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DEVELOPING UNIVERSITY-LEVEL INTRODUCTORY ICT EDUCATION IN TANZANIA: A CONTEXTUALIZED APPROACH

ACADEMIC DISSERTATION

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Abstract

This research is a result of a project named *Information and Communication Technology Education for Development: a Tanzanian Perspective*. The purpose of the project was the development of contextually relevant university-level ICT education in Tanzania. The preparations for the project commenced in 2000. Intensive development research process concretized in the Contextualized Programming course 2004-2005, the focus of this study.

The goal of this research was to design, implement and evaluate contextualized ICT education approach in Tanzania as a joint effort of Tumaini University, Iringa University College, Tanzania, University of Southern Denmark, and University of Joensuu, Finland. The main part of the research was carried out during the academic year 2004-2005 as a form of implementing the Contextualized Programming course at Tumaini University. The course had 27 second-year B.Ed. students, with the average of nine years' experience as subject teachers in mathematics and science. A total of 16 of the students were men and 11 women. Most of them had not been using computers before coming to the University.

The major objective of the course was to prepare students for their future profession as ICT teachers and get application oriented skills and knowledge for that. A sub-goal was to prepare them to be innovators in the society based on their ICT expertise.

The methodological approach of this interdisciplinary study is *development research* because of its long-term sustainable practical and scientific goals. The whole research project was carried out as a case study at Tumaini University, Iringa University College. The data collection was done by mixed method approach focusing especially on the deep qualitative data to crystallize the outcomes of the research.

Technology transfer to developing countries is an acute issue. Context-based higher level ICT education projects like this have rarely been carried out in developing countries, and thus there is a need for this type of multidisciplinary research.

This research answers to three main research questions:

What kind of theoretical and practical framework is appropriate for understanding the process of ICT transfer in the context of a developing country such as Tanzania? The methods to answer this question were literature review, background studies and observations. The main answer was ultimately crystallized in the CATI (**C**ontextualize, **A**pply, **T**ransform, **I**mport) model for the joint development of ICT education in local, developing context. The foundation for this model is context-based planning continuing with implementation, which can lead to contextualized meeting points and benefit the development of the local community in a sustainable way.

How was contextualization taken into account in the Contextualized Programming course? This question was answered by CATI based content analysis focusing on the development, implementation and follow-up of the course. The research indicated that connecting ICT education to the local needs is promising. The course in 2004-2005 had several context related elements, like objectives, learning materials, exercises, and field projects. One of the main problems was the missing participation of the local teaching staff in course implementation, which caused sustainability problems. On the other hand the course development and implementation had several side-effects such as the establishment of Tumaini University Science Park.

What are the meaningful contextual learning outcomes of the students referring to applying ICT skills and knowledge? The answer to this question was found from interviews and a questionnaire-based analysis focused on students' awareness of ICT and application ideas to their local context. The amount of students' contextual application outcomes based on their ideas was increasing and promising, although generally not fulfilling the contextualized level based on the CATI model during the three months teaching experiment. Most of the students were located in the application level of the CATI model.

This research process also led to the development of the Contextualized Bachelor degree programme in IT at Tumaini University.

Keywords: computer science education, contextualization, developing countries, development research, ICT education, IT education, situated learning, Tanzania.

Tiivistelmä

Tansanialaista tietotekniikan yliopisto-opetusta kehittämässä: kontekstualisoitu lähestymistapa

Tämä tutkimus on osa projektia ”Tieto- ja viestintätekniikan opetus kehitysmaakontekstissa, erityisesti Tansaniassa”. Tavoitteena on ollut kehittää kontekstuaalisesti relevanttia tietotekniikan opetusta Tansaniassa yhdessä tansanialaisen Tumainin yliopiston kanssa. Tavoite konkretisoitui Tumainin yliopistossa toteutettuun Kontekstualisoitu ohjelmointi -kurssiin lukuvuonna 2004-2005.

Tähän tutkimukseen kuuluivat tietotekniikan opetuksen toistuvat suunnittelu-, kehitys-, toteutus- ja arviointikomponentit, jotka toteutettiin Tumainin yliopiston, Etelä-Tanskan yliopiston ja Joensuun yliopiston yhteistyönä vuosina 2000-2006. Kontekstualisoidun ohjelmointikurssin opiskelijoina oli 27 toisen vuoden matematiikan ja tietokonesovellusten opiskelijaa Tumainin yliopiston Iringan toimipisteen kasvatustieteen kandidaatin tutkinto-ohjelmasta. Heistä 16 oli miehiä, 11 naisia ja heillä oli keskimäärin yhdeksän vuoden työkokemus alalta, mutta valtaosa tutustui tietotekniikan käyttöön vasta yliopisto-opintojen aikana.

Kontekstualisoitu ohjelmointi -kurssin tavoitteena oli perehdyttää opiskelijat ohjelmointiin ja tietotekniikan mahdollisuuksiin tansanialaisessa toimintaympäristössä. Käytännössä kurssin lähestymistavassa haettiin oppimiskokemuksia, jotka linkittyisivät paikalliseen arkielämään sekä johtaisivat uusien innovatiivisten sovellusmahdollisuuksien kehittämiseen. Lähestymistapa erosi merkittävästi vallitsevasta opettajajohtoisesta oppimisesta. Tutkimusprosessi kursseineen pyrki myös osaltaan vastaamaan teknologiatietotaidon ja -infrastruktuurin siirron haasteisiin. Tällaista monitieteistä lähestymistapaa tietotekniikan ja tietojenkäsittelytieteen opetukseen on sovellettu vähän erityisesti kehitysmaakontekstissa.

Tämän tutkimuksen lähestymistapa perustuu syklisen kehitystutkimuksen (development research) metodologiaan pitkäkestoisine käytännöllisine ja teoreettisine kehitystavoitteineen. Erityisesti tutkimus hyödynsi laadullisia menetelmiä, joita tuettiin määrällisen aineiston perusteella luodulla yleiskuvalla.

Tämä tutkimus vastaa erityisesti kolmeen tutkimuskysymykseen:

Millainen teoreettinen ja käytännöllinen viitekehys on tarkoituksenmukainen teknologiansiirtoprosessin ymmärtämiselle kehitysmaakontekstissa kuten Tansaniassa? Tähän kysymykseen vastaaminen kristallisoitui erityisesti

tietotekniikkaopetukseen liittyvän teknologiasiirron tarpeisiin kehitetyn CATI-mallin luomiseen. Malli sisältää tasot kontekstualisoida (**C**ontextualize), soveltaa (**A**pply), siirtää (**T**ransfer) ja tuoda (**I**mport), ja se kehitettiin vuosina 2000-2005. Mallin lähtökohtana on tarpeisiin perustuva kontekstilähtöinen suunnitteluprosessi, joka tarjoaa kestävän pohjan saavuttaa myös paikallista yhteisöä hyödyttävä sovellusvaihe, joka nivoutuu paikalliseen ajatteluun ja tukee paikallista kehitystä.

Kuinka kontekstualisointi toteutui Kontekstuaalinen ohjelmointi -kurssilla lukuvuonna 2004-2005? Kontekstuaalinen ohjelmointi -kurssin suunnittelussa ja toteutuksessa lähdettiin liikkeelle Tumainin yliopiston kanssa rakennetuista kontekstuaalisista tavoitteista. Niiden toteutumista analysoitiin ja arvioitiin CATI-mallin avulla. Kurssin tavoitteet olivat hyvin sopivia paikallisiin olosuhteisiin ja tukivat laajempia kehitystavoitteita (kontekstuaalinen taso C). Kontekstilähtöisesti rakennetut oppimateriaalit, harjoitustehtävät ja kenttäprojektit saavuttivat sovellustason (A). Suurin ongelma kurssin toteutuksessa oli ennakkokaavailuista poikennut paikallisten opettajien vähäinen osallistuminen opettamiseen, mikä aiheutti kurssin pitkäkestoisen vaikuttavuuden ja kestävän kehityksen kannalta merkittäviä ongelmia (siirtotaso T). Toisaalta kurssin toteutusprosessista kasvaneet positiiviset sivuvaikutukset, kuten Tumainin yliopiston tiedepuiston perustaminen vuonna 2006, suuntasivat toteutuksen selkeästi tulevaisuuteen (sovellustaso A).

Millaisia merkittäviä tietotekniikan oppimisen soveltamiseen liittyviä mahdollisuuksia kurssi tuotti? Haastattelu- ja kyselypohjainen aineisto osoitti, että opiskelijoiden taidot hahmottaa paikallisia tietotekniikan sovellusmahdollisuuksia olivat selvästi lisääntyneet Kontekstuaalinen ohjelmointi -kurssin aikana. Suurin osa opiskelijoista hahmotti ja innovoi tietotekniikan uusia mahdollisuuksia sekä koulumaailmassa että paikallisessa kulttuuriyhteisössä laajemminkin. Osa opiskelijoiden sovellusajatuksista ylsi CATI-mallin innovatiiviselle kontekstualisoinnin tasolle (C), pääosa niistä sijoittui sovellustasolle (A).

Tämä tutkimus johti myös osaltaan tarvelähtöisen, kontekstualisoidun tietotekniikan (IT) kandidaatin opinto-ohjelman aloittamiseen Tumainin yliopistolla vuonna 2007.

Avainsanat: kehitysmaat, kehitystutkimus (development research), kontekstualisointi, situationaalinen oppiminen (situated learning), tietojenkäsittelytieteen opetus, tietotekniikan opetus, Tansania

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It was in July 2000 when my wife, Pirita, and I, found ourselves in Tanzania. I now wonder what inspired Professor Erkki Sutinen to send us to Tumaini University in Iringa. But since we are confirmed, long-time adventurers, we decided to go. We arrived there to a warm and heartfelt welcome on the part of Dr. Kati and Jyri Kemppainen and their children – the first of many warm welcomes to Iringa on that day and on subsequent occasions. Africa is a place that quickly insinuates itself into one's heart.

I have had a number of years in which to realize that the needs of Africa – and Tanzania in particular – are always very close to the heart of my supervisor, Professor Sutinen. On so many different occasions he has encouraged both me and other researchers to persist and persevere with our researches into the development and teaching of ICT in Tanzania. In this research I have been deeply privileged to be able to implement and apply some of his seminal ideas in this field. I would like to express my sincere gratitude to him for being an incomparable supervisor.

I was also privileged to have Professor Henrik Hautop Lund appointed as my co-supervisor when I began to work full time on my PhD thesis in 2003. I will always remember his burning desire to return again and again to Tanzania to work on the development of robotic-related education for Tanzanian children and adults – all so that they might also, both now and in the future, enjoy the future.

Many thanks for my reviews Professor Johannes Cronjé, and Adjunct Professor Mikko Korpela for the constructing feedback, which led to is final outcome.

I would also like to express my gratitude to Tumaini University, Iringa University College, for entering into a productive and fruitful research and development partnership with us. My especial thanks go to Provost Nicholas Bangu, for his constructive collaboration, feedback and his enthusiasm that inspired us to carry on even when times were difficult. Many thanks to the former head of the ICT Department, Emmanuel Lupilya and to all the students with whom I worked.

My particular thanks go to Marcus Duveskog, who lived for years in Tanzania while he supported this research in the field. Thank you very much indeed for everything. I would also like to thank the other co-authors of the six articles that form part of the substance of this dissertation: Raimo Haapakorpi, Ebenezer Laisser, Fredrick Ngumbuke, Niko Myller, Jacob Nielsen, Carolina Islas Sedano, and Dr. Matti Tedre. I am grateful for the services of my English-speaking language editor, Roger Loveday, and for the feedback I got from Adele Botha, Minnamari Naumanen and Marilyn Thompson. Many thanks for the fine illustrations provided by Carolina Islas Sedano. Thanks for the employees of FELM in Tanzania, and for other persons, who have been participating in this process.

I would like to express my heartfelt gratitude to the Academy of Finland who provided most of the funds for this research (Decision 201682), as well as to the Department of Computer Science and Statistics and the Faculty of Science at the University of Joensuu, who supported me in many different ways. I am also indebted for the patient support of the Finnish Embassy in Tanzania, NordForsk of The Nordic Council of Ministers, the Christian Association for the Support of Science and Arts (Tieteen ja taiteen kristillisen tukisäätiö), and The International Multidisciplinary PhD Studies in Educational Technology (IMPDET) programme of University of Joensuu.

My years of childhood and adolescence prepared me well for what I have been able to achieve here. I cannot adequately express my gratitude to my parents, Virpi and Veikko Vesisenaho, for their unstinting kindness, love and support at every turn of the road. It was they who cultivated in me the gifts that have enabled me to bring this work to completion. I would also like to thank my brother, Tero Vesisenaho, and my sister, Terhi Ristimäki. Unquestionably the memory of my godfather, missionary Eero Komulainen, has also inspired me to this developmental field. I would like to thank my parents-in-law, Pirkko and Paavo Rintamäki, for their unfailing kindness, interest and support.

Life is certainly an adventure. Our two beloved sons, Kuisma and Tuukka, were both born during this crucial period in our lives. I would therefore like to express my especial gratitude to my wife, Pirita, for all her hard work, understanding, dedication and self-sacrifice during this period. Things were not always easy and certain obstacles prevented us from doing what we would have preferred to do – for example, prevented us from going together as a family to Tanzania. But we have all reached this point of achievement and gratitude. Thank you from the bottom of my heart, Pirita, Kuisma and Tuukka.

Most importantly of all, I would like to express my heartfelt gratitude to God for his unfailing kindness, goodness and mercy throughout the course of this challenging period.

Mikko Vesisenaho

Ylämylly

13 September 2007

Abbreviations

Abbreviation	Description
A-Block	African (Intelligent) Building Block (Nielsen & Lund, 2006)
ACM	Association for Computing Machinery
ASEE	American Society for Engineering Education
B.Ed.	Bachelor of Education
CATI levels	Contextualize, Apply, Transfer, Import
COSTECH	Tanzania Commission for Science and Technology
CS	Computer Science
CSE	Computer Science Education
FELM	Finnish Evangelical Lutheran Mission
FIE	Frontiers in Education conference (organized by IEEE)
FODEM	Formative Development Method (Suhonen, 2005)
GDP	Gross Domestic Product
GNI	Gross National Income
ELCT	Evangelical Lutheran Church of Tanzania
I-Block	Intelligent Building Block (Lund, 2003)
I/O	Input/Output
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IFIP	International Federation for Information Processing
IGIP	International Society for Engineering Education
IMPDET	International Multidisciplinary PhD Studies in Educational Technology
IPSP	Internet Project Strategic Plan (Ashford, 1999)
IS	Information System
ISO	International Organization for Standardization
IST-Africa	Information Society Technologies in Africa conference
IT	Information Technology
NGO	Non-governmental Organization
NQC	Not Quite C (programming language)
Q1-Q3	Research Questions 1-3
SD	Standard Deviation
SIGCSE	Technical Symposium on Computer Science Education (organized by ACM Special Interest Group on Computer Science Education)
TEA	Tanzanian Educational Authority
TEDC	Technology for Education in Developing Countries workshop (organized by IEEE)
TSh	Tanzanian Shilling
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollar
WG 9.4	Social Implications of Computers in Developing Countries (a working group of IFIP)
WSIS	World Summit on Information Society

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Original publications included in this thesis (reprinted with permission)

PAPER I. Vesisenaho, M.O. & Lund, H. H. (2004). I-BLOCKS for ICT Education Development, Case Iringa, Tanzania. In F. Flückiger, R. Ruprecht & R. Scheurer (Eds.), *Proceedings of the 33rd International Symposium IGIP / IEEE / ASEE*, September 27–October 1, 2004, Fribourg, Switzerland (pp. 364-371). Fribourg: University of Applied Sciences of Western Switzerland.

PAPER II. Lund, H.H., Nielsen, J., Sutinen, E. & Vesisenaho, M. (2005). In Search of the Point-of-Contact: Contextualized Technology Refreshes ICT Teaching in Tanzania. In P. Goodyear, D.G. Sampson, D. J. Yang, Kinshuk, T. Okamoto, R. Hartley & N. Chen (Eds.), *Proceedings of the 5th International Conference on Advanced Learning Technologies, ICALT 2005*, July 5–8, 2005, Kaohsiung, Taiwan (pp. 983-987). Los Alamitos: IEEE.

PAPER III. Vesisenaho, M., Kemppainen, J., Islas Sedano, C., Tedre, M. & Sutinen, E. (2006). How to Contextualize ICT in Higher Education: A Case Study in Tanzania. *African Journal of Information & Communication Technology, AJICT, 2(2),* 88-109.

PAPER IV. Sutinen, E. & Vesisenaho, M. (2006). Ethnocomputing in Tanzania: Design and Analysis of a Contextualized ICT Course. *Research and Practice in Technology Enhanced Learning, RPTEL, 1(3),* 239-267.

PAPER V. Vesisenaho, M., Duveskog M., Laisser, E. & Sutinen, E. (2006). Designing a Contextualized Programming Course in a Tanzanian University. In D. Budny & G. Bjedov (Eds.), *Proceedings of the 36th Frontiers in Education Conference, FIE 2006*, October 28–31, 2006, San Diego, California (pp. 1-6). Champaign, Illinois: Stipes Publishing Co.

PAPER VI. Bangu, N., Haapakorpi, R., Lund, H.H., Myller, N., Ngumbuke, F., Sutinen, E. & Vesisenaho, M. (2007). Information Technology Degree Curriculum in Tanzanian Context. In P. Cunningham & M. Cunningham, M. (Eds.), *Proceedings of Information Society Technologies Africa, IST-Africa 2007*, May 9–11, 2007, Maputu, Mozambique, International Information Management Corporation. CD-ROM.

1 Introduction

This research is motivated by the belief that it is possible to introduce information and communication technology (ICT) into developing countries in a way which is beneficial for the community and relevant to be used in novel and creative ways. It offers empirical evidence from a long-term study, undertaken by a consortium of partners from Europe and Tanzania, showing that it is possible to introduce ICT of the highest standards into a developing country such as Tanzania in a way that meets the various challenges and difficulties that are characteristic for countries of the developing world.

The research itself was stimulated by the desire to investigate the implications of the enormous gap in all aspects of ICT development and preparedness between developed and developing countries (Agonga et al., 2003c). This gap, widely known as the *digital divide*, continues to create serious divisions among people in the developed and developing world. In the developed world, the average citizen enjoys access to advanced forms of ICT as a matter of course. But in the developing world, a reliable internet connection, for example, is generally, for many reasons, an unattainable dream, even for those who can afford to acquire it. It is ironic therefore that ICT, which is so widely hailed as a means for promoting democracy and real understanding among the peoples of the planet, causes division rather than mutual comprehension among the nations that make up the international community. (cf. Castells, 1997/2004a; Digital Divide.org (n.d.); Naidoo & Schutte, 1999; Negroponte, 1995; Rogers, 2003)

The divisions occasioned by unequal access to the ICT and Internet not only promote differences and misunderstandings between industrialized and developing countries; they also foster various kinds of differences and inequalities within developing countries themselves. The digital divide also increasingly nurtures social, economic and democratic divisions among various groups of people within developing countries. (Rogers, 2003) This way the digital divide continues to create internal divisions between the elites and grassroots communities in societies in developing countries (Agonga et al., 2003c). A class of people who do not regularly utilize primary ICT resources such as the Internet to engage, mobilize and participate in public life, are different from those to whom such a resource is simply unavailable in a way that can ultimately seriously compromise the social, economic and democratic fabric of a developing country. (Norris, 2001/2004)

The overall goal of development efforts and projects is to promote the use and diffusion of globalised technology – focusing nowadays more on ICT – and to empower *local* people through education and access to initiate changes that bring improvement to the lives of their fellow citizens in their own communities (World Bank, 1998). The challenge in the field of ICT is to adapt technologies to local conditions in developing countries in such a way that local communities willingly embrace such innovations and adjust them to their own developmental needs and purposes (Agonga et al., 2003c; Ouma-Onyango, 1997), not just being uncritically reliant on imported technology (Kopoka, 1996). Sustainable economic growth requires the creation and diffusion of internationally recognized forms of technology in a way that supports local growth and development (UNDP, 2001).

