditions are created to make this happen. Thus I agree with Fisher et al. (2009) who suggest that the institutions should make the task of vocabulary learning intentional, transparent, usable, personal and a priority. This task is very important as it will enable the students to read more complex science texts and through a strong foundation of scientific vocabulary they will be able to acquire the knowledge needed for a global job market.

It was found that the multimedia instrument in particular enhanced the students' language acquisition in the present environment. We noted that through video, graphics and animation with colour and sound we managed to increase students' interest in the material provided and they could successfully retrieve what was presented to them (see Rusanganwa 2012).

There are of course other possibilities of learning vocabulary in a second and foreign language using ICT (e.g. ALEXIA (Chanier & Selva, 1998), CAVOCA (Groot, 2000), WUFUN (Ma & Kelly, 2006), flashcard software (Nakata, 2011)). If students have sure resources 'to draw' vocabulary from, then they will be able to undertake extensive reading and this will help them to identify problems, ask questions, analyse and develop strategies and hence be part of the transformation of their learning.

Referring back to the findings from interviews administered to university physics teachers, their feedbacks show that they are trying to use ICT to improve their teaching. At least they are able to access information through internet and use projectors to present their course notes to their students which corresponds to the Type I use of ICT (Peeraer & van Petegem, 2012). It is also encouraging to see that they are dissatisfied with the basic knowledge of technology and would like to take a step ahead. In their proposals for needed training, they cite the need to make their subject understood through simulation of complex concepts. Therefore they would like to learn how to create video clips and CDs, to use Moodle and develop materials for distance learning. From these findings, it is worthwhile to argue that if learner-centred pedagogies are adopted and ICT affordances are exploited, the teachers will be empowered to open up new and more effective ways of facilitating physics teaching. That would allow teachers to be creative and innovative in their ICT use (Type II, according to Peeraer & van Petegem, 2012).

To conclude, this thesis has found that one way to enhance physics teaching and learning in the Rwandan context, is through developing a strong foundation in the English language in general and technical vocabulary in particular in addition to the integration of ICT in physics teaching. The case of integration of ICT as a supporting tool for teaching and learning can also be discussed from a quality perspective of the findings. Masoumi and Lindström (2011) suggest that there are worldwide requests for enhancing and assuring quality in the use of ICT. With particular relevance for developing countries a quality framework was developed for e-learning. Their model covers seven main categories including most aspects of e-learning in virtual institutions. For example, the *instructional design* *factor* emphasizes the need for selecting proper learning scenarios and organising accurate learning resources. The *pedagogical factor* stresses student-centeredness and learning environments in terms of communication, collaboration, and interaction. These two factors were strongly adhered to in the present study. Also, the fact that the participants in my study proved to gain better study results when they used ICT-supported learning, relates in a promising way to the main aspects of the framework for quality in e-learning.

Limitations

A number of limitations have been spotted in this thesis, which addresses a valid problem of a weak foundation in language and vocabulary intended to support science learning in Rwandan universities. The studies presented in this thesis were carried out to unveil the problem and offer solutions. However, they were limited in a number of ways. For instance, the attendance in the lesson in study I involved 43 students out of 176 students who were registered in the departments. Though this was an impressive number through which one could gather enough data, it would be difficult to generalize the results. Furthermore, the length of a 90-minute recording of the fourth session of eight cannot be expected to tell the whole truth about the students' level of understanding and reaction. This is because the recording was done in the middle of the 4 weeks module and one cannot tell for sure if students' level of English will continue to be low and consequently needing teacher's support through code-switching.

In the second study we had 82 participants who were involved in selecting relevant technical vocabulary for their learning. This was an impressive number to be involved in the task. However, the constructed instrument was intended to be applied in the environment of a one-computer classroom. To adapt it to the current requirements, it needs to be modified and made applicable for interactive and autonomous use.

In study 3 we had a total of 32 students in two groups who fulfilled all the requirements to participate in the tests. In the group of multimedia we had 13 students and despite significant effect of the methodology used we still feel that a larger sample would make the conclusion more convincing. A further limitation was seen in the small number of words and the learning of only certain aspects of the vocabulary (i.e. written and spoken form, meaning, and concept). A fuller study would also include the morphology and derivation of encoded words, their syntax and collocations. This again needs to be fully developed to modify the program and employed techniques to make them applicable for interactive and autonomous use.