If development projects can be indigenized in this sustainable way, they have some chance of becoming sustainable and of making a real difference to the welfare of local communities through the agency of empowered and altruistically conditioned local operatives. The World Summit in Information Society (WSIS) is one global attempt to this direction as the vision of the WSIS of 2003 was a world in which everyone enjoyed an equal opportunity to benefit from ICT (WSIS, 2003a). The key principles of the WSIS include issues relating to decision making, infrastructure, capacity building, confidence, environment, ICT applications, cultural diversity and identity, media, ethics and worldwide cooperation for a more equal future (WSIS, 2003b).

Although it is easy to say that ICT should serve altruistic developmental goals, such an assumption presupposes no single methodology for the introduction of ICTs. The introduction of ICT into a community involves everyone who is a partner in innumerable and sometimes even unforeseeable dynamic processes that can only be satisfactorily resolved by the ingenuity, dedication and goodwill of all concerned. The difficulties that arise in meeting local demand also create challenges for research and development. (Agonga et al., 2003b) Ouma-Onyango (1997) as well as Tanzanian Kopoka (1996) note that, the most fundamental need in developing countries is for an information-based and human-centered approach to technology transfer, and as Pulkkinen (2003) reminds us the ICT education projects are easily missing the human, social component. There has not been a holistic theory or model of technology transfer to the developing world. When such predictions or models exist, they are nearly always based on conditions prevailing in industrialized societies[1] and are business driven. (Agonga et al.,

[1] The industrialized societies can also be called developed, high-income or Western countries (Allen & Thomas, 2000).

2003a; Ouma-Onyango, 1997) A great deal of research and action is still required before the WSIS vision can become a reality in several different contexts (Suárez, 2005).

Rationale for this research

This research is human-centered, and it focuses on the issue of contextualized ICT education in Tanzania. I have considered the implications of what it means when one says that there is a need for more contextual understanding and need-based approach in the field of ICT. This research critically examines the feasibility and progress of ICT transfer and the contextualized approach to implementing introductory computer science (CS) education for university level ICT students in the Tanzanian context. This approach to ICT is holistic including mainly elements of computer science education (CSE), and some elements of engineering and information system education.

A major purpose of this research is to build up scientific knowledge about conditions and problems of contextualization in the accomplishment of ICT and ICT education transference, to reach conclusions about how contextualization can best be accomplished, and to establish why contextualization is both needed and appreciated when transferring ICT to developing countries. This research is also to obtain a clearer understanding of the practical needs and challenges of ICT education and ICT education projects in a Tanzanian context and to support the development of higher level ICT education and development in general in the country (cf. Bloom, Canning & Chan, 2006). The focus of this research is on contextual understanding.

The methodological approach that I found to be the most useful and appropriate for accomplishing these goals is *development research*. This is because development research accommodates the kind of long-term practical and scientific goals that were part of my purpose (Reeves, 2000a; van den Akker, 1999). The experimental part of this research was carried out as a case study (Merriam, 1998; Yin, 1993) at Tumaini University, Iringa University College (later referred also as Tumaini University) in 2004-2005. For data collection, I made use of a mixed method approach (Creswell, 2003) that focused on gathering deep qualitative data to crystallize the general outcome of the research (Richardson, 1997).

My personal research involvement in ICT education for development started at Tumaini University in Tanzania in the year 2000 with the support of University of Joensuu, and the Finnish Evangelical Lutheran Mission (FELM). From the very beginning of the collaboration between Tumaini University, and its partners, the goal was to provide a context-sensitive ICT education that would also benefit local society in practical ways by focusing on meeting the needs and realizing the aspirations of local people.

The first systematic ICT project at Tumaini University was undertaken with FELM in 1999 and concentrated on ICT infrastructure development (Ashford, 1999; Kemppainen, 2006). FELM has actually been engaged in long-term projects in the development field since 1870 in Africa, and, more particularly, since 1948 in Tanzania (Peltola, Saarilahti & Wallendorf, 1958). Researchers of University of Southern Denmark joined the collaboration in 2003 to provide subsidiary support in the field of educational robotics.

My personal understanding of the difficulties of applying technology in the Tanzanian context grew from the most challenging and demanding period of the research. It required a lot of special efforts and even risk taking. It was because of these initial difficulties and challenges that it became clear that successful and sustainable development in this field depends upon establishing a pool of local experts and initiators who can take personal responsibility for the way in which ICT develops in the host country. This realization exerted a decisive influence on the final implementation and practical outcomes of this research project (cf. Sutinen, Vesisenaho & Virnes, 2002; PAPER IV).

Information and communication technology (ICT)

There are several definitions of *technology*. The word *technology* is conventionally related to practical applications and the solution of practical problems because an earlier use of the word in English refers to the making of technical tools (Gyekye, 1997). It may also describe a tool or instrument that is used to accomplish a task or to support a service or production process (Ouma-Onyango, 1997), which leads to that there is normally a purpose for the use of technology, and it requires also applying knowledge of the humans in organizations. The development of technology also needs specified knowledge. (Wilson & Heeks, 2000). With the introduction of electronic technologies, the word *technology* has widened its scope of denotation and now includes reference to innumerable electronic tools and applications and to the demand for technology to be more knowledge- and even information-based (Castells, 1996; Ouma-Onyango, 1997; Sussman, 1997). This specifically electronic development of technology has created what is called *information technology (IT).* Wilson and Heeks (2000, p. 413) defines IT as "*electronic means of capturing, processing and storing information*", which is quite technical definition. Webster (2004) reminds us that in *information society* – the society that is driven by a technology in so many vital respects – technology should ideally take its place as only one point of view. While this may be theoretically desirable, it is becoming more and more evident that revolutionary technologies such as the Internet have given rise to a variety of problems that no one could have foreseen before the advent of the information society.

In this research *information and communication technology (ICT)* refers to advanced technology that also supports the creation of knowledge. The term information and communication technology is oriented towards application and is less theoretical than the term *computer science (CS)*. The term information technology (IT) may be used interchangeably with ICT.

Techno-economical transfer – the push effect

There are several obvious uses to which technology can be put. Winner (1996/2004) states that some people use technologies aggressively to secure their dominance over others. Norris (2001/2004) notes that, in practice, technology has often been utilized to benefit the industrialized world. In the same way, it is necessary to ask whether technological development projects are undertaken by Westerners as part of a long-term project to impose certain cultural and economical values, symbols, creations and motivations on Africa. Are the knowledge and skills like information still expected to flow primarily from North to South (Mowlana, 1986) ? And if the kind of techno-economic importation we are dealing here with takes root in developing countries, it also becomes legitimate to inquire about the long-term effects that such innovations, new ideas, practices and objects have on the host culture (Matengu 2006). Technological development should ideally be used for national development objectives and applied to the solving of economical and social problems, although technology is frequently used to promote warfare, exploitation, surveillance and the accumulation of wealth in the hands of small groups of people (Kopoka, 1996).

During the past few years, development aid has focused more and more on knowledge based aid and transfer (World Bank, 1998). What is the meaning of knowledge transfer in ICT or ICT education? While it has too often come to mean focusing on transferring technological solutions, it should be extended to focus also on the social system and on pedagogy (Pulkkinen, 2007). ICT education is to produce innovative students. This means that such students are trained not only to be users; they are also trained to become advanced users, maintainers and developers (cf. Braa, Monteiro & Reinert, 1995; Gyekye, 1997). While this kind of an innovation-based approach is both necessary and desirable, it requires a high degree of participation and commitment on the part of local communities (Gyekye, 1997; World Bank, 1998). Matengu (2006) reminds that local innovation and creativity are far more critical to the welfare of local communities than is the mere physical availability of technology.

Context

Technology is always used and implemented in a specific context. An etymological dictionary explains that the word *context* is derived from the past participle of the Latin verb "*contexere",* which means *a joining together*, in conjunction with particle "*com"* which means *together with* (Harper, 2001).

Because different researchers have defined the word *context* in different ways, the actual context of research is determined by the project itself. The context may even be a familiar ideology such as capitalism, fascism or any other kind of *ism* occurring within a particular time frame (Grossberg, 1997). A context may also be a specific part of everyday life when it occurs as a particular social practice or ritual (Frow & Morries, 2003). A context may thus refer to the spatial and institutional locations of social situations that are crucially dependent on the norms, values, and relationships that condition the actors who participate in such situations (Pawson & Tilley, 1997).

Swantz (1989) uses an anthropological point of view to define *context* in terms of its intellectual, physical, institutional, social and cultural components. Information system researchers Tiihonen, Mursu and Korpela (2006) define context in terms of the natural, cultural, historical and immediate situations, and Avgerou (2002) considers contents of innovations and their relation to the social context. Tedre (2006) emphasizes the importance of social studies and processes in computer science (CS), and his emphasis widens the applicability and context of CS. Daniels, Berglund and Petre (1999) describe the social and technological context within which computer science students operate, and they designate this as the context in which skills and knowledge are applied.

I define the specific context of this research as consisting of Tumaini University, the Iringa region, the secondary schools for which students were preparing themselves to teach, and the Tanzanian society in which the participating students are living.

Contextualization in ICT education – the pull effect

A contextual way of learning makes it easier for students to retain knowledge because it offers them models that scaffold their learning processes and can relate the learning to their existing mental models. On the other hand, a very strict context emphasis can undermine the generalizability of a learnt knowledge and skill, and there is a risk for stereotypical oversimplifications. (cf. Gyekye, 1997; Hountondji, 1996) While any teaching needs to be supported by an adequate theoretical component, it needs to be balanced by being properly related to its environment and natural conditions. Unless a course is thoughtfully situated in the context of all the elements that support it in the community and the institution, it will not be able to serve its purpose adequately. A successful course therefore takes account not only of the environment and infrastructure, but also of all relevant social, cultural, economic, political and personal conditions.

Contextualization in ICT education means taking all prevailing conditions in the local environment and society into account when one plans and implements ICT education. Contextualization in ICT education unites development with a clearly defined needs-based approach. (cf. Sutinen & Vesisenaho, 2005) This kind of approach accords great importance to the sharing of acquired knowledge and expertise with local residents, as well as the kind of engagement on the part of the local population that will stimulate active participation and sustainable long-term development (Gyekye, 1997).

It is necessary first to consider the ways in which conventional computer science education (CSE) operates. Conventional CSE (and engineering education) are often characterized by an emphasis on imparting a standardized *theoretical knowledge* to students (Beynon & Roe, 2004; Donaldson, 2006; PAPER IV; cf. ACM & IEEE, 2001). This makes the learning alien to context, which is easy to be noticed in several articles related to CSE and developing countries (see Section, 2.2) and even in more application oriented ICT education (Cronjé, 2006).

The precise relation between theory and practice as well as local and global is not easy to define and find (Braa et al., 1995; Cronjé & Blignaut, 2005). Cronjé and Blignaut (2005) have considered the possible problem of increasing the gap between local and global if one localizes education too comprehensively (Figure 1) because a purely local focus in education can limit the applicability of skills and knowledge to a narrowly restricted environment. On the other hand a purely global and international focus can make knowledge irrelevant to the needs and problems of a local society. The global and the local knowledge have less and less in common with one another. Must such a situation only be defined in terms of either local or global instead of both working together?

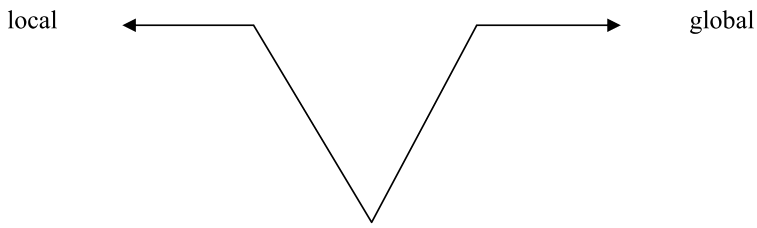


Figure 1: Local versus global approach to education moving further and further away from one another (cf. Cronjé & Blignaut, 2005)

Figure 2 represents the problem slightly differently as it has contextual relevance to standardized performance as dimensions. A figure that accords a high degree of commitment to both of these necessary components of quality ICT education would optimize both to local contextual concerns as well as to a standardized, global education. Although it may be difficult to establish a healthy sustainable balance between these two dimensions (see Section 2.1), the focus throughout this research has been on establishing the required balance through the application of a contextualized needs-based approach (the pull effect).

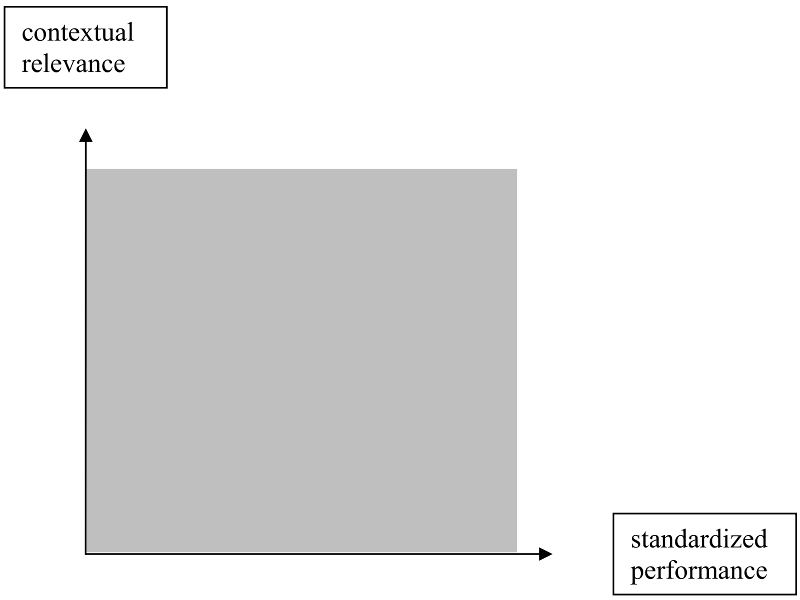


Figure 2: Contextual relevance versus standardized performance

Situated learning is therefore used as the pedagogical framework of this research. In situated learning the student is provided with opportunities to acquire knowledge and expertise through guided *exploration* to support his or her personal learning path. The goal of situated learning implies understanding and an ability to join disparate elements together rather than performing operations in a mechanical way without any linkage to the applicable context. (Brown, Collins & Duguid, 1989; Herrington, 1997; Section 2.3.4) This way both students and teachers acquire a sensitive understanding of the learning content to be applied in the context. That way their expertise will also benefit the local community.

ICT education and ICT in Tanzania

While Tanzania has a good record of enrollment for primary education, enrollment figures for secondary and tertiary education are less satisfactory (World Bank, 2005). The *Computer Science Syllabus for Secondary Schools* (Forms I-VI) was published in 1996 by the Ministry of Education and Culture (1996), and slightly renewed in 2005 (Ministry of Education and Culture, 2005). It is mostly private secondary schools in Tanzania that have been able to offer computer science or computer literature education (Ministry of Communications and Transport, 2003). ICT is rarely applied in other school subjects (Ottevanger, van den Akker & de Feiter, 2007), but the Tanzanian Educational Authority (TEA) has recently launched initiatives for the development of ICT in the educational sector. The main initiative it has been focusing on has been the establishment of a Tanzanian Educational Network. (Tanzanian Educational Authority, 2006)

There were four institutions that offered university level (also referred to as *tertiary* or *higher level*) computer science, ICT or engineering education in Tanzania in 2005. The largest of these institutions is the state-owned University of Dar es Salaam, which adopted its first CS curriculum in 1974 (Mgaya, 1994). In 2005 the total student enrollment of universities was less than 900 in the field. None of the four constituent institutions of the university offered CS teacher education, which is also lacking in several other developing countries.[2]

Because ICT usage and infrastructure in Tanzania are currently in a developmental state, the country still lacks adequate resources for the efficient operation of ICT resources and so can only offer unequal access to computers and networks (World Bank, 2004; Section 3.1). The East Africa Submarine System Project (2006) has

[2] Personal communication with the Higher Education Accreditation Council, Dar es Salaam, Tanzania on May, 24, 2005.

been designed to make reasonable Internet connectivity and bandwidth available in the near future. One may reasonably assert that the successful development of higher education in developing countries is co-supported by the provision of infrastructure and facilities that will support education, training, innovation and knowledge-creation in the coming decades (The Task Force on Higher Education and Society, 2000).

Although there is lack of ICT resources in Tanzania, there have been notable efforts to remedy this situation. The major policy documents concerned with national ICT issues are the National ICT Policy (Ministry of Communications and Transport, 2003) and Development Vision 2025 (Planning Commission, 1999). The National ICT Policy document gives an account of the most important problems that currently affect the ICT sector in Tanzania. These include factors that hinder the development of quality ICT education and ICT availability in general (Ministry of Communications and Transport, 2003). The Development Vision document foresees that ICT development will act as one of the primary stimulants of economic growth in the country (Planning Commission, 1999).

Context of this research

This research was carried out at Tumaini University, Iringa University College. It is a ten-year-old institution of higher education founded and owned by the Evangelical Lutheran Church of Tanzania (ELCT), situated in the southern highlands of Tanzania. Iringa municipality itself, the capital of the region, has a population of 350,000 (The United Republic of Tanzania, 2002). Because the region is largely rural, its main sources of income are derived from agriculture. While the number of small-scale industries in the region is growing, there are only a few industrial companies in Iringa itself. (Iringa Municipal Council, 2003)

The university college comprises four faculties: Arts and Social Sciences (including Department of Education), Business Administration, Law, and Theology. The number of enrolled students has increased rapidly and stood at two thousand in the academic year 2006-2007. Students come to the university from all over the country and many of them are studying with the support of scholarships. In 2004, 40 percent of graduates were female (Bahendwa, 2004).

The stage of the basic IT infrastructure of the university was relatively good, based on the IPSP development project in 2000-2004 (cf. Ashford, 1999; Kemppainen, 2006). The university got Internet connection in 2002, but the bandwidth has still been limiting the usage of Internet. The capacity of the connection, although increasing, was still less than one megabyte per second for the whole campus in 2006.

The college started nevertheless to offer basic computer literacy courses since its establishment with second hand computers, and since 2002 it has offered several IT courses offered especially for the B.Ed. students (PAPER III). One of those courses is Introduction to Programming, whose further development is focused on in this research.

Structure of the thesis

Chapters 1-6 of this thesis summarize the research process and findings reported in the included publications (referred as PAPER I, II, III, IV, V & VI). It provides a literature review and describes the methodological foundations of the research. Chapter 2 contains a literature review that examines the development projects, contextual computer science education (CSE) and participatory approaches to CSE available in Africa relevant to the field of the research. Chapter 3 describes the specific context of this research and concludes by stating the research questions. Chapter 4 explains the particular methodology used in this research as well as describes the case on which this research is based. Chapter 5 summarizes the results of the research, and Chapter 6 closes by making conclusions and offering recommendations.

Author's role in the publications

I am the principal contributor of PAPER I, II, III and V, which focus on background, analysis and reporting, and the parallel principal contributor of PAPER IV focusing especially on the analysis by the CATI model. I acted as a consultant on the CATI model and previous research results for PAPER VI. I was also the final editor and composer of the subsequent scientific PAPER VI. The connection of these publications to the research and to one another is presented in Figure 3.

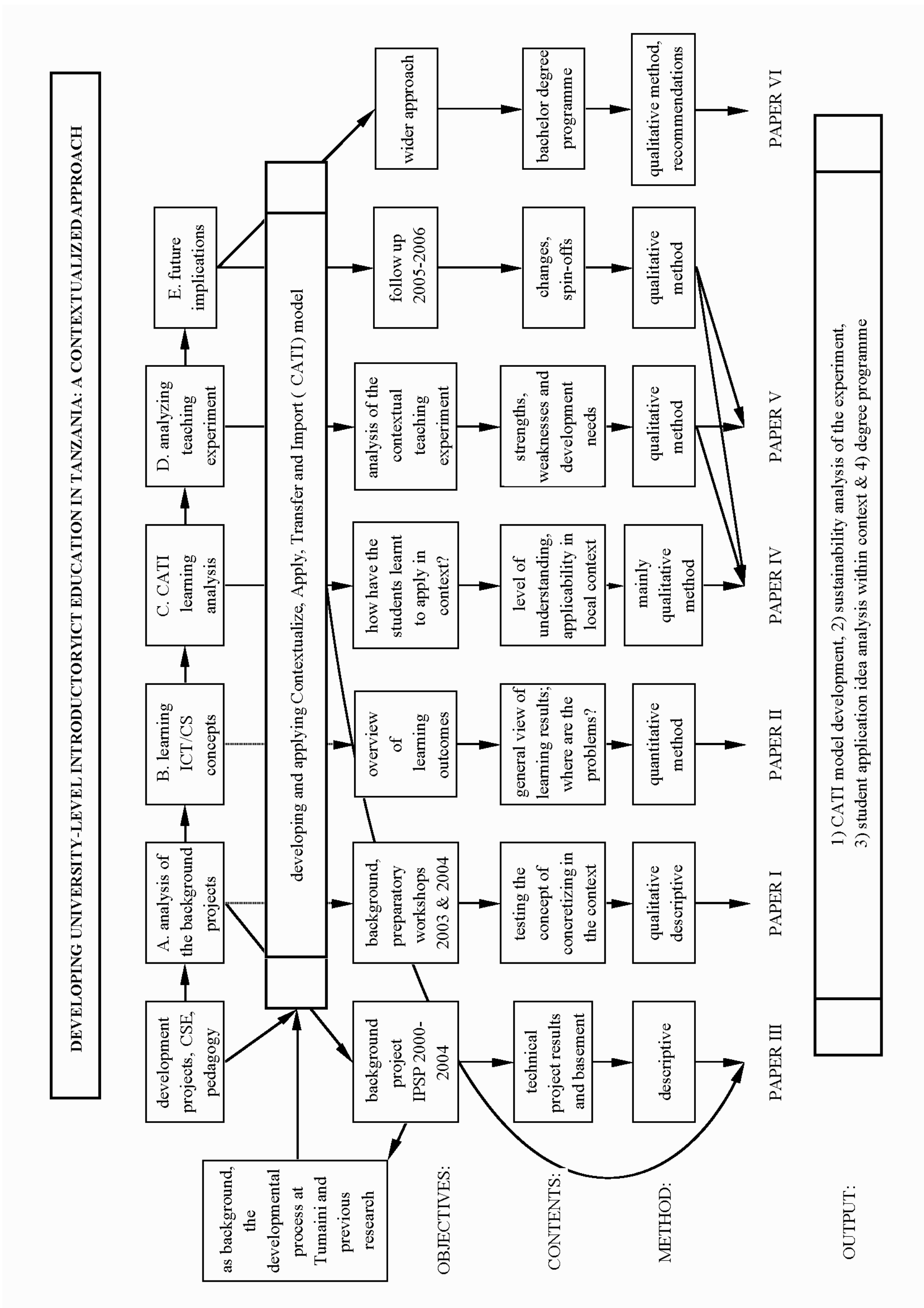


Figure 3: Structure of the research

2 Literature review

This chapter presents the focused theoretical basis and reasons for this research in the context of an analysis of the published research and theory that is relevant to this study. I begin with the challenges and problems presented by various development projects and their evaluation in developing countries (Section 2.1). I will then continue with a review of the reports that describe the field of ICT education with contextualized CSE projects in an African context (Section 2.2). In Section 2.3 a need for participatory approaches and a constructivist pedagogical approach to CSE are presented. These components give an overview of the interdisciplinary nature of this research and are all linked to one another with the aim of development of the contextualized approach to CSE in Africa. In the following Chapter 3 these phenomena will be discussed in terms of their implementation in Tanzanian context (Section 3.1). The chapter concludes with research questions (Section 3.2). (Figure 4)

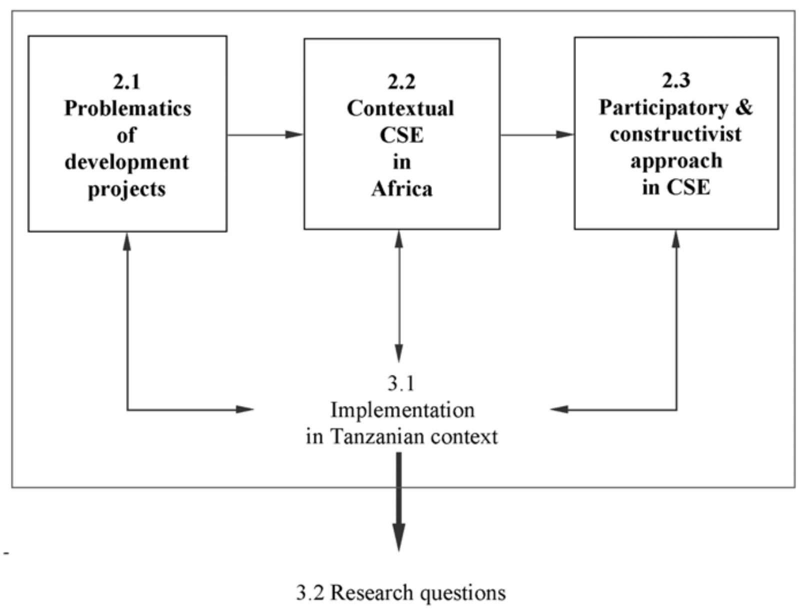


Figure 4: Structure of the literature review for this research

The literature selected for this review was chosen on the basis of relevance and the repute of the authors and researchers concerned. The selection criteria that I used were designed to assess and evaluate the impact of development projects (Section 2.1) as well as participatory approaches to constructivist pedagogy in CSE and educational technology (Section 2.3). The developing countries related CSE studies were selected on the basis of the degree of their relevance to the research topic (Section 2.2).

2.1 Developmental projects and problems of knowledge transfer

The dominant paradigms of development assistance to developing countries need to be revised. The current reliance on a philosophy of total financial sponsorship in conjunction with the narrow evaluations of the physical implementation of projects needs to be replaced by more selective, high-quality assistance. The assistance should be focused on local context in conjunction with an interrogation of current assessment criteria. The main focus of development of this kind is the provision of finance and expertise that lead to policy reforms and institutional changes that unequivocally *improve people's lives.* (World Bank, 1998)

Because this research is related to developmental issues, I will first clarify issues surrounding developmental projects in developing countries, their impact and evaluation, and will then continue by focusing on ICT projects and the problems of knowledge transfer.

2.1.1 Developmental projects and evaluation

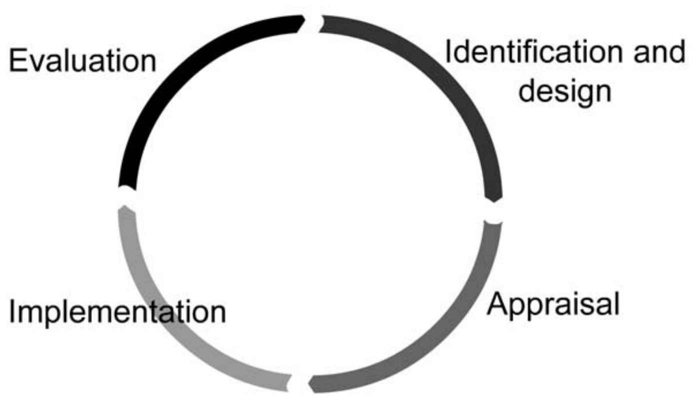


Figure 5: Development project cycle (Roche, 1999)

The project cycle in Figure 5 provides a diagrammatic overview of developmental project planning and implementation. The operation of developmental project planning and implementation can be represented in terms of a spiral. The elements of the spiral are: identification and design; appraisal; implementation; and evaluation (Roche, 1999).

Impact assessment is related to the whole cycle as an evaluation that takes place over a longer period of time (Roche, 1999). Further on a number of sources suggest that the terms *efficiency*, *effectiveness*, *impact* and *sustainability* are key terms for evaluating development projects (Koponen & Mattila-Wiro, 1996; Oakley, Pratt & Clayton, 1998; Roche, 1999). These terms can be defined in the following ways:

- *Efficiency* measures the *productivity* of a project. It gives an indication of how thoroughly and economically inputs have been transformed into outputs.
- *Effectiveness* is a measure of how successful objectives are reached in achieving *short-term outcomes*.
- *Impacts* refer to the way in which the project brings about changes in people's lives and in the circumstances in which they live. When viewed in this way, a project may be analyzed as a series of actions or initiatives. Impacts can also be defined as *long-term outcomes*.
- *Sustainability* is a measure of the extent to which the environmental, economic, financial, socio-cultural, political and material benefits that accrue from *a particular development initiative remain viable and self-sustaining* even after the development project has come to an end.

Efficiency is based on economical measurement, and is often effected by the high cost of Western staff and products. The effectiveness of a development project is usually assessed by measuring the extent to which the various objectives of a project have been fulfilled in the short-term. (Oakley, Pratt & Clayton, 1998; Koponen & Mattila-Wiro, 1996) Impact, on the other hand, may be evaluated by measuring changes in the context wrought by the implementation of the project (Roche, 1999).

According to the Brundtland Report, the World Commission on Environment and Development defines *sustainable development* as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (United Nations, 1987). It is important to remember that changes are effected through the agency of the social, economic, political, historical and environmental institutions of the recipient country, and it is essential to take account of such factors when devising sustainable and accountable development projects. A proper study and understanding of such factors would enable the designers of a project to be more precise in the effects which they hope to achieve (Roche, 1999). Foreign aid should therefore be tailored to harmonize with whatever conditions prevail in the country as a whole – as well as in the particular sectors for which it is intended (World Bank, 1998).

Oakley, Pratt and Clayton (1998) assert that the problems encountered by development projects are lack of long-term impact analysis, sustainability, gender issues, and the possible gap between short-term and long-term objectives. Practical problems that are critical for the project implementation are over-optimistic time frames, a donor-driven mode of cooperation that results in top-down planning and parallel implementation structures, a reliance on inappropriate or unsuitable imported technologies, and breakdowns and failures in communication. It is immediately obvious that some of these problems arise out of conditions in the social and cultural environment that may be beyond the control or reach of donors. Others have been caused by an inflexibility that prevents recipients from adapting to the changes they will have to make if implementation is to be successful. Yet others are occasioned by unwillingness, reluctance or inability on the part of local partners – for whatever reasons – to commit themselves to the conditions that will bring a particular project to a successful conclusion. On another level, problems common to both donors and recipients may be generated by failures or weaknesses in the design and planning phases of a project. (Koponen & Mattila-Wiro, 1996)

Critiques of developmental aid can give rise to the metaphorical "vicious circle" represented in Figure 6 and described by Roche (1999). He designed the vicious cycle of prediction to diagnose and elucidate what might go wrong within and between non-governmental organizations (NGOs).

Figure 6 shows the gap that can arise between rhetoric and reality. There is a tendency to replicate past implementations by minimizing risk factors to confirm basic results and funding. These kind of approaches avoid innovation and hinder the development in the projects. (World Bank, 1998) The process analysis is only helpful for the future if it leads one to investigate the *real* outcomes of the component processes of a project and to inquire into the factors that will affect subsequent donor decisions and the next steps of implementation (Roche, 1999), and the evaluation is based on the objectivity (Pawson & Tilley, 1997). Some of the projects also predominantly serve to benefit the financial and other interests of the sponsors themselves rather than those of the recipients (World Bank, 1998; Koponen & Mattila-Wiro, 1996).

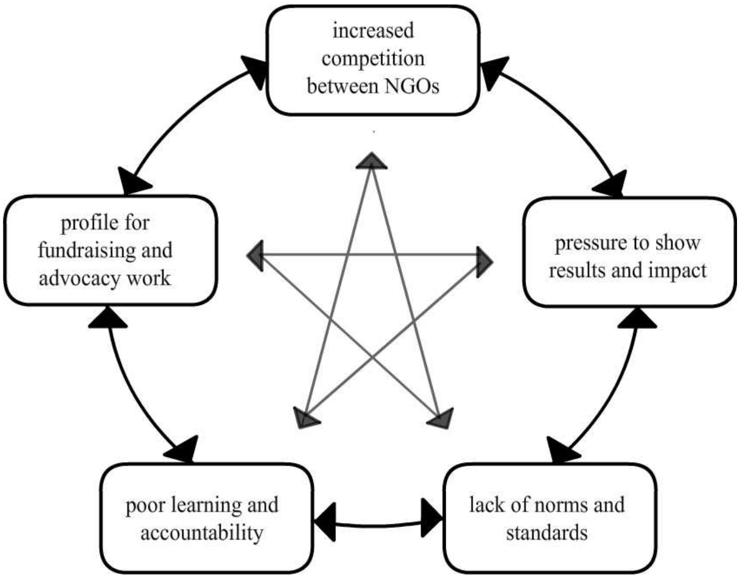


Figure 6: Vicious circle of development projects (Roche, 1999)

One of the greatest problems in project assessment seems to be concerned with the evaluation of *qualitative* change (World Bank, 1998). Because some outcomes are by their very nature unpredictable and therefore difficult to assess, project designers and implementers should be open to the possibility of making mistakes by taking risks that might maximise effectiveness and by tolerating a certain degree of uncertainty in their calculations and evaluations. (Roche, 1999) There should be an opportunity to change objectives in the middle of a project because of contextual changes that have arisen during the application of the development process (Koponen, 2006).

In the field, numerous company-driven projects have been narrowly conceived and implemented, and lack the commitment, competence and resources needed to be sustainable (World Bank, 1998). Such a lack of commitment is often caused by an unequal and disrespectful relationship between a donor organization and the recipients together with differences in administrative cultures. Mutual trust, farsightedness and goodwill including a sensitive reciprocal understanding of the culture, assumptions, attitudes, beliefs and prejudices of the other is needed from both sides. (cf. Castells, 1997/2004a; Kayizzi-Mugerwa, 2003)

> *"For a true partnership to emerge, both sides need to let go of the old conceptions and focus on strengthening institutions that can facilitate greater recipient ownership."* (Tsikata, 2003, pp. 49-50)

This also means the move of development dynamics from unidirectional beneficiary involvement to the condition of local ownership and responsibility. Donors who are open to innovations, and who openly demonstrate genuine respect for recipients, are likely to introduce long-lasting and sustainable benefits into a donor country. (Koponen & Mattila-Wiro, 1996; World Bank, 1998)

Wide cross-sectoral development is ideal. Considered risk-taking, systematic evaluation procedures and the sensitive and respectful dissemination of knowledge are all required for successful development. All these factors promote an innovative and research-based approach. (World Bank, 1998) Koponen (2006) outlines a context-specific approach in which the first requirement is to monitor overall changes in the context and relate them to the goals of the project concerned. Such an approach requires a wide range of data resources, analytical protocols, trained personnel and the capacity to sustain long-term research in order to generate multidimensional data and make it useful to the project. An approach of this kind is also discussed by Oakley, Pratt and Clayton (1998) in their analysis of how an overall summary of results should be understood. In their view, changes in a project should only be effected on the basis of a clear understanding of all relevant contextual factors (Figure 7). While a number of conditions might indicate the necessity for a change, changes can produce unpredictable and unexpected consequences in the long run. Context and possible actions should be carefully balanced with one another before any kind of intervention is prescribed (Roche, 1999). The goal is to achieve sustainable changes.

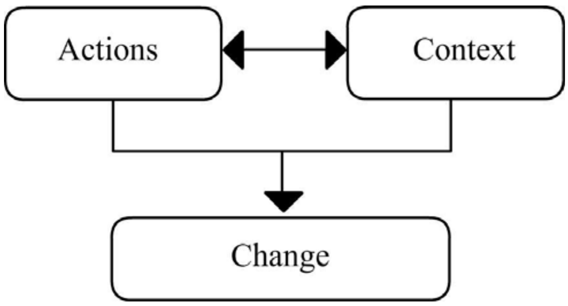


Figure 7: Actions and context combine to produce change (Roche, 1999)

2.1.2 Technology transfer and development

While development agencies have been showing an increased interest in the role that information and communication technologies (ICTs) can play in development, there is still insufficient amount of data and research to verify the impact that ICTs make on recipient countries (Agonga et al., 2003c). In a parallel development, more and more development projects are concentrating on the transfer of knowledge and expertise rather than on financing goods, infrastructure and other physical necessities. But are there any differences? (World Bank, 1998) Both physical and knowledge transfers require capital, although the respective kinds of capital they need slightly different conditions for successful transfer. While knowledge capital is not immediately visible, its successful transfer is often far more demanding and indeed expensive than straightforward physical transfer. The effectiveness and sustainability of donated infrastructure depends almost entirely upon the availability and quality of the *knowledge* transfer that was concurrently envisaged as a support system for the physical infrastructure. ICT transfer is actually related to knowledge, but it also needs the infrastructure to use and develop the knowledge, which is often very challenging (Brewer et al., 2006).

Sussman (1997) draws our attention to the common delusion that the mere presence of computers will somehow guarantee that decision-makers will make sound and intelligent decisions. This presence of technology – no matter how advanced – is in no way indicative of the intelligence, wisdom or insight of those who use it. Technology itself is a tool that simplifies operations. Its effective usage depends entirely upon the human qualities of those who use it, and it is these human qualities that need to be carefully studied and properly understood so that they can be used as a basis for the successful transfer of constructive knowledge and attitudes.

Anthropologist Swantz (1989) considered the transfer of technology and stated that the technological product is successfully transferred to the recipient country and embedded in its culture once the recipients have learned how to reproduce the technology. Nowadays her reproduction aspect implicates more and more rarely even in industrialized countries, but the idea of reproduction also presupposes being able to cope with unforeseeable and critical occurrences through the application of essential knowledge and creative problem-solving skills. While every recipient country needs technology to accelerate growth and to enhance productivity, the precondition for embedding such technology successfully in the local environment is the proper training and orientation of local experts who can operate, maintain and repair the technology without reference to donor sources (Ouma-Onyango, 1997). The need for local capacity has resulted in local and international initiatives to train the personnel and should, in the long term, benefit technological and other transfer initiatives (Agonga et al., 2003c; Braa et al., 1995; UNDP 2001; Castells, 2001/2004b; Kimaro, 2006; Kopoka, 1996; Leadbeater, 1999/2004; Matengu 2006; Rogers 2003; Soriyan, Mursu, Akinde & Korpela, 2001; Task Force on Higher Education and Society, 2000). An environment hospitable to successful technological transfer from the West can be created by African universities through the provision of top-class scientific and technological training and education. It also requires a social and political environment that is sympathetic to technological transfer and supportive of necessary conditions such as the provision of suitably qualified staff. (Ajayi, Goma & Johnson, 1996)

As we return to the definition of the key evaluation terms for development projects focusing especially on ICT education, the concepts of efficiency, effectiveness, impact and sustainability (see Figure 2, page 8; Section 2.1.1) are illustrated in Figure 8 and could be translated in the following way.