The fourth study involved interviews with 12 university physics teachers. Obviously, this number seems to be small if you need to gather significant data. However, in qualitative research Bryman (2008) argues that what counts is the quality of the data (p. 183). Nevertheless, with the small number of participants it would be difficult to generalize the findings from three universities to be applicable to universities of the whole country.

Despite the mentioned limitations to this thesis, the researched problems were brought to the fore and strategies to confront them showed to be feasible. It is encouraging to note that physics teachers are already aware of the problem and that they are eager to work with the tools available to solve it. What remains is to apply the proposed solutions on a large scale using innovative and transformative ways.

Implications and Future Research Directions

Implications

This thesis presents a work that has been done to enhance physics teaching and learning supported by technical vocabulary and ICT in Rwanda. It is claimed that physics is a cross-cutting discipline that has applications in many sectors of economic development, including health, agriculture, water, energy and information technology. Also, the application of science through technology is crucial for providing the infrastructure that all modern countries need (SciDevNet, 2006*)*. It follows then that enhancing physics learning can contribute to the development of nations especially in developing countries. Physics is a pillar for understanding physical phenomena. Schauer et al. (2008) assert that project laboratories will be the typical learning environment for physics and engineering students for the next generation and these will require a constructivist approach. Since we need physics in all technological areas we have to support all the efforts of facilitating the teaching and learning of this subject. Supporting physics learning in tertiary institutions is expected to boost academic excellence and ultimately the country's growth. Given today's rapid progress appearing in all walks of life in Rwanda, various government policy and planning documents put Higher Education and the use of Information and Communication Technology (ICT) as the basis for sustainable socio-economic development, which will result in poverty reduction and good governance.

I believe that the findings in this thesis can have a global interest especially in third world countries drawing on the example of Rwanda. Attention needs to be given to supporting physics learning to produce the required experts in technology and the sciences. What is needed now is to have a clear plan, to coordinate activities, and to develop programmes accompanied with follow-ups for student and teachers.

Future Research Directions

From the limitation revealed in the studies above, further research needs to be done using bigger population samples in the field of physics learning. Moreover, the future move should be directed to strengthening not only physics but also other pure science and social science subjects.

However, as I have emphasized, a strong foundation in the language of the subject is indispensable. There is a necessity to establish a more specialized vocabulary corpus of every field and make it accessible to its members. Future research in the domain of physics and other subjects could investigate how a well-stocked database of technical vocabulary may be created and made available for the needs of the learners.

As for better teaching and learning in physics, new methods of teaching and innovative computer ways of facilitating subject understanding should be explored. Further research may be conducted to find out how teaching materials to express physical phenomena can be created to transform the traditional teaching of physics.

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APPENDIX

INTERVIEW GUIDE: ICT mediated physics teaching

1. In what way(s) may Information and Communication Technology (ICT) be useful within your teaching?

2. Do you use any technology in your teaching?
What kind? What is the source of the technology you use?

3. Do you think mastery of languages whether English or French play any role when using technology? How?

4. Do you see areas where you need technology to play a role in making your subject better understood by your students? If so, which area(s)?

5. Have you received any training in the use of technology after the introduction of the Bologna system? If so, what kind of training? Was it related to your teaching?

6. Apart from training organized by your institution, have you received any other training through your own efforts? If so, what kind of training?

7. Have you created any teaching material using modern technology? If yes, what kind of teaching material? For which course did you create the material? What type of technology did you use?

8. Have you used illustrations (e.g. pictures or film clips) in your teaching? If so, what kind?

9. If given opportunity, what kind of educational technology would you like to learn?

10. Is your institution involved in teacher training?
When you train these teachers what technology do you introduce to them?

11. As a physics teacher, do you think your institution encourages you to use technology in your teaching? If so, in what ways?

12. Have you experienced any problems when using ICT? If so, what problems?

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