- *Efficiency* can be measured in terms of simple expenditure and performances. In this sense, efficiency is rather more quantitative than qualitative. The traditional quantitative measurement of efficiency is nearly always made by reference to standardized performance rather than contextual relevance. A relevant question could be: *How many students have passed the course? What was the total cost of the course?*

- *Effectiveness* is measured by relating objectives to outcomes. Because a great number of ICT education related objectives are still standardized and often make minor reference to contextual applicability (cf. Pulkkinen, 2007) a relevant question could be: *Are the students thoroughly familiar with the objectives of the course?*

- *Impact* is measured by assessing whether or not beneficial changes have been acquired for the local context. Impact is therefore a complex issue that draws on both quantitative and qualitative elements and measures. The measurement of impact is more dependent on an assessment of contextual relevance than on standardized performance – although it obviously needs to be measured by reference to both of these factors. A relevant question could be: *Have the students successfully applied their acquired ICT knowledge to the context?*

- *Sustainability* is measured by the extent to which the initiative has become successfully embedded in the local context and the extent to which it is able to reflect standardized global performance benchmarks. It therefore reflects the broad impact of ICT on the surrounding society, but as well global knowledge and skills. Sustainability is measured equally by optimal reference to contextual relevance and standardized performance for development. A relevant question could be: *Will the students be able to apply their innovative talents and the knowledge and skills provided by the* *course in such a way that they will be able to benefit local communities over a long period of time?* (see CATI model in Section 5.1)

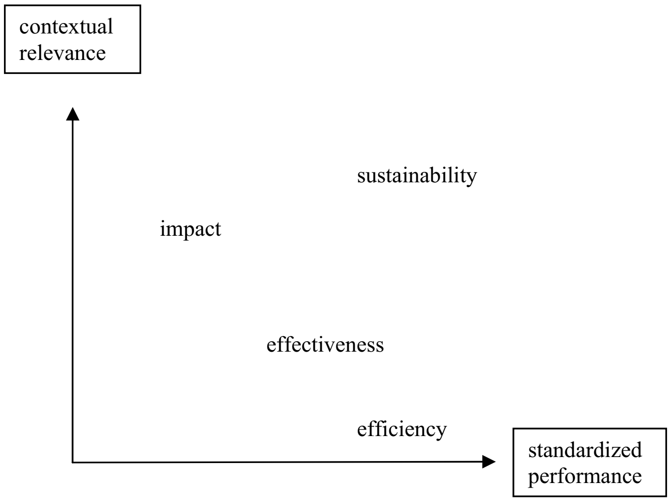


Figure 8: Efficiency, effectiveness, impact and sustainability situated in relation to the dimensions of contextual relevance and standardized performance

Since no holistic theory or model of ICT transfer exists, academic long-term research is urgently needed to provide a basis for the construction of such a model (Ouma-Onyango, 1997; cf. Koponen, 2006).

2.2 Contextual computer science education studies in Africa

In this section I will offer an overview of existing research that relates to Computer Science (CS), higher level ICT and engineering education, in the context of developing countries, especially in Africa which is relevant to the focus area of this research. Although most available research on ICT and Africa is concerned with the basic use of computers and Internet, and the support and delivery of distance education by using technology, these are not the central focus of this section.

Zaku (1989) discusses the matter of engineering education in the developing world. He asserts that the planning of a university curriculum should accommodate the cultural characteristics, aspirations and needs of the particular community that it serves. Education designed without a proper consideration of context produces graduates who are frequently unaware of problems in their own communities. Students have in fact been acculturated with Western norms and standards and would be more suited to living and working in Western societies rather than in their own local cultures. Graduates of this kind are obviously no asset to local development. Although they possess all the necessary theoretical and practical skills, they make no positive contributions to their local communities, and are frequently alienated from their own cultures. This applies to CSE as well as to engineering education. The University of Dar es Salaam, for example, used the traditional approach without contextual adaptation for its first computer degree programme in 1974, and radical changes have not taken place even later (Mgaya, 1994; University of Dar es Salaam, 2006).

An approach to the curriculum that is based on an analysis of the target context would include a great deal of flexibility and dedication to practice and applicability. This would soon close the gap between the requirements of a theoretical university education and the needs of local communities. (Zaku, 1989) Thus approached, high-level technological education can become a primary asset in the economic development of a developing country (Beute, 1992; Zaku, 1989). Amadei (2003) reminds us of how important *sustainability* is in educational technology for the needs of developing countries. All CSE should be sensitive to the social, environmental, economic, cultural and ethical needs of the country in which it is embedded because such considerations are even more critical to a country's welfare than the merely technical infrastructure or knowledge necessary for the accomplishment of projects. Duveskog, Sutinen, Tedre and Vesisenaho (2003) call for creating points of contact between teaching programming and the social context in Tanzania in their research related to integrating HIV and CS education. All these studies focus on the locally based needs or implementations, as well as this research. The way is to overcome the gap between practice and theory.

Negroponte (2003) suggests that ICT learning should ideally be project-oriented, in spite of the risks and difficulties that such an orientation would evoke in some developing countries. He is of the opinion that successful technological learning should be based on self-selected and independent modalities that include learning by means of play. This, he believes, would produce a more creative society, as well as beneficial effects that would continue to be felt for several generations. Although such an approach would be challenging, it might also produce extremely successful results in the developing world. Negroponte’s thoughts might be a bit unrealistic, but also give direction to constructivist approaches such as situated learning (see Section 2.3.4).

Blake and Tucker (2006) have the opinion that computer science teaching should become much more socially aware and sensitive to social and communal contexts.

Such an approach would apply a community-based approach to computer science education because CSE would become embedded in interdisciplinary and needs-based teaching and learning approaches. In order to make such an approach successful, it would have to be based on firm commitments and partnerships and on community participation and be framed in terms of a cyclical action-research methodology. The context sensitive approach has also its risks as it can lead to an over-contextualized approach, but on the other hand can also fulfill both contextual and global needs (see Chapter 1, Section 2.1).

In order to present a comprehensive picture of what has been gained from research into computer science education (CSE) in Africa, and especially of the extent to which such research may be relevant to contextual considerations, I will continue by presenting a categorized summary of six international CSE and ICT conferences that are relevant to this research. This survey will show the extent to which Africa related contextualized CSE, higher level ICT, and engineering education issues have been studied and reported upon as recently as 2005-2006 (Table 1).

The relevant conferences included the two major CSE conferences Frontiers in Education 2006 (FIE, 2006) and the Technical Symposium on Computer Science Education 2006 (SIGCSE, 2006). Four other conferences which focused on developing countries and ICT included Information Society Technologies in Africa Conference (IST-Africa, 2006), Technology for Education in Developing Countries Workshop 2006 (TEDC, 2006), International Federation for Information Processing, Working Group for Social Implications of Computers in Developing Countries Conference 2005 (IFIP WG 9.4, 2005), and eLearning Africa Conference 2006 (eLearning Africa, 2006). I classified the papers presented in all these conferences according to the focus areas of the researcher, firstly by selecting papers that related to Africa; secondly, by selecting papers that also related to CSE, and thirdly by selecting papers that reflected a contextual approach or considered issues of the contextualization of CSE in Africa (Table 1).

Table 1: Contextual CSE studies relating to Africa in major CSE or Africa related ICT conferences in 2005 or 2006

	Total number of papers	**Africa**	**Africa *and* CSE**	**Africa *and* contextual CSE**
FIE, 2006	427	2	2	2
SIGCSE, 2006	104	-	-	-
E-LEARNING AFRICA, 2006	139	120	-	-
IFIP WG 9.4, 2005	51	39	1	1
IST-AFRICA, 2006	136	77	2	2
TEDC, 2006	26	15	2	2

The proceedings of the Frontiers in Education (FIE, 2006*)* conference, organized by the Institute of Electrical and Electronics Engineers (IEEE), contained two articles relating to Africa. These were "Applying information technology to improve teaching and learning in an African university" (Obuobi, Richards Adrion & Watts, 2006) and "Designing a contextualized programming course in a Tanzanian University" (PAPER V).

The research of Obuobi et al. (2006) was concerned with the development of learning material and delivery in campus and in distance education at the University of Cape Coast in Ghana. One of the aims of the researchers was to devise ways of reducing the workload of teachers who are obliged to teach large classes. Another of their aims was to investigate cost effective ways to develop infrastructure that would support teaching, learning and research. In order to realize these goals, they investigated course management systems, multimedia learning materials, and offered a summer school on the theme of distributed and embedded systems and networks. Most of these initiatives were dependent on efficient delivery, which implied the need for sustainable technology. The main purpose of the summer school initiative was to support students who would be the future developers and manufacturers of distributed and embedded systems for tasks in health care and telecommunication contexts in local society.

SIGCSE (2006), the Special Interest Group on Computer Science Education Conference, organized by the Association for Computing Machinery (ACM), offered one article on contextual development issues: "Computing in context: Integrating an embedded computing project into a course on ethical and societal issues" (Martin & Kuhn, 2006). The main purpose of this research was to construct interactive prototype production to address social, ecological and ethical issues in the United States but not in Africa, and thus was not relevant to this research field.

The theme of the eLearning Africa (2006) conference was "ICT for development, education and training". While several relevant issues were discussed, none of them were related to CSE. The topics dealt with at the conference were concerned with policy, distance, and university education development in general.

The Working Group for Social Implications of Computers in Developing Countries Conference 2005 (IFIP WG 9.4. 2005) was titled "Enhancing Human Resource Development through ICT". This conference focused on information system (IS) development, on ICT in education in general, and on other topics relating to e-government and theoretical approaches. One paper, "Nigerian university software development training: From building walls to building bridges" was related to university CSE (Soriyan et al., 2005). The paper described an approach in which the needs of the software companies and the education offered by universities would be mutually supportive. The context related approach of the study is based on practical assignments and periods spent in companies during certain courses.

The IST-Africa (2006) conference scheduled two papers relating to contextual issues of CSE in Africa. These were "Implementing Information and Communication Technology in Higher Education in Tanzania" (Vesisenaho, Islas Sedano, Tedre & Sutinen, 2006a) and "Socially aware software engineering for the developing world" (Blake & Tucker, 2006). The first of these articles relates to our research project and the development of ICT education in Tanzania. The second paper analyzes the relevance of the traditional CSE approach in South Africa. Both of the papers focused on the need for the kind of CS education and curriculum development that is deeply participatory and based on contextualized local needs and applications interested in this research. Blake and Tucker (2006) were mainly concerned with software engineering while Vesisenaho et al. (2006a) focused on implications of how ICT issues might affect community development and welfare.

Articles dealing with the present research project were presented by Vesisenaho, Lund & Sutinen (2006b) and Nielsen & Lund (2006) in the Technology for Education in Developing Countries Workshop (TEDC, 2006). The first paper dealt with contextual learning outcome analysis related to this research. The second is also partly linked to this research, but focusing more on the development of technological tools for ICT education in developing world. Nielsen & Lund (2006) see several opportunities on the prototyping based approach with artificial tools and robots to support first steps of learning and also in wider scale development.

It is evident from this analysis that there is a serious lack of research into contextualized CSE, engineering and higher level ICT education in Africa.

2.3 Participatory approach to computer science education

2.3.1 Constructivism in computer science education

John Dewey (1938/1997) was the most notable of all educational philosophers to propose progressive pedagogy in the early 1920s. Dewey was of the opinion that the learning experiences from real-life situations are related to good learning. A learner should be able to expand his or her experience of the real world through personal engagement. These *authentic learning tasks* of the kind that Dewey recommends makes a learner better prepared to cope with problems in the real world because the learning experience itself replicates conditions in the world outside the educational institutions.

Constructivism in education is a descendent of Dewey's progressive pedagogy. According to Duffy and Jonassen (1991), constructivist pedagogy avoids a direct emphasis on theory, book learning and the examination of remembered information. It seeks instead to develop and strengthen a learner's ability to devise and construct plans in response to situational demands, problems and opportunities. In terms of such an arrangement, students are invited to construct their knowledge from direct experience of authentic learning problems and to relate them to their personal circumstances. Constructivism allows teaching and learning to rise above the demonstrate-and-replicate paradigm of conventional learning, and to become an active, context-situated collaborative process in which evaluation is directly integrated into the teaching and learning process. It is the responsibility of the instructor to construct and devise learning contexts and forms of assistance that will enable a learner to discover by means of personal experimentation what he or she needs to know. Constructivism offers us an ideal methodology for teaching also by technology. (Merrell, 1991)

Hadjerrouit (2005) expresses that even though constructivism in CSE is still in its infancy and effective instructional strategies have only recently begun to emerge, there are some researchers like himself who advocate constructivism as the most suitable educational methodology for teaching CSE. He advocates the construction of personal knowledge in CSE through encouraging cognitive skills, providing authentic tasks, relating tasks to one another, fostering collaboration among learners, and through creating conditions in which students can apply creativity and ingenuity to obtain the knowledge and expertise that they need in the CS field.

Ben-Ari (1998) claims that the application of constructivism to CSE must take into account two characteristics that do not appear in natural sciences. Firstly he points out that a novice student possesses no effective mental model of a computer or for instance programming as an accessible ontological reality. A student might therefore lack the basic mental models needed for handling CS concepts. Under such circumstances, the construction of CS concepts might become haphazard and unrelated to a student's existing knowledge, and that would mean the student would have to learn everything right from the beginning. Secondly an auto-didactic approach of programming education and CSE in general restricts the student, and feedback from the computer itself or from a teacher might discourage students, who are used to a reflective or social style of learning. This would also result in the student's own mental models being unacceptable because courses do not make allowance for intuition and the use of alternative frameworks of the syntax and semantics in a programming language. (Ben-Ari, 1998) There could be a huge cognitive gap between the programming language designer or teacher and the learner (Lui, Kwan, Poon & Cheung, 2004).

A professional programmer needs to be in possession of a great deal of detailed information and to follow normative planning procedures, and such assets are only accomplished through well instructed learning and practical training (Ben-Ari, 1998; Eckerdal et al., 2006). On the other hand, the ability to abstract and to relate different levels of abstraction is a key skill for computer scientists. Such skills require a deep understanding of the structures and concepts that scaffold them and understanding of this kind is fundamental to a constructivist approach (Eckerdal et al., 2006; Meyer & Land, 2003).

Kutay and Lister (2006) suggest that a key to constructivist learning in this sphere might be social interaction and the sharing of views. In the same way, group assignments, group-sponsored working platforms and group reflection sessions could promote a more constructivist approach to CSE (Ben-Ari, 1998). Since many students find it difficult to learn computer science, especially at elementary levels (e.g. Bonar & Soloway, 1983), teachers are needed to support, guide and motivate the construction process (Ben-Ari, 1998; Jenkins, 2001).

There are researchers who seem to advocate a narrow view of constructivism in CSE that is not fulfilling the basic characteristics of constructivism. For instance, Lui et al. (2004) implement constructivism as trying to explain an objective reality to which mental models need to be adjusted. Their approach is to support weak learners in programming with several examples but also to maintain a controlled step-by-step instructed learning.

Beynon and Roe (2004) have a relevant question: how compatible is traditional computer programming with constructivist learning techniques at all? Since for instance a computer programming task is often very specifically defined, it does not allow much space for personal construction on the part of the student. Supporting technologies in addition to social approach might be needed.

2.3.2 Constructionism, concretizing and visualization in learning programming

Papert (1993) sees *constructionism* as a deeper way of learning than constructivism. The word constructionism may be understood by reference to construction with tools supporting learning, such as Lego bricks. Programming languages are like metaphors of different parts or actions joined together. A concrete *construction* process could support a learner's own understanding of the phenomenon. While such an approach may provide students with useful learning opportunities, the approach itself requires a great deal of flexibility on the part of the educational system. Computers with other technological artifacts can support well that type of learning. Papert (2000) asserts that there are two important points to bear in mind when using constructionist programming processes in learning: firstly, it offers students the possibility of gaining valuable experience and developing intellectually, and, secondly, there is the actual process of learning programming that needs to be mastered (cf. Bilotta & Pantano, 2002; Resnick et al., 1998). In programming, students need clear mental models of what they are dealing with and how their programs work (Milne & Rowe, 2002), and they need to see how discrete structures relate to one another. If they are able to construct their models three-dimensionally, it could help them to understand complex phenomena (Naps, et al., 2002). Socially organized distributed constructionist activities organized in this way often support learning processes well (Resnick, 1996).

Papert's (1980; 1993) constructionism in LegoLogo and other programmable environments were joining programming and *concretizing* it with physical artifacts (cf. Resnick, 1993). Later the technically more advanced Lego Mindstorms set, for example, its NQC (Not Quite C) programming language and several visual programming environments with the RCX programmable central units, also supports the concretized learning processes (Ferrari et al., 2002).

Although the concretizing systems have even been under discussion as possibly replacing the traditional programming education, Fagin (2003) argues that they might be better suited for supporting the learning of basic computing and robotics principles by novice students using exploratory approaches. One problem that hinders wider usage is that all of these environments are limited and content specific (Fagin & Merkle, 2002). Barnes (2002) states that they are useful as physical adjuncts in teaching introductory programming, when using for instance Java to learn programming. A student also needs to demonstrate advanced skills in those construction related programming processes and solve real world oriented problems. Concretizing and robotics are recommended as one part of a Java programming course, but they cannot fulfill the whole content of the advanced courses so far.

Lund (2003) presents a *programming by building* approach to the learning of programming. In the examples that he provides, he uses Intelligent Building Blocks (I-Blocks) to promote exploratory learning. What distinguishes Lund's approach from most of the other approaches is distributed processing: Each block has an in-built processor, and it can process, perform actions, and deliver input and output. While these blocks may initially be used separately from the central computer, they can later be connected to the programming interface (Nielsen & Lund, 2006; see Section 4.2.2).

When we continue with a less concretized approach to learning CSE and especially programming, we reach visualizations. There are several studies that have investigated *visualization* in the teaching of programming. While reports of benefits vary, the studies themselves are very different in their aims and their purposes (Gross & Powers, 2005; Hundhausen, Douglas & Stasko, 2002). Major types are related to the visual presentation of, for example, the control structures of the programming (Hendrix, Cross Il & Maghsoodloo, 2002) and complicated functionality-oriented integrated development environments (Hundhausen et al., 2002). All of these tools are related to the human-centric approach of CSE (Kline

& Seffah, 2005). According to Ben-Ari (1998), the connection between the learner's mental model and the visualization has to be obvious when one uses visualization for teaching programming. The student should be able to construct a viable model with which he or she can predict the following steps of the process. In practice this means that supportive elements should focus on the construction of the model rather than on step-by-step instruction.

The Java Interactive Visualization Environment offers several ways of presenting the program and its forward and back execution. It provides a detailed view with tables, compact views of the diagrams, sequence diagrams and call-paths. Gestwicki and Jayaraman's (2005) research shows that these elements are useful for debugging, especially when there is a difference between the user's imagined structure and the actual structure that is needed.

There is evidence that Jeliot program visualization and animation environment facilitates the learning of the basic concepts of algorithms and programming in an introductory programming course when considering for instance I/O operations, and if, while and for commands. Method calls, variables, and operations are displayed on a screen allowing the student to follow the execution of a program. The environment allows the student to write, create, test and modify the programs with the visual feedback of the process. Jeliot provides a model that assists the understanding of especially novice students. (Levy, Ben-Ari & Uronen, 2003; see Section 4.2.2) Sajaniemi and Kuittinen (2005) report that animation supports a student's comprehension of introductory programming because it presents the new conceptual frameworks in an interactive way and because it scaffolds the mental processes that are necessary for the competent performance of good programming skills.

As McDougall and Boyle (2004) have shown, a significant number of the skills and techniques for programming can be acquired outside a classroom environment. Their research focused especially on experiments undertaken in the MicroWorld multimedia programming environment. One promising way is to carry out the actual projects imitating the field experiences and needs using visualizations and concretizing. I-Blocks and Jeliot are good examples of these and are used in this research.

2.3.3 Human-centered approach to ICT design in developing world

Norman (2002) states that as we consider how we intend to support the needs of the user, we also need to consider the question of human-computer interaction. The question is how suitable the product and its design is for teaching and learning

CS. The key issue is the needs of those who will be the users of the equipment or product. In order to design innovative technology effectively, the designer needs to enter into a process of dialogue with representative future users in context. It is only when a working version of the equipment has been made that final decisions about usability will be taken in an authentic working environment. At that point, the device should be able to stand alone and guide the user independent of the designer. The device itself should offer its user a conceptual model that is clear and comprehensible. Effective usability usually includes actions that are contextual and visible, but also those that are global and invisible. If it is to remain as error-free as possible, the device might even require built-in constraints that lead the user in predetermined directions.

When Donaldson (2006) analyzed engineering design processes in Kenya, he found out that the analysis of local needs and adaptability was generally weak and that the designed and manufactured artifacts tended overwhelmingly to imitate foreign-designed products. She found that original and creative design was almost totally absent from the products and that there had been virtually no connects between the designers and the ultimate users of the products. She felt this could be attributable to the influence of the theory-oriented Western curricula and pedagogy that neither encouraged local initiatives nor accommodated itself to local needs. These factors indicate the need for a model that would allow the development of contextually relevant teaching. If one needs to learn to understand local users, their culture and their environment, one clearly needs a learning process that includes those kinds of elements. Donaldson has found the same deficiencies and defects in the African Virtual University.

In *human-centered design* (also called *user-centered design*), the key principle of software design is to incorporate the active involvement of representative users. Such a process includes activities that lead to an understanding and definition of the context of use, the typical user and of organizational requirements. Such measures produce design solutions that are evaluated by the designers against the requirements that have already been determined. The outcome of such a process is likely to be a product that will satisfy typical customers. (ISO Standard 13407, 1999)

The design process is not only a product of dialogue between customers and product developers. It includes a consideration of all materials collected during the design process. Fallman (2003) points out that one should make a distinction between *the design-oriented research process* and *the research-oriented design process*. The first process contributes to the development of sound knowledge about the wider context, and the second process determines the final product.

Contextual design and *participatory design* are the main methods employed in human-centered design (Preece, Rogers & Sharp, 2002). Contextual design requires procedures for handling the collection and interpretation of data from field work to instruction of software development for understanding users' needs. If one brings an ethnographic perspective to the design process, the resultant design should create products that harmonize with the customers' expectations, attitudes and cultural assumptions. (Beyer & Holtzblatt, 1998) The input and feedback of representative users are indispensable for the participatory design process. Participatory design also goes further in participation than contextual design; representative users should be invited to join the development team – even though they possess no professional skills or knowledge. (Ehn, 1993; Greenbaum, 1993)

Puri, Byrne, Nhampoldo and Quraishi (2004) note that only a few participatory design cases are available from developing countries. A thoroughly meaningful participatory design process is also distributed among and modified by a number of diverse socio-economic, cultural, and political contexts and actors. In a study of Swedish and Tanzanian participatory design cases, Elovaara, Igira and Mörtberg (2006) have observed differences in hierarchical boundaries between professionals, IT infrastructures, and the technological skills of participants as well as differences in accepting the monitoring of working environments. Understanding and applying information gathered from an investigation of needs is crucial for successful design. Successful design also needs the cultural and even tacit knowledge and information. One of the most important conclusions of their research is that meaningful participation needs to be carefully negotiated with local players and that all due regard must be given to the local settings and prevailing circumstances.

Blake (2006) and Marsden (2006) have the view that traditional human-centered design procedures will never be completely successful in the developing world. They both feel that the context of the professional designer is too far removed from the understanding and environment of locals. They see that the design process will not be at all straightforward in such circumstances because of various kinds of misinterpretations and unexpected and unforeseen needs and barriers on both sides. In his discussion of the application of socially aware software engineering methods, Blake suggests that designers identify competent local interpreters and education-oriented members in the target society and that they involve such people in a cyclical structure of action research in a sensitive and respectful manner. He feels that such applications could lead to the development of software that would harmonize with the needs and expectations of local IT communities in developing countries.

It is particularly important to maximize participation in design in a developing country so that the design process will not be dominated by typical Western procedures, prejudices, attitudes and cultural expectations (cf. Blake, 2006; Elovaara, Igira & Mörtberg, 2006; Thioune, 2003). My research has been firmly based on the need for *human-centered approaches* in technology design and learning processes, in course design, in the design of web-based learning materials, and in the development of physical artifacts for learning for the Contextualized Programming course 2004-2005 at Tumaini University. But at the same time, the students of the course will also be designers in the future.

2.3.4 Situated learning as pedagogical framework

Cronjé and Brittz (n.d.) emphasize the current need for authentic approach, based on real-world activities, in ICT curricula in the developing world. Such an approach would combine instructivist and constructivist elements to support learning and to produce optimal learning. They recommend the application of *design*, *illustrate*, *evaluate* and *interpret* as keywords in educational initiatives of the kind. Assignments and projects, as well as the content of the course, should be undertaken in a real-world context or as near as possible to a real-world context issues for instance with computers. This kind of educational approach, if conscientiously applied, should result in an expansion of learner creativity and the meeting of authentic real-world needs. (cf. also Cronjé, 2006)

Situated learning is a pedagogical approach in which learning is most effective if it is embedded in the social and physical contexts within which it will be used. Such education is predicated on being relevant to ordinary, everyday activities and the prevailing cultural conditions of the users for whom it is intended. (Brown et al., 1989)

Situated learning relates learning to real-life conditions and situations rather than to artificial classroom assumptions. It therefore requires instructional learning materials to be socially and culturally situated and all models to be authentic. This kind of learning is assumed under the general heading of constructivist educational philosophy. Knowledge learnt in schools and universities may often be disastrously unrelated to real-life conditions or problem-solving contexts and missing the applicability link. (Herrington, 1997) Situated learning is also predicated on a problem-based approach to learning through the agency of authentic, real-life tasks and is especially beneficial to stimulating critical and creative thinking skills in students (Savery & Duffy, 1995). Such an approach also emphasizes the desirability of personally constructed knowledge, the importance of exploration and experiments, the necessity for personal invention and evaluation, and an ability to describe what one knows and to explain why it is important to a wider context (cf. Jonassen, 1991).

Herrington (1997) summarizes the most important characteristics of situated learning as the kind of learning that attributes central importance to (see Section 4.2.2 for implementation in this research):

- an authentic context that reflects the way in which the knowledge obtained will be used in real life;
- authentic activities;
- access to expert performances, best practices and the modeling of processes;
- multiple roles and perspectives;
- the collaborative construction of knowledge;
- coaching and scaffolding;
- reflection;
- articulation; and
- authentic assessment.

It is also important to ask how many of the necessary learning activities can actually be well performed in a conventional, formal classroom setting. A partial solution to this difficulty would be to employ a computer-based approach to education, but there is still need for further research in this field. (Herrington, 1997)

When relating to Tanzania, Cooksey and Sibylle (1997, p. 122) write: *"Poor quality and the practical irrelevance of most formal education at all levels, seriously undermines Tanzanian's development efforts."* Apart from the low enrollment figures in higher education in Tanzania, the country is faced with the much more serious problem that education is not meeting the needs of the Tanzanian society (Mmari, 2001). And even though changes in educational sector take time to become effective, there are several valuable and forward-looking current developments in education taking place in Tanzania (Ministry of Education and Culture, 2004; see Section 3.1).

Because of the proven value of constructivism, constructionism and human-centered design to teachers and learners alike, I decided to adopt a situated learning approach to this ICT-related development research at university level in

Tanzania. An important goal was to increase the applicability of the ICT knowledge in the context.

3 Context and research questions

This chapter examines the Tanzanian context of the research from the point of view of ICT education development (Section 3.1). It utilizes the insights gained from the literature review (Chapter 2) concluding with a statement of the research questions in Section 3.2 (Figure 9).

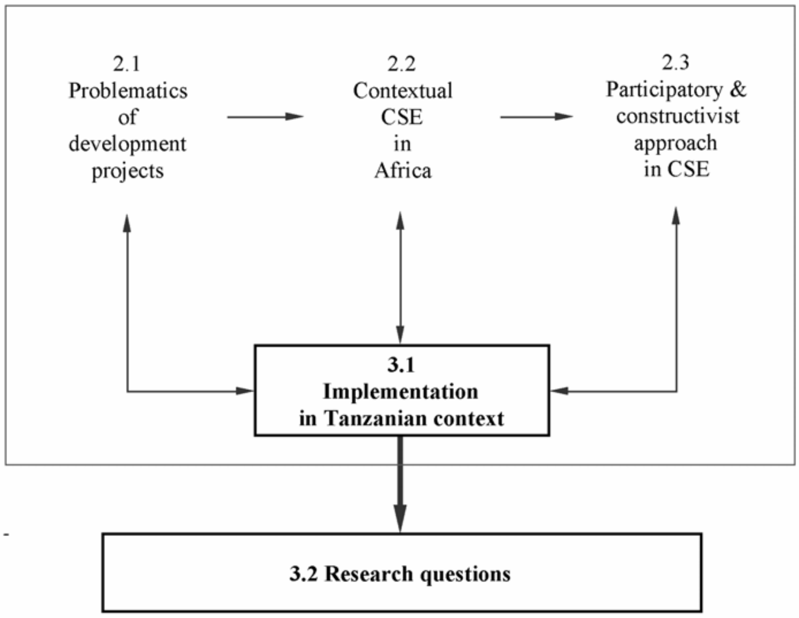


Figure 9: Literature and context as a basis for the research questions

3.1 Context of this research

East African culture and its context

In order to make this research sensitive and applicable to the context in which it was done, it is necessary to undertake an overview of some of the cultural and philosophical traditions of East Africa. Although, by the very nature of the case, any survey such as this will be selective, it is necessary for a Western researcher operating in an essentially alien culture to reconstruct some of the cultural and philosophical assumptions that we encountered in that part of East Africa in which we undertook the research. Teferra (2002) reminds us that because knowledge is culture specific, the culture concerned exerts a determining effect on whatever learning takes place in that culture (cf. also Pagram & Pagram, 2006).

Louw (2004), for example, makes reference to differences between the way in which Western-oriented people and traditional Africans analyze events. According to Louw, an African's analysis of reality refers more to the *moment and past* while a Western-oriented person's analysis of reality will refer more to the future. Sometimes combining these two might be a challenge.

In traditional African culture, people are more *community-oriented* than in Western cultures. Beller (2001) refers to them as living in what he calls a we-community. This means that a traditional African will place the interests of the tribe or community above his or her own personal or individual interests. This can be a benefit for collaborative learning activities such as learning ICT to support the whole community.

Philosopher Gyekye (1997) is of the opinion that African culture has used to be more *practice-oriented* and less science-oriented than the Western counterparts. If this is true, it might also affect the way in which African students approach learning ICT because modern technology is Western science-based. There might also be cultural attitudes towards development such as automation that have discouraged people from using modern technology. Eglash (1999) has observed that there are ideas in the field of mathematics that Africans find difficult to process, but that there are also concepts that are more familiar for Africans and used in Africa, but are difficult for people brought up in Western cultures to understand and process.

It would be ideal if technologies were adapted to the cultures in which they were used. But most of the technologies that Africans use were not developed in an African culture. Potential African contributions to technology have therefore not yet been realized. (Amato, 1997; Gyekye, 1997) The question therefore is: how can Western technologies be adapted so that they harmonize with local African cultural and epistemological assumptions and are suited to meeting distinctively African problems and conditions? (Harding, 1997) By answering this the technology could serve the community.

Tanzania

Tanzania is an independent East African united republic formed in 1964 that consists of previously known Tanganyika and Zanzibar. Tanzania has a population of 38 million inhabitants and has a total land area of 945,000 square kilometers. It is also a member of the East African Union. (cf. Oliver & Fage, 1988; World Bank, 2006a)

Tanganyika was in German colonial possession from the late 1880s until 1919 and in British colonial possession from 1919 until 1961 when it was granted full independence. Between the 1960s and the 1980s, Tanzania followed the system of African socialism (*ujamaa*). Julius Kambarage Nyerere was the first President of Tanzania from independence in 1964 until his retirement in 1985. The change from Nyerere's *ujamaa* to a market economy started in the late 1980s. (Oliver & Fage, 1988) Hamdok (2003) describes the change from socialism as being gradual in the 1990s, which means that changes did not start very fast, but they have been peaceful, and all parties are becoming more and more responsive to the needs of the citizens of the country.

Table 2: Overall economical statistics of Tanzania (World Bank, 2006a)

	Population	**GDP**	**GDP growth per capita**	**Agriculture % on GDP**	**Services % on GDP**	**Industry % on GDP**
Year 1995	28.6 million*	5.3 USD billions	5.4 % **	47.1 %	38.4 %	14.5 %
Year 2005	38.3 million	12.1 USD billions	7.0 %	44.5 %	37.6 %	17.8 %

Note: * reference: Population Trends (1995); ** average 1995-2005

From the economy point of view the Tanzanian gross domestic product (GDP) is 12.1 billion USD and was expanding at a rate of 7 percent per year in 2005 (World Bank, 2006a). This places Tanzania in the 92nd place out of 183 ranked countries in the amount of GDP (World Bank, 2006b). Agriculture is the main source of income for the country accounting for 44.5 percent of the GDP, and industry, a growing sector, is accounting for 17.8 percent of the GDP (World Bank, 2006a). (Table 2)

Tanzania has maintained a high enrollment rate in the seven-year Swahili-based primary education program. The country is now recovering from a dip in primary school enrollment figures in the 1980-1990s, and the total number of learners enrolled for first grade is larger than the age group that it is intended to accommodate. In spite of the satisfactory accommodation of pupils in the lower grades of the primary level, there is still a lack of capacity for those wishing to enroll in secondary and tertiary education. The enrollment rate for the four-year O-level course and the two-year A-level course in English-based secondary education was 5.9 percent in 2000. The enrollment for tertiary education was 1.2 percent in 2004. (World Bank, 2005; Table 3)

The problems reported that impede learning and practical application of it at all levels and that therefore compromise the quality of education at all levels are the following: insufficient and inadequate learning facilities, overpopulated classrooms and low teacher-student ratio, traditional teaching methods, problems with skills of English language, over emphases of theory and missing applicability link, an insufficient number of computers in all educational institutions, and the emigration of staff to other positions. (cf. Mboma, 2001; Mgaya, 1994; Mkude, Cooksey & Levey, 2003; Mmari, 2001; Rutashobya & Olomi, 2001; Saint, 2000)

Table 3: Educational statistics of Tanzania (World Bank, 2005)

	Literacy in age group 15+	**Gross primary enrollment of age group**	**Intake rate grade 1 of the age group population**	**Secondary enrollment of age group**	**Tertiary enrollment of age group**
Year 1990	62.9 %	67.2 %	77.6 %	4.7 %	0.3 %
Year 2004	69.4 %	100.9 %	115.8 %	5.9 % *	1.2 %

Note: * from year 2000, later data not available

In 1995, the first systematic education and training policy for Tanzania was devised by the Ministry of Education and Culture (1995). This was followed by an Education Development Programme (cf. Ministry of Education and Culture, 2004) that laid the foundations for the Primary Education Development Plan of 2001 (Ministry of Education and Culture, 2001) and the Secondary Education Development Plan of 2004 (Ministry of Education and Culture, 2004). According to Mkude et al. (2003), the National Higher Education Policy was published in 1999. The focus in all these plans was on facilitating access to education and improving the existing quality of education at all levels.

ICT education in Tanzania has developed in parallel in the different levels of education (Mendes, Tuijnman, & Young, 2003). By 2004, four separate institutions were offering university-level computer science, IT or ICT education. The institutions in question were the Institute of Accountancy in Arusha (Advanced Diploma in CS), the Institute of Finance and Management in Dar Es Salaam (Advanced Diploma in IT), Mzumbe University in Morogoro (a bachelor's degree in ICT Management), and the University of Dar Es Salaam (a bachelor's degree and a master's degree in CS). The total enrollment of CS/IT students in all of these institutions was less than 900 in 2005.[3] (cf. PAPER III) The largest of the educational institutions mentioned above is the state-owned University of Dar Es Salaam, which began to offer a master of science degree in CS in 1974 – the first-ever IT or CS degree program to be offered in Tanzania (Mgaya, 1994).

Although ICT resources are insufficient in Tanzania (Ministry of Communications and Transport, 2003), various national initiatives are already underway to remedy this shortage. The documents that describe these initiatives are National ICT Policy (Ministry of Communications and Transport, 2003) and Development Vision 2025 (Planning Commission, 1999). The Development Vision document outlines five key goals for Tanzania, one of which is the creation of a well-educated society with high-quality continuing learning opportunities for everyone in the country. The availability of information and communication technologies are specifically mentioned as a key condition for the realization of the vision and as one of the main catalysts for economic growth in the country. According to Mkude et al. (2003) the National Higher Education Policy outlines that there is a need to encourage researchers to contribute to the progress and well-being of society in order to meet the needs of future generations. Mkude et al. (2003, p. 62) concludes:

[3] Personal communication with the Higher Education Accreditation Council, Dar es Salaam, Tanzania on May, 24, 2005.

"*Training and research objectives shall target the development and promotion of a strong indigenous base of science and technology to enable Tanzanians to solve their development problems.*"

The Tanzanian Educational Authority recently launched various initiatives for the development of ICT in the educational sector. The main proposal for the secondary level education is the Tanzanian Educational Network to contribute to the development of education (Tanzanian Educational Authority, 2006). Some components of ICT training have also been added to be available in teacher education (cf. SchoolNet Africa, 2004).

The necessary infrastructure for the support of ICT in Tanzania is currently under development. The number of Internet users in proportion to the general population was seven per 1000 in 2004, and the ratio of personal computers to the general population was six per 1000. There were no reported broadband subscribers per 1000 persons in Tanzania in 2004, which might be a bit misleading fact at the moment, but shows the general state of broadband connections' availability. (World Bank, 2004) The East Africa Submarine System Project (2006) was designed to meet this urgent need for suppling a reasonable amount of bandwidth in the future. It looks promising, although the project has met financial difficulties and it looks as though target dates will not be met. (Table 4)

Table 4: ICT infrastructure statistics in Tanzania (World Bank, 2004)

	Computers/ 1000 persons	**Internet users/ 1000 persons**	**Broadband subscribers/ 1000 persons**	**International Internet bandwidth (bits/person)**	**Population covered by mobile telephones**
Year 2000	3	1	0	0	- *
Year 2004	6	7	0	0	25%

Note: * no data available

Various overseas international initiatives are supporting basic and higher educational opportunities in Tanzania. The World Declaration on Education for All (UNESCO, 1990), the Millennium Development Goals (United Nations, 2000), and the World Summit on Information Society (WSIS, 2003a) have influenced Tanzania as well as many other developing countries to increase the extent of educational developments. (cf. Sumra, 2001)

Iringa municipality and Tumaini University

Iringa was established as a municipal area and as a regional capital in 1893 by the proclamation of the German emperors. The town of Iringa is located in the southern highlands of Tanzania. (Nyagava, 1999) A population of 350,000 is living within its municipal boundaries. It is also a regional capital whereas the region's population is 1.5 million, and most inhabitants are living in rural areas. (United Republic of Tanzania, 2002) Agriculture is the main source of income and livelihood in the municipality so far, while there are more and more small-scale industries, although still few in number. The average annual income is only 108 000 TSh per capita, equivalent to approximately 100 USD in 2003. The Iringa municipality council hopes to increase this figure to 450 000 TSh by 2010. In addition to peaceful living, the current goals of the Iringa municipality are to promote local economic growth, maintain environmental sustainability, expand the communication network and improve higher education infrastructure. In 2003, the Iringa municipality area was home to several primary and secondary schools, a vocational education centre and the private-owned Tumaini University. (Iringa Municipal Council, 2003) The number of higher level educational institutions is growing.

Tumaini University, Iringa University College, was established in 1994. The university, which has been granted full national accreditation, comprises four faculties: Arts and Social Sciences (which include Departments of Journalism, Cultural Anthropology and Tourism, and Education), Business Administration, Law, and Theology. (Tumaini University, 2005) A total of 200 students were enrolled in the university in 1999, but these numbers have increased rapidly to 2000 in 2006-2007. In 2004, a total of 40 percent of graduates were female – a relatively high proportion in Tanzania (Bahendwa, 2004).

The mission of Tumaini University includes a commitment to provide staff, facilities, and support of the kind that one would find in a first-class university, to promote research, to provide an environment of acquisition of knowledge, and to support service to the community, region, and nation through the agency of churches, the government, industry, and public and private organizations. This mission reflects a contemporary understanding of the three main tasks of a university: teaching, research, and commitment to the community. The university is owned by Evangelic Lutheran Church of Tanzania (ELCT). (Tumaini University, 2006)

Since the mid-1990s, Tumaini University has been offering IT application courses that train students especially to use office software (Tumaini University, 2004;

Vesisenaho et al., 2006b). The IPSP project of the university had an important role in the ICT infrastructure development between 2000 and 2004. The purpose of this project was to improve the IT infrastructure and so increase access to information. The key areas of the project were: (1) human resource development, (2) institutional capacity building, and (3) infrastructure development. (Ashford, 1999; Kemppainen, 2006; PAPER III) An essential part of the project was to establish Internet connection to the campus. The Internet connection was finally obtained in 2002 after two years of delay. Accessing information still remained a problem in 2004 because the bandwidth of the university was as limited as 128/64 kilobits per second and even in 2006 the capacity was 704/128 kilobits per second for a university that possessed over 200 computers. The fee for using such a connection was as high as 3,000 USD per month in 2006. Over and above the cost, there are practical problems, such as frequent incidences of power cuts in Tanzania, which impacts the use of ICT. Apart from these, the basic infrastructure of the university is good by local standards, and it offers a solid foundation for educational development.

A new B.Ed. program specializing in the teaching of mathematics and computer applications as minor started in 2001. This new program eventually offered a whole range of new ICT courses including a programming course – the development of which is the focus of this research. (Tumaini University, 2005; PAPER III)

3.2 Research questions

In order to teach computer science successfully in a developing country, one needs to acquire a sensitive and realistic understanding of the context of the country concerned. All teaching and learning initiatives should be based on understanding of the local context, and the readiness and background of the students. Such an approach can lead to innovative developments of a desirable kind (Sections 2.1-3.1). These issues create the first research question:

Q1: What kind of theoretical and practical framework is appropriate for understanding the process of ICT transfer in the context of a developing country such as Tanzania?

Because there was not enough research of the contextual needs of students such as mine (Chapter 1, Section 2.1) nor any previous attempts to concretize and contextualize CS teaching and learning in a developing country context such as Tanzania (Chapter 1, Sections 2.2-3.1), I based the experimental contextual programming course 2004-2005 on the model developed when answering the first question. This in turn led us to the second research question:

Q2: How was contextualization taken into account in the *Contextualized Programming course*?

Applicability of information technology is a crucial problem because technology by *definition* is used in practice or supports practices in a certain environment. Information technology therefore raises vital questions of pedagogy. (Sections 2.1-3.1) The third research question is related to the evaluation of the learning outcomes of students in the context:

Q3: What are the meaningful contextual learning outcomes of the students referring to applying ICT skill and knowledge?

Although I have already dealt with answering these research questions in six articles (PAPER I-VI), I shall join together, summarize and reformulate the results in the overall context of this research in Chapter 5. The conclusions and recommendations for the future work and policy are set out in Chapter 6. (Table 5)

Table 5: Research questions answered in different chapters, sections, and articles.

Research questions	Section or Chapter	Article (PAPER)
Q1.	5.1	I,II,III,IV
Q2.	5.2	I, IV,V
Q3.	5.3	II, IV
Recommendations	6	V,VI

4 Research methods

This chapter provides a description of the methodology used to answer the research questions outlined in the Section 3.2. First it describes the research methodology and secondly the needs analysis, development, implementation, evaluation and revision of the Introduction to Programming course (later Contextualized Programming) of the academic year 2004-2005.

From an ontological point of view, any research has both subjective and objective aspects. While the content of learning arises out of objective conditions, the social environment can only be understood subjectively. Each person interprets the world in terms of subjective criteria and constructions. (Burrell & Morgan, 1979)

From an epistemological point of view, such an interpretation presupposes that reflection on one's own learning and on elements of critical theory contributes towards evaluatory understanding (Guba & Lincoln, 2005; Orlikowski & Baroudi, 1991). From a constructivist point of view, all research constructs something that is new and uniquely personal to the researcher (Guba & Lincoln, 2005). Schwandt (2003) defines social constructivism as a construction process that is never totally personal or independent because it is conditioned by socio-cultural and historical factors that lead it towards an objective dimension defined by Burrell and Morgan (1979). Because this research project is strongly based on social and cultural conditions, it is especially related to the social constructivist approach.

This research uses a functionalist approach that is based on Burrell and Morgan's (1979) two-dimension–four-paradigms structural analysis of social theory. This particular methodology looks for explanations and generates usable knowledge. It is also problem-oriented and utilizes practical goals. The aim in using this method is to achieve understanding while continuing on a functional level to innovate and solve problems as they arise.

4.1 Methodological overview

4.1.1 Qualitative, quantitative and mixed method research

> *"Qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible. These practices transform world."* (Denzin & Lincoln, 2003, pp. 4-5).

Qualitative researchers often study phenomena in their natural settings and attempt to make sense of or interpret phenomena in terms of the meanings that people bring to them (Denzin & Lincoln, 2003). Qualitative research can also give coherence to different kinds of data and explain how the different parts work together. The primary elements in qualitative research are the researcher, fieldwork, inductive strategy, and rich case description. (Merriam, 1998)

Quantitative research deals with components of a project independently and is directed at analyzing the relationships and regularities that appear between selected factors (Merriam, 1998). Thus it generates measurable changes and produces data that is more generalizable than in qualitative research (Cohen, Manion & Morrison, 2000).

A mixed methodology research design includes at least one quantitative method and one qualitative method and makes use of data collection, data analysis and/or data interpretation (Onwuegbuzie, 2002). These processes can be undertaken sequentially or concurrently, and in such a design, priority may be given to either quantitative or qualitative methods or they can be equally utilized. The integration of data may then occur in data collection, data analysis, interpretation or in some combination of these activities. It is also possible to transform qualitative data into quantitative numbers for purposes of comparison. (Creswell, 2003)

In this research quantitative and qualitative data were collected concurrently and also sequentially (see Figure 17, page 68; Table 10, page 71) and the data was analyzed mainly by using qualitative methods. The quantitative analysis provided general information that was later used as a basis for further and deeper qualitative analysis. The integration of the analysis was undertaken both during the process and at the end of the research, and included data transformations from qualitative content analysis to quantitative numbers. (cf. Reeves, 2000a)

4.1.2 Development research

Development research permits the application of long-term goals to both practical and scientific objectives. Terms design research and formative experiment can also be used to refer to the similar methodology. (Reeves, 2000b; van den Akker, 1999) The dual objectives of this research were to develop creative approaches that would solve a variety of problems in teaching, learning and performance while constructing a body of design principles that could be used to guide future development. Such an objective requires a pragmatic and collaborative approach to the application of learning theories as they are applied by researchers, practitioners and other participants in the process. At the same time development research provides information that can be used in making future decisions (Reeves, 2000b).

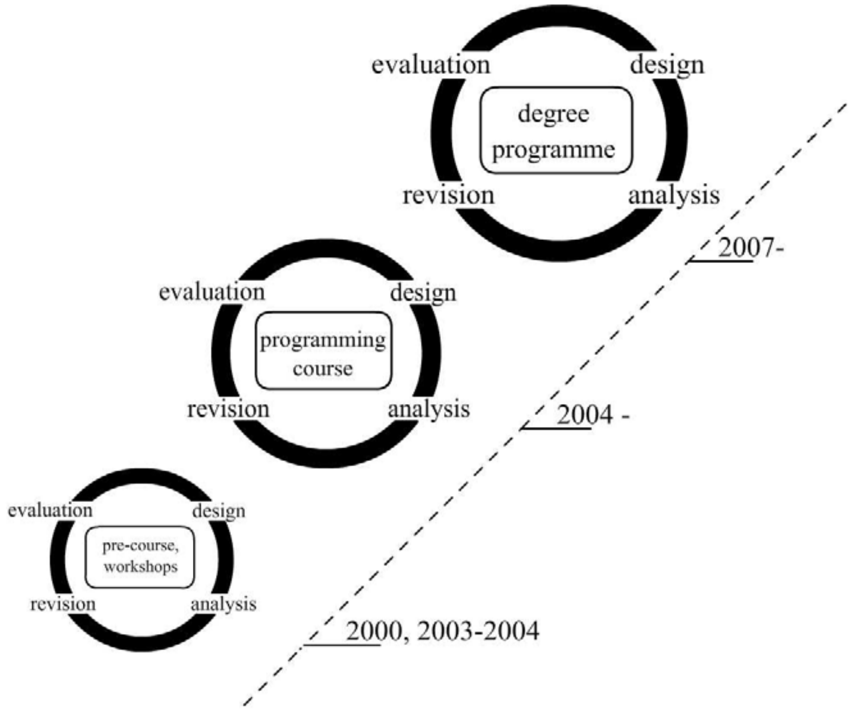


Figure 10: The cyclic structure of development research adapted to this research setting

A development research process may be applied over months or even years and its purpose is to enhance the quality teaching and learning (Reeves, Herrington & Oliver, 2005). Such a process requires prototyping that will increasingly accommodate the requirement for innovation. It may be conceptualized as a spiral model of causality that produces consecutive cycles of analysis, design, evaluation and revision within the context of its theoretical scaffolding (Figure 10). It includes several modes of data collection and interpretation points that affect subsequent phases of the research and lead sequentially to the final output of the research. (van den Akker, 1999; cf. Reeves, 2000b)

The main elements of development research resemble for instance the elements of the FODEM model in computer science with needs analysis, implementation and formative evaluation. FODEM was developed for designing digital learning environments for sparse learning communities by Suhonen (2005). This research also resembles the spiralistic model of the software development process, in which the focus is more on business product development and frequent risk-analysis

(Boehm, 1988); or the deeply participatory action research and its cyclic structure (Cohen et al., 2000; Stringer, 2004).

The development research differs from the previously presented FODEM model and software development model by being a more research oriented approach. Development research is also a comprehensive approach including the goal of wide long term impacts, and even the policy level recommendations. Development research approach is exploratory with expectation of the practical design process outcomes as well, but it does not require as intensive participation of the researcher in target community as the action research.

The reason for the chosen research approach is rooted in the primary goal of supporting the development of education rather than only describing the phenomenon. This approach includes the theoretically underpinned and empirically tested design principles and methods in complex nature consisting of interaction with the field and its actors. Van den Akker (1999) defines the nature of education related development research as design science, which introduces the problem-oriented and interdisciplinary nature of the approach. Table 6 shows how the main elements of the development research were carried out in this research.

This research focuses on a formative type of development research that includes the entire development process and an evaluation of sub-experiments. The sub-experiments also include some supporting summative measures. (cf. van den Akker, 1999)

Table 6: Characteristics of development research (cf. Herrington, 1997; Reeves et al., 2005)

Characteristic of development research	**Concretized in this research**
Focus on broad, complex problems critical to higher education	ICT education is relevant as a tool for university-level educational development in Tanzania.
Integration of design principles with technological factors to provide plausible solutions to complex problems	Course, context and learning technologies are integrated to support the complexity of learning ICT.
Rigorous and reflective inquiry to test and refine innovative learning environments and to reveal new design principles	Constructivist situated learning, digital learning environment, activating technology, and research-based approach are used.
Long-term engagement involving continual refinement of protocols and questions	The process began in 2000 and has continued into the present with new approaches and refinements.
Intensive collaboration among researchers and practitioners	Intensive communication among the researchers, teachers and students as well as between collaborating institutions and other stakeholders such as politicians, secondary school teachers and their students are carried out.
Commitment to theoretical constructions and explanations while solving real-world problems	Exploratory and theory-based creative approaches were used for solving real world problems in the Tanzanian context.

4.1.3 Case study

The development research component of this study is carried out as a case study. A case study is an intensive, holistic description and analysis of a single unit or bounded system. (Merriam, 1998) It is widely used in situations where there is a need to define a topic broadly and to describe a large number of contextual phenomena (Yin, 1993). A case study design can also produce an in-depth understanding of a particular situation and an analysis of its meaning in a discovery process. Insights from this type of research can exert a strong influence on policy, practice and research. (Merriam 1998) The role of the researcher in the case study method is to be a versatile expert because he or she has to function simultaneously as a scientist, a field worker, a tool maker and a technical developer (Denzin & Lincoln, 2003). One of the critical requirements in the case study method is to obtain data from multiple sources (Yin, 1993).

Roche (1999) asserts that the appropriate circumstances for using case study in research in a developing country would include a need to analyze the qualitative impact of broad and multidimensional questions that arise out of complex circumstances. In practice this means for example the need to understand a specific group of people, a particular problem or a unique situation in great depth. While the conclusions from such research may not be generalizable because they focus strongly on qualitative issues, they may nevertheless suggest important implications for other similar contexts. (Roche, 1999) The de-contextualization of the research phenomena and especially of the interpretations are a challenge that demands deep understanding and coherent explanations from the problem field. Such descriptions should not sacrifice their richness, diversity and complexity to the needs of analysis. (Pawson & Tilley, 1997; Roche, 1999; cf. Jonassen, 1991)

The main events and actions in this research were carried out in an institution, Tumaini University, in Tanzania, where I had many opportunities to design and study the Contextual Programming course in detail. I used multiple, but especially qualitative, methods to obtain the information I needed to answer the research questions. I used exploratory approach in the research although Yin (1993) emphasizes that exploratory methods are mainly useful in the preparatory phases of research. This was because the very nature of development research is built around a theoretically reasoned exploration-based approach (van den Akker, 1999).

4.1.4 Credibility, transferability, dependability, confirmability and crystallization

From a constructivist point of view, credibility, transferability, dependability and confirmability replace the positivistic criteria of validity, reliability and objectivity. The overall term for these new criteria is *trustworthiness*, which is concerned with the unique contribution made by the high quality hermeneutic process based on constructivist nature. (Guba & Lincoln, 1989; cf. Lincoln & Guba, 2003)

Credibility replaces internal validity, and refers to an evaluation of whether the description and explanation of the case fit the real events as they happened in the field (Guba & Lincoln, 1989; Janesic, 1994). Because this research was undertaken in collaboration with Tumaini University, I gave representatives of Tumaini University opportunities for review during the process. I also held several meetings to discuss the research and its outcomes as they are reflected in analyses and reports. I conducted discussions with the members of staff and also with students of Tumaini University. The semi-structured interview format also gave me the opportunity to ask the participants clarifying questions when their answers were not clear. Some unclear and missing elements in the questionnaires were later interpreted or completed by the students themselves. Since the first meeting with the representatives of Tumaini University we decided together to be as open as possible also for critique as it is a way for development. I utilized the services of a parallel coder for the content analysis to avoid subjective views of the data. (cf. Guba & Lincoln, 1989)

Transferability in turn replaces external validity or generalizability and means applying the same findings in another context (Guba & Lincoln, 1989). This type of research is particularly resonant in certain contexts and it makes use of wide and thick that are contained in publications (PAPER I-VI) and this research report. It is clear though that the outcomes of the deep qualitative approach cannot be straightly generalized into other contexts. They can only be used as a basis for exploring other contexts in other times and places. (Guba & Lincoln, 1989) The development and applicability of ICT has been in a state of constant flux during this research. The applicability of this research to other institutions has to be carried out with extreme sensitivity to the context of each case. This in turn requires a thorough understanding of the context where the research was originally conducted. (Greenwood & Levin, 2005)

Dependability in this research replaces conventional reliability which refers to the stability of data over time. While dependability allows a researcher to make methodological changes during the course of the research, these have to be well described and reported. The other decisions and interpretations made during the research process as well have to be well described in the context of the research report. (Guba & Lincoln, 1989) The literature review (Chapter 2), the description of the context (Section 3.1), the case description (Section 4.2), and this section on methodology together with the included articles (PAPER I-VI) provide a reasoned justification for the methodological selections in this research. It is necessary for long-term research of this kind to permit some degree of flexibility with regard to methodology so that changes in the research environment can be accommodated during the long duration of the empirical component.

Confirmability, which corresponds to conventional objectivity in empirical science, requires the research findings to be firmly based on the data (Guba & Lincoln, 1989). The main elements of the questionnaires in this research are set out in Appendix C, and the answers to the questionnaires and interview records are all available from the author. This data, which is also presented in articles (PAPER I-VI) and in Chapters 1-6 of this research report, all prove the confirmability of this research. Other factors that contribute to confirmability are the continuous collaboration with Tumaini University, the public presentation of reports on work in progress – such as the TEDC 2006 presentation in Iringa (Vesisenaho et al., 2006b), and the independent parallel coding in content analysis.

Because this research used mainly qualitative methods, the results are mainly not validated by simultaneous triangulation, but by *crystallization* (Denzin & Lincoln, 2005). Crystallization requires a phenomenon to be investigated from a number of different aspects. The outcomes become crystallized as they are reflected, and refracted, and as they change and grow during the course of empirical work. In triangulation the data is collected and analyzed in a specific timeframe with different data, instruments or sources, but in crystallization the process can take much longer as different methods are used to obtain a deeper, richer, more complex and thorough understanding of the research topic. (Richardson, 1997; Richardson & St. Pierre, 2005) Crystallization qualifies the concept of ultimate validity because it is based on the assumption that there is no single truth about any particular phenomenon. There is always more to know. (Denzin & Lincoln, 2003)

When data is observed and interwoven from many different aspects and under different conditions, the resultant observation permits a researcher to crystallize a rich understanding of the phenomenon under investigation. This is also the reason why it is useful to have access to many different types of data and to use of different methods of data collection such as discovering, observing, discussing, story-telling and re-presentation. (Guba & Lincoln, 2005).

The crystallization process of this research is well suitable for the multidimensional interdisciplinary nature of the research. This research is based on computer science, but it also applies knowledge, data, expertise and methodology from the science of education and development studies.

4.1.5 Ethical considerations

The ethical dimensions of this research have been carefully monitored and implemented. The ethical basis of the research has been assured by frequent joint consultations and agreements with all participants including the staff members and students of Tumaini University who participated in the development process. This means in effect that the university has been carefully appraised of what will happen in the research. It also means that the university has given its official consent to the jointly implemented learning experiments and other events related to the research process. The Tanzanian Commission for Science and Technology (COSTECH) has consented this research to be conducted (Appendix A).

The privacy, anonymity and confidentiality of the students have also been assured by various measures. The students were informed that the implementation of the course would form a part of a developmental research process of education at Tumaini University and that they would therefore on their acceptance be participants of this development and research (Appendix B). They were also explained that data from the research questionnaires, observations and interviews would have no effect on their official grading and assessment. All research outcomes were reported in a way that the anonymity and confidentiality of all participants was assured. (Cohen et al., 2000)

4.1.6 Summary

This interdisciplinary research focused on the problem of how best to implement contextualized ICT education in developing countries. This specific initiative was conducted between 2000 and 2006 at Tumaini University in Tanzania. The overall methodological approach was to explore the problem field by development research with its accommodation of long-term development goals and reliance on innovation from both practical and scientific aspects (Reeves, 2000b; Reeves et al., 2005; van den Akker, 1999). The Contextualized Programming course at Tumaini University, Iringa University College, offered to 27 Bachelor of Education students in 2004-2005 provided the settings for a case study that gave innumerable opportunities to focus on the development, implementation and evaluation phases of the project (cf. Merriam, 1998; Yin, 1993). A mixed methodology approach was utilized because it allowed to make some quantitative analyses to support the emerging data which had been gathered by using especially qualitative methods that crystallized the outcomes of the study (Denzin & Lincoln, 2003; Onwuegbuzie, 2002; Richardson, 1997).

Table 7 offers an overview of how the research questions composed in Section 3.2 were studied and reported:

Q1. What kind of theoretical and practical framework is appropriate for understanding the process of ICT transfer in the context of a developing country such as Tanzania?

Q2. How was contextualization taken into account in the Contextualized Programming course?

Q3. What are the meaningful contextual learning outcomes of the students referring to applying ICT skills and knowledge?

Table 7: Overview of how the research questions were answered and reported (see Figure 10, page 49)

Research question	**Method**	**Focus**	**Output**	**Report Chapter or Section**	**Article (Paper)**
Q1.	Literature review, observations, questionnaires, experiments, monitoring the overall design process	Pre-analysis, cyclic development and implementation processes in 2000-2005	CATI model	1, 2.1-2.3, 3.1, 5.1	I, II, III, IV
Q2.	Course design analysis	Contextualized Programming course 2004-2005	Course development, implementation, and evaluation	2.2, 2.3, 3.1, 4.2, 5.2	I, IV,V
Q3.	Interview and questionnaire based analysis	Contextualized Programming course 2004-2005: learning evaluation	Students' applicable learning analysis	3.1, 4.2, 5.3	II, IV
Recomm-endations	Summary and further needs analysis	Follow-up	Contextual impacts	6	V,VI

4.2 Case description

4.2.1 Needs analysis

The needs analysis for this research was undertaken in 2000-2004 and focused on a conceptual understanding of computer science education in the Tanzanian context (cf. Duveskog et al., 2003; Laisser, Lupilya & Vesisenaho, 2003; Sutinen et al., 2002; PAPER I-III). The field experiments for this phase commenced in 2000 when I taught a two-month intensive orientation course in educational technology for two Tanzanian undergraduate business students (Figure 11).

Figure 11: Orientation course in Iringa in 2000, laboratory activities (left) and context related batiks multimedia project (right).

When these same two students later came to complete master's degrees in computer science at University of Joensuu in 2000-2002, we were able to cooperate in developing appropriate computer science courses for Tanzania and especially Tumaini University. In 2003 and 2004 my local and international colleagues and I gave altogether three programming and robotics workshops for students of Pommern secondary school (Figure 12) and Tumaini University (Figure 13) applying the "programming by building" approach (Lund, 2003). We did this in the hope of being able to identify and determine modification of ICT education that might benefit the Tanzanian ICT and more specifically programming courses. We also received welcome input from the studies undertaken in other Tanzanian universities by members of staff of Tumaini University for the purpose of strengthening the infrastructure project IPSP (Ashford, 1999; Kemppainen, 2006). This entire need analysis phase was accomplished in conjunction with Tumaini University, and was supported by previous research and literature.

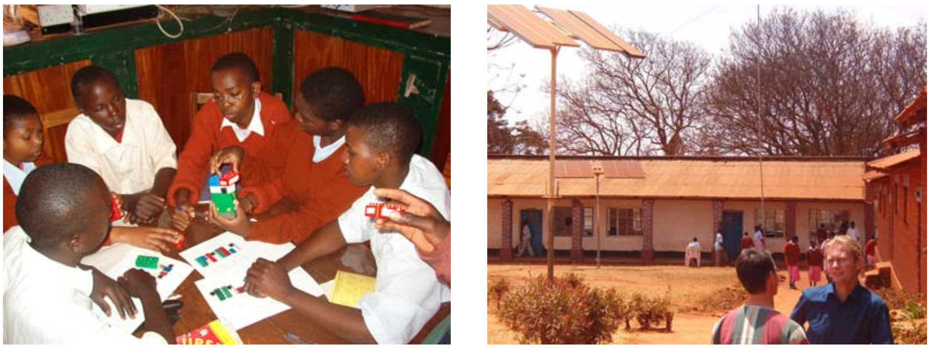


Figure 12: Preparatory workshop at Pommern secondary school 2004

Figure 13: Preparatory workshops at Tumaini University 2003-2004

The problems that emerged in the preparatory phase were obviously related to the partial inadequacy or lack of the ICT education that the Tanzanian students had received. It became clear to us that the main need was for a pedagogical model that would enable local students to understand the most important elements of an international ICT curriculum such as ACM and IEEE (2001; cf. also ACM, 2005). The model should take account on their own personal needs and attainments as well as the needs of the society and context in which they lived (see Figure 8, page 21). An example of this was provided at Tumaini University by the encountered problems in teaching programming – a fundamental skill in authoring ICT and learning computer science (Denning et al., 1989). The approach had been very theoretical focusing on large amount of difficult concepts without the application linkage. The ICT infrastructure in Tanzania was still in an early phase of development and the ICT knowledge, experience and skills of the local people were restricted. It also soon became obvious to us that East African social and cultural conditions would exert a unique effect on all our joint development research activities (Section 3.1). In the light of all these problems and difficulties we decided that the emphasis of our research should be on the provision of meaningful ICT education in a Tanzanian context. We also realized at that early stage that we would have to focus intensively on programming education as a means to support mastering and developing local technology and ICT knowledge capacity (see Chapter 1, Sections 2.1-3.1).

4.2.2 Development and implementation of Contextualized Programming course

One of our educational development goals was to identify useful linkages between contextual issues and ICT education. The Introduction to Programming course was selected as the main target and focus of this research. This course was already an obligatory course for second-year undergraduate Bachelor of Education students who had mathematics and computer science as the practical application subjects for their degree. (Tumaini University, 2004) We selected this particular course for three main reasons: Firstly, it was the only computer science course available at that time at Tumaini University apart from other more application-oriented ICT courses; secondly, teaching up until that time had been very concept-based (cf. PAPER III) – a method of learning that is particularly difficult for students without strong ICT backgrounds because programming is generally not an easy skill for novices to master (e.g Bonar & Soloway, 1983); and finally, we knew that a higher-level contextualized ICT education that we proposed to offer was extremely rare and mostly nonexistent in the developing countries in which we were interested (see Section 2.2). We therefore formed the intention of designing a completely new context-sensitive Introduction to Programming (Contextualized Programming) course that would suit the needs and attainments of the students whom we expected to encounter in our experimental research conditions at Tumaini University.

My main purposes were therefore to focus on the collaborative design process of the course, to evaluate contextualization in both the process and the course, and to evaluate the learning outcomes of the course. The outcome evaluation would be based on an analysis of the contextual outcomes – by which I mean not only the general side-effects, and spin-offs and follow-up events, but also an evaluation of the contextual thoughts, responses and attitudes of the students on the course as they arose. This method of evaluation is actually quite different from the customary way of evaluating a programming course. Many conventional evaluations are based on program summary analyses, classifications of information types and levels of object descriptions in programming education (Good, 1999; Good & Brna, 2004). Bonar and Soloway (1985) refer also to a description and analysis of the emergent "bugs and errors" that illuminate the mental models that the novices use for programming.

Course development

The Contextualized Programming course was to be offered between October 2004 and January 2005, and we selected the second year teacher trainees for the target group. They would not only be the participants in our research; they would be developers of the course and capable of exerting an impact on their communities through the education of future generations of ICT users (Hawkins, 2002).

The development process of the Contextualized Programming course (called also preparatory phase) was undertaken as a joint operation between Tumaini University, the University of Southern Denmark and the University of Joensuu in Finland. Collaborators from Tumaini University were able to act as experts with regard to contextual issues and were also responsible for many of the practical arrangements. The University of Southern Denmark contributed with their expertise in educational robotics, and the University of Joensuu was mainly responsible for the production of course materials and CSE approach in general. It was also agreed that the role of the local university teacher was indispensable for development and implementation.

We defined the objectives and contents of the course on the basis of consultations that we held in the preparatory phase in 2000-2004, and decided to maintain the original course description with minor changes:

> *"This course introduces students to the basics of computer programming using the BASIC language. It includes lectures on programming structure and design. During class, students write programs to solve a variety of problems and to perform different tasks. After successful completion of this course, students should have a general knowledge of the methodology of creating computer programs*." (Tumaini University, 2003, p. 71).

An exception was the change of the programming language to Java. (Vesisenaho et al., 2006a; PAPER II, IV)

The main reasons for selecting Java as the language were its wide global use, opportunities for Web programming and advanced programming opportunities compared to for instance C++ (Kölling, 1999; Sebesta, 2004), and its suitability for novice students in the introductory programming education (e.g. Haataja, Suhonen, Sutinen & Torvinen, 2001). Java is therefore commonly used as the first programming language.

There is a debate in computer science education as to whether the teaching of programming should begin with objects or not. The main question-pair is: Is there a need to study the basic concepts and structures by using a procedural method first while changing later of object-oriented approach (Ben-Ari, 1998), or should the approach be based on objects from the very beginning, because it could be difficult to change the mental models necessitated by the object-oriented approach later on (Kölling, 1999)?

My approach in this course was similar to that of Ben-Ari (1998) – whose method has been successfully adapted for teaching by means of distance education at the University of Joensuu (Haataja et al., 2001). We therefore began this phase of the teaching with procedural ideas, and only later in the course changed to an object-oriented approach. This method gave students an understanding and practical knowledge of basic concepts before they were introduced to more difficult topics.

In this course we focused more than in the previous programming course in the institution on imparting a basic understanding of ICT, robotics and programming in a way that was sensitive to the local Tanzanian context. Because the course was designed to impart the learning of technical skills in both theory and practice, we expected the students to have a good general and practical knowledge of the methodology of creating computer programs as well as a general understanding of robotics and modern technologies after they had successfully completed the course requirements. The emphasis throughout was context-sensitive: we expected to see evidence of how the students were able to use programming and other applications to benefit their community and their future work.

The content of the three months' course included:

- learning programming by building with I-Blocks in a workshop;
- an introduction to Jeliot-supported programming;
- the basics of Java programming language, control structures, arrays, program structures, and applet programming;
- contact lessons, exercises and project work; and
- final examination and workshop. (see Table 8)

The 50 contact hours provided by the course was to be six hours per week over and above the time spent in workshops and in examinations. We also planned to set up opportunities for supervised laboratory activities once a week on a voluntary basis. All these sessions were to be held in either a computer laboratory or some other technology-rich environment.

The intention was that the course would be taught jointly by a local teacher working in conjunction with a teacher from the University of Joensuu. As the principal researcher I was to be present at the workshops together with other collaborators from Finland and Denmark. It was also to be my responsibility to support the teaching of the course by online web-forums from Finland and by observing the exercises and learning diaries of both students and teachers.

Table 8: Topics included in the Contextual Programming course

Week	Topic	Contact hours
I	Programming through building with I-Blocks	9
I	An introduction to Jeliot-supported programming	6
II	The basics of Java programming language	6
III	Control structures	6
IV	Arrays	6
V	Program structure	6
VI	Understanding applets	6
VII-XI	Project work	supervising
XII	Examination and the final workshop	5

The final course grade awarded to students was to be compiled from the results obtained from: the final examination (50%); project work (25%); and exercises (25%). We based this segmentation of the final course grade on guidelines obtained from Tumaini University.

There were not to be any other theme-related courses running simultaneously with our course, which could affect the course outcomes. I did not expect that age or teaching experience would affect the results, as the course participants were all expected to have several years' practical experience as teachers.

My general role as a researcher and project manager was to analyze the needs analysis phase, to design the content, and to decide the didactic approach for the Contextualized Programming course in conjunction with the multicultural development group. It was also my responsibility to structure and oversee the evaluation processes and to synchronize the activities and obligations of all partners who were involved with the project.

Implementation

All 27 B.Ed. students, in a class of 11 female and 16 male students, were participating in the Contextualized Programming course as an obligatory second year course for completion of the degree from October 2004 to January 2005. The average age of the students was 35 years and only one of them had no working experience as a teacher. They had an average of nine years' practical teaching experience as mathematics and science teachers. Four out of every five of the students had encountered computers for the first time at university, and their prior ICT experiences have been limited to office software and the first steps in the use of email facilities and web browsers. Only one out of 27 students had prior experience of preliminary programming.

The lessons began on schedule with the *Programming by Building with I-Blocks workshop*, a one and half day workshop giving students the basic understanding of programming with robotics without a normal computer. The weekly contact *lessons* were supported by context-sensitive *weekly exercises* which included a *learning diary* for reflecting the contextual applicability of the learning experiences, and by an additional voluntary tutored three-hour session. Teaching was eventually implemented almost wholly by the teacher from the University of Joensuu instead of the local teacher, whose intensive role had been agreed during preparation phase with the Tumaini University.

It is important to realize that the main objective of this course was not only to give students a theoretical understanding of programming but to equip them to become proficient in programming in the context of their lives and the society in which they lived. In order to do this we had to ensure that all the students had obtained a thorough understanding of everything that they needed to know in both theory and practice. This insistence on our part unfortunately led to a slippage of the schedule which resulted in the object-oriented part of programming receiving only a limited amount of attention.

The technological support component of the course was based on activating web-materials, I-Blocks and Jeliot (cf. PAPER IV). The development of the *web-based course materials* was intended to be a joint activity, but the practical implementation of this segment was performed by two research assistants from University of Joensuu with feedback from a Tanzanian lecturer of Tumaini University.

We published the six units (villages) of the course materials on the local web-server so that students would have the course materials that they needed for the coming weeks. The instructional interface metaphor was a traditional rural African village (Figure 14), a metaphor readily accessible to all the Tanzanian students. We deliberately adopted this particular symbolic setting because we wanted to demonstrate that computer programming does not have to be presented in obscure "high tech" Western-specific formats but it can be easily grasped if it is taught by means of imagery and concepts that are entirely derived from the local social and cultural context of learners. The students who used the site could obtain the information they needed by clicking on the huts in the village. We also included contextual programming examples that the students could download and modify. Even though the students were given weekly problems to solve, they were also encouraged to come up with their own ideas and plans for making programs.

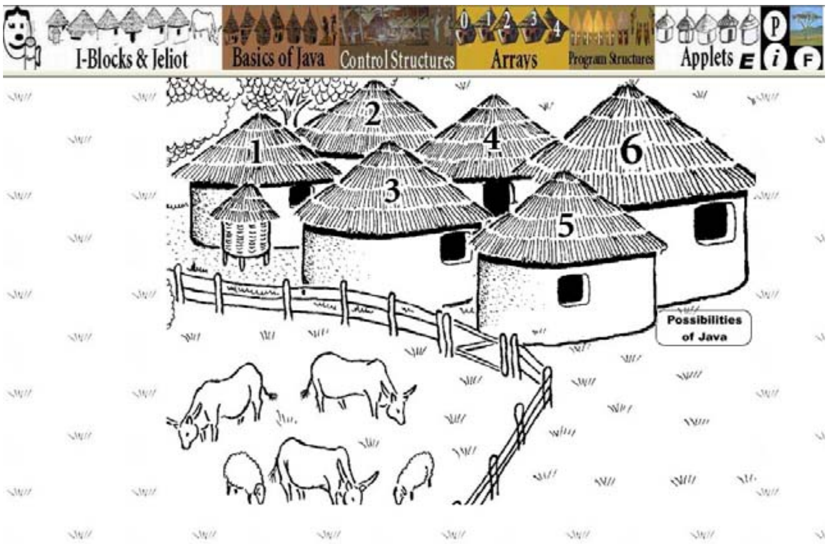


Figure 14: The learning village as a graphic metaphor of the course material

The course was also supported by the four PHP-based forums: question–answer, project work, general information, and free discussion. The light HTML material included also Flash animations. In addition to this, we circulated most of the web-material in the form of printed handouts to students because students only had limited access to computers and because dependence on web material as a source of information was a novel experience for the students. There were also some Bell and Parr's *Java for Students* and Chapman's *Introduction to Java* books available later in the course.

I-Blocks are intelligent building blocks which have been designed to give practical demonstrations of the first steps in programming including an understanding of the basic concepts and the logic of programming. In this research I-Blocks were used in programming by building workshop and in student projects, and they also enabled students to link what they had learned on ICT to the actual society where they lived and where they had grown up by inspirating students to invent new ICT-based applications. This “programming by building” approach (see Section 2.3.2) by means of I-Blocks is based on research and development that was mainly undertaken by our partners at the University of Southern Denmark (Lund, 2003). The I-Blocks also underwent further development during the course of our project (cf. Lund & Vesisenaho, 2004; Nielsen & Lund, 2006; PAPER I, II, IV).

Figure 15: I-Blocks with microprocessor and communication channels covered by Lego Duplo® (Lund, 2003)

I-Blocks (Figure 15) allow users to build a program by connecting blocks of the following three types:

- input blocks with a sensor or mechanism to set a value;
- output blocks to produce for instance a tone, light or signal and display a value; and
- operator blocks for arithmetical or logical operations.

There is also an interface that allows students to program I-Blocks for different functions in an easy way. The QEL Micropro program was used to download programs to the microchip inside each I-Block.

We used the *Jeliot* program visualization software for the further teaching of programming. Jeliot allows students to visualize each step in their Java programs (Figure 16), and it has been shown to be particularly helpful to students who are new to programming (Levy et al., 2003; see Section 2.3.2). It is a hands-on tool that allows students to experiment with code and observe the otherwise inaccessible configurations in a running program. The approach offered students visual and functional connection points with their mental models.

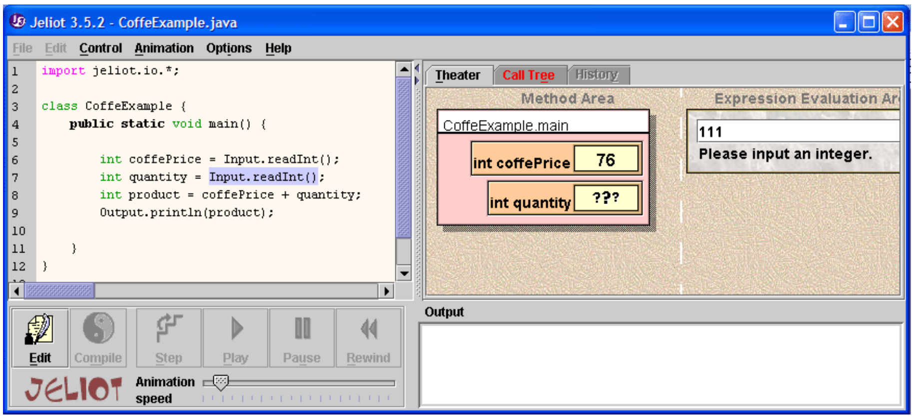


Figure 16: A screenshot of Jeliot visualizing a program. The code is in the left window, its dynamic visualization in the right**.**

For the purposes of the *project* assignment, students were divided into groups of three to five members. Half of the groups was to teach basic ICT skills to secondary school students by using I-Blocks. The remaining groups were required to use Java programming to develop programs that would be beneficial to secondary school teachers or students. The Java groups programmed a calculator, made graphic representations of polynomial functions, created a program for a simplified Bao game, and coded three different mathematical presentation programs for educational purposes. All of the project outcomes were immediately applicable and relevant to future subject teachers of mathematics and science. The students reported on their projects and presented the outcomes and reflections at the end of the course. Both teachers involved in the course supervised the projects.

A *final examination and workshop* with project presentations concluded the course. The course examination included the following three types of exercises:

- Question 1 dealt with important concepts of computer programming and required the students to explain how to apply these concepts in Java;
- Questions 2 to 5 dealt with programming and algorithms, explanations of

short programs, finding errors, and creating and completing Java and Jeliot methods; and

- Question 6 was a creative problem-solving assignment based on I-Blocks.

Each of the students presented their projects and all the other students and teachers offered feedback in the final workshop.

As explained in Section 2.3.4, *situated learning* created a pedagogical framework for this implementation. Table 9 shows, how the situated learning approach was taken into account in practical implementation.

Table 9: Situated learning in the Contextual Programming course (see Section 2.3.4)

Situated learning element	Implemented in the Contextual Programming course of 2004-2005
Authentic context that reflects the way the knowledge will be used in real-life	Project works, I-Blocks, content of digital learning materials, exercises
Authentic activities	Field activities, exploratory I-Blocks, workshops, application ideas for different subjects
Access to expert performances and the modeling of processes	Jeliot, lectures, workshops with experts
Multiple roles and perspectives	Group works, projects, exercises, the mixed methodology used in the research
Collaborative construction of knowledge	Paired or group works in lectures, projects
Coaching and scaffolding	Tutoring and supervising one another
Reflection	Learning diary, questionnaires, interviews
Articulation	Discussion-based learning, learning diary, reporting, workshop presentations
Authentic assessment	Contextual applicability exercises; field projects and their assessment

4.2.3 Evaluation

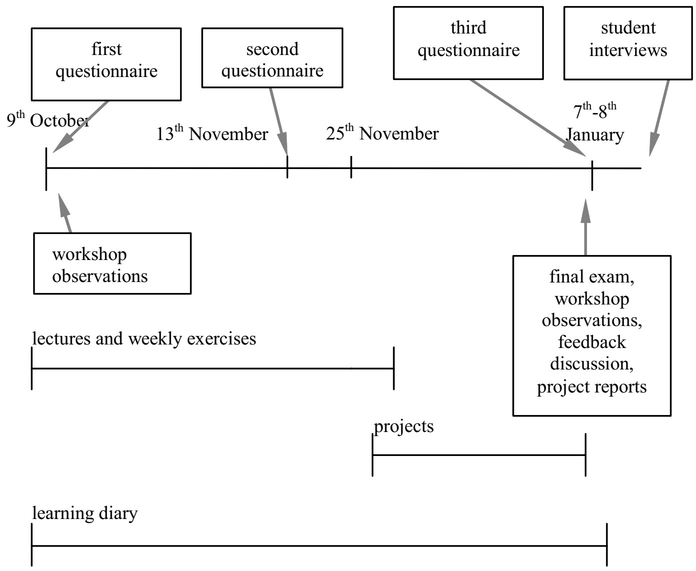


Figure 17: Data collection during the course in 2004-2005

The data of this research was collected mainly through observation, pre-tested questionnaires and interviews between October 2004 and January 2005 (Figure 17). The aim of the data collection was (1) to evaluate the success of the contextualization component of the experiment, and (2) to obtain information about the qualitative changes in students' application-oriented knowledge. The students' weekly exercises during lecture periods and their learning diaries were used mostly as a tool to support students' personal training, refresh their knowledge of applications and context-related thoughts, and to obtain feedback about our teaching.

We administered questionnaires to students at the beginning of the course, in the middle of the course and at the end of the course. The first questionnaire focused on students' previous experiences, explanations of ICT-related issues, levels of ICT understanding and awareness of ICT-related opportunities. There were also a number of robotics-related questions in this questionnaire that were not an immediate interest of this study but which were relevant to the overall research project. The second and third questionnaires were constructed along the same lines as the first, but without background data. Most of the questions in the questionnaires were open-ended because of the qualitative nature of the methodological approach and because I did not want to restrict or limit what students might have to say (see Appendix C).

Each of the participants in the course was interviewed separately after the conclusion of the course. The interview was qualitative and semi-structured and focused mainly on the application thoughts of students and general understanding of the course theme (Warren, 2002). Interviews were carried out in English, which is the official teaching language of the university. While I initially encountered some language problems during the interviews, the thematic structure of the research questions gave students the freedom to clarify and expand upon what they had said, as well as opportunities to discuss the same matters again and again from different perspectives. I was conscious all the time during the interviews of the challenges of cross-cultural communication and strove in every way to make the interview format comfortable and non-threatening (Ryen, 2002).

I used a qualitative content analysis of data collated from the first and third questionnaires and from the interviews to obtain deep insights into the phenomenon (Neuendorf, 2002). I based the categories of analysis that I used for content analysis on the contextualization, application, transfer and import levels of the CATI model developed during the needs analysis and course development phases of the research process (PAPER III, IV). While this approach provided us with a great deal of useful information about the students' learning outcomes, it also allowed us to test the CATI model developed in an earlier phase of this research.

For the content analysis I used Atlas.ti versions 4 and 5 to elaborate on the data. In addition I counted the frequency of the code categories and thus provided quantitative data as well. I based the overall analysis on the successive steps of Kelle's (1997) computer-aided content analysis, namely, structuring the material, doing comparisons, and the building of theory and conclusions. My purpose in this part of the research was to identify and describe the differentials in the quantity, quality and structure of the students' knowledge, and thus to illuminate the inductive development of the research. I also arranged the independent parallel coding of all interview data to ensure the trustworthiness of the use of the CATI model.

I used free-marginal Kappa, a chance-adjusted measure of agreement, to evaluate inter-rater reliability (Brennan & Prediger, 1981). The inter-rater reliability (dependability) for the analysis of 189 codes by CATI levels was *moderate*; Kappa was 0.62. The overall inter-rater reliability for students' general level CATI coding (27 codes) was *high* with a Kappa value of 0.81. This suggests a positive similarity between the coding results and the applicability of the CATI-based model to content analysis (PAPER IV).

I also undertook the quantitative segment of analysis to identify possible changes in students' awareness of ICT and the opportunities that it offers by using paired samples t-test (PAPER IV). In addition I analyzed students' results in exercises, projects and final exam assignments comparing I-Block and Java groups by using Mann-Whitney U and Wilcoxon tests (PAPER II). The support of SPSS software version 12 and 13 was used in these analyses.

In addition, the development (preparation), implementation and follow-up phases of the course design were analyzed by monitoring the different events and phases of the course design processes, and their outcomes. The joint CATI level for each event and phases was based on the negotiated joint view of a Tanzanian ICT expert and myself (PAPER V).

Table 10 summarizes the way in which the data was collected and analyzed during the research process.

Table 10: Data collection and analysis

Data	Time	Focus of analyses
Before the course		
Infrastructure project IPSP implementation / documentation, observations	2000-2004	CATI model development and content analysis
Course in 2000, master's studies in Finland, pre-workshops	2000, 2000-2002, 2003-2004	Observations, joint material and approach development, questionnaire-based feedback, CATI model development
During the course		
Observations	October 2004 – January 2005	Contextual outputs
Questionnaire I	October 2004	Background and starting knowledge
Questionnaire II	November 2004	Midway information and feedback
Questionnaire III	January 2005	Comparison with Questionnaire I
Final examination	January 2005	Results of different exercises, and those from student subgroups
Course grade	January 2005	Comparison between different groups in the course
After the course		
Interviews	January 2005	CATI model-based content analysis
Course design analysis (preparations, implementation, follow-up)	2003-2006	CATI model-based content analysis

4.2.4 Revision

The course that my colleagues and I implemented in Tanzania was preceded by our learning experiences with the two Tanzanian students in 2000 in Tanzania, and thereafter with the same students in Finland between 2000 and 2002. We incorporated what we had learned from these experiences for our workshops of 2003 and 2004. These preliminary experiences with analysis and theoretical knowledge related to context influenced strongly on our Contextual Programming course of 2004-2005.

We applied minor revisions to the Contextual Programming course while it was already up and running so that we could give the students an improved learning experience. Among such minor revisions was, for example, a revised approach to the teaching of some concepts and ideas about programming. The weekly exercises and learning diaries provided us with invaluable cues for such revisions.

The revision phase of the Contextual Programming course influenced the implementation of the course during the subsequent year 2005-2006 by decreasing I-Block activities and increasing the time frame of the course content in general. Our initial batch of students became project tutors in their subsequent year. New students implemented projects in a hospital setting as well. Some of the initial batch of participant students continued to elaborate on what they had learned by writing bachelor's thesis on topics related to the approach used in the course. We also introduced a new version of I-Blocks, called *A-Blocks*, in 2005 (Nielsen & Lund, 2006). These A-Blocks were based on our earlier experiences and observations, and took the form of cubes with better usability features.

The cycle of revisions and improvements led to a further development of the course's theme, which in turn led to suggestions for the contextual IT degree programme combining CS and engineering elements in the local context (see Figure 10, page 49; Figure 19, page 81). While the reported experiences and outcomes of the course were not directly adapted for the degree programme, they nevertheless provided valuable contextual background for its development. Since the degree programme is scheduled to commence in September 2007, the spiral-shaped cycle of development still continues.

5 Results

This chapter will focus on the main elements taken from the research questions. It will also summarize the results reported in publications included in this thesis (Table 11; PAPER I-VI).

Although elements of this research were undertaken between 2000 and 2006, its decisive implementation took place in the academic year 2004-2005. During the period between 2000 and 2004, my colleagues and I undertook contextual analyses and teaching experiments of limited duration. In the academic year 2004-2005, the teaching component of the Contextual Programming course was subjected to intense scrutiny and analysis. The course was delivered for the first time in Tanzania, and the experimental conditions were set up in full at Tumaini University, Iringa University College, Tanzania. The course implementation focused on constructivist situated-learning activities in teaching computer science in a Tanzanian context – an area of research that had received hardly any attention prior to our intervention (Sections 2.2, 2.3, 4.2). The academic year 2005-2006 was devoted to a final analysis, to follow-up and to further plans for future implementations and development.

Table 11: Research questions and the sections, chapters and papers in which they have been answered (see Table 7, page 56)

Research questions	Chapter or Section	PAPER
Q1. What kind of theoretical and practical framework is appropriate for understanding the process of ICT transfer in the context of a developing country such as Tanzania?	Section 5.1	I,II,III,IV
Q2. How was contextualization taken into account in the Contextualized Programming course?	Section 5.2	I, IV,V
Q3. What are the meaningful contextual learning outcomes of the students referring to applying ICT skill and knowledge?	Section 5.3	II, IV
Recommendations	Chapter 6	V,VI

This continuing research and development process well demonstrates the iterative and spiraling nature of development research (Section 4.1.2). This type of research also requires a continuous interaction between *action* and *context* in a way that leads to developmental change and improvement (Sections 2.1, 3.1). Such changes may sometimes be unexpected and surprising because the process is never quite as straightforward as it appears to be in the planning stage.

The instruments that I used to find out the answers to the research questions produced mostly qualitative data (Section 4.1). Qualitative data, for example, emerged from the answers that students gave to open questions in questionnaires and from information obtained from them in interviews. Analyzing experimental approaches to the educational content and monitoring student performance produced additional information. I also carried out some quantitative measures to obtain an overall picture of the changes that had occurred.

5.1 Framework for understanding ICT transfer in a developing country context

Between 2000 and 2005 my colleagues and I tackled the problems of ICT transfer to a developing country. The results of this phase indicated general overemphasis on theory and a tendency to adopt conventional Western methods of teaching and using ICT. Such difficulties, if not addressed right at the beginning of planning and implementation, are capable of producing varying degrees of non-sustainable development (Section 2.1). From the point of view of the ICT infrastructure or even knowledge and skills, this can make the technology itself irrelevant to apply. In the higher level ICT education, problems of this kind mean that contextual needs are not met and that students are not trained to think or solve locally relevant problems. (Sections 2.1-2.3, 3.1)

It is against such a background that the CATI (Contextualize, Apply, Transfer, Import) model for sustainable ICT education and ICT project implementation was developed in 2000-2005 as an outcome of this research. The model is set out in graphic form in Figure 18.

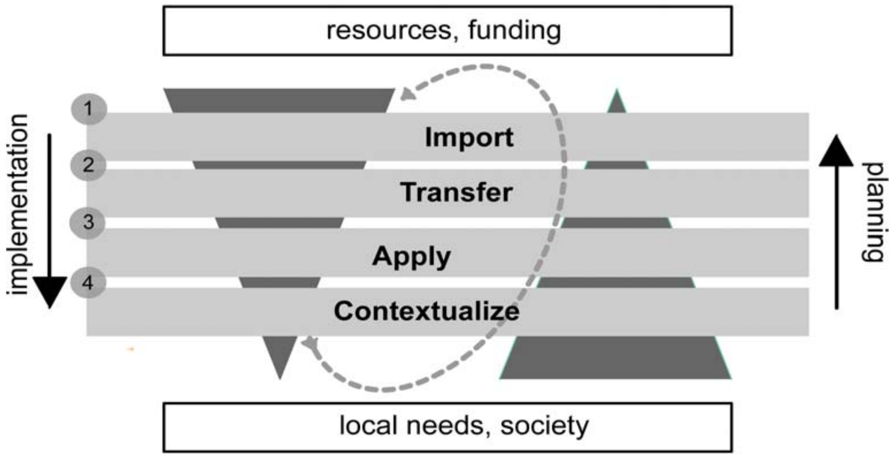


Figure 18: CATI model for contextual IT development (PAPER III)

Each *level* of this model refers to a particular aspect or phase of development, and is briefly explained from the technology and knowledge-transfer standpoint. Especially according to the implementation side the levels can be defined in the following way:

• *Import* refers to any situation where a technology and/or knowledge is imported without any prior needs analysis of the local conditions into which it needs to be imported. While it is relatively easy to make the technology locally available in the physical sense, an inattentiveness to specific local conditions and needs may make the technology completely opaque, alien and unusable for local operators.

• *Transferred* technology, innovations, knowledge and skills have been made accessible to their users and may thus hold out *some* potential for application in a local context. This may occur even if the local need analysis has been deficient or somehow inadequate and incomplete.

• *Application* means that the potential of transferred assets such as innovation or technology has been realized. A local IT operative has been successful in making his or her technology and skills relevant, useful and affirmative to some extent in practice in the local environment.

• *Contextualizing* means that local users and developers have become capable of integrating ICT with the needs, conditions and concerns of their local communities. Local and immediate conditions and innovations form the basis for contextualized the use of ICT.

The CATI model was specifically devised to elucidate the benefits that might accrue to a local, developing society in which technology and skills have been applied. When locally conditioned needs, problems and deficiencies become apparent during the planning phase, and later during the teaching and implementation phases, valuable opportunities for creating sustainable conditions arise and should immediately be exploited for the benefit of the local recipients and participants. While it is during the planning phase that decisions have to be made about the schedules, infrastructure, education and other resources that will be needed, the CATI based planning emphasizes the need for ongoing flexibility and adaptation throughout the life span of any project or initiative of this kind.

The *planning phase* of the intervention or project should always start with the contextual needs. The society related needs defined by the local participants or users are the basis. When these contextual needs are found and are shown to be relevant to apply, the planning continues with more specified nature. The applicable problem field is specified more carefully, and the problem solving further continues to the transfer and import stages, in which the plans for carrying out the project are already concrete. When the first cycles of planning are completed, the resource question has to be solved. This is done after a careful, contextual planning process.

In the *implementation phase,* during the first steps in the import level, it might become clear that additional resources are needed before further implementation can take place. Although these further elements of infrastructure and education-provision might need to be imported, such procedures are relatively straightforward. While it is in the transfer level that the first signs of application become apparent, the impulses that first appeared in the transferred stage become consolidated and systematized in the application level. If a project or development initiative reaches the contextual level, it should be giving unequivocal empirical evidence of how valuable and useful ICT is to the local community. The development of this final stage should lead to what we have termed *deep contextual applicability*.

The CATI-based approach to implementing ICT in indigenous conditions also results in the mastering of computers in ICT education and practice. While basic computer literacy is both necessary and beneficial, the development of innovations and deep-knowledge capital benefits in a society only become apparent once local practitioners have been trained and educated until they master ICT at the deepest possible levels (Chapter 1, Section 2.1).

To summarize, I developed the CATI model together with my colleagues to be used and applied as an instrument for producing sustainable ICT in developing countries. It achieves this by offering tools for supporting and analyzing the planning and implementation processes, by deciding upon the kind of ICT and ICT education necessary in the circumstances, and by evaluating the ability of students to apply previously acquired knowledge. By doing this, I have answered the first research question Q1, namely: *What kind of theoretical and practical framework is appropriate for understanding the process of ICT transfer in the context of a developing country such as Tanzania?* (PAPER I-IV)

5.2 Contextualization account in the Contextualized Programming course

My colleagues and I developed the *Contextualized Programming* course to answer local needs for applicable deep ICT knowledge for development, which has been rarely studied in the field of CSE (Sections 2.1.2, 2.2). We decided that local context and development should be the basis for a development like this. Tumaini University was offering an Introduction to Programming course for B.Ed. students, which we decided to use as the foundation on which to build our intervention. (Sections 3.1, 4.2)

I initiated the preparation process of the Contextualized Programming course in 2003 by consulting representatives of Tumaini University and my Western colleagues. We discussed items such as the content of our projected course and thereafter had exploratory workshops in late 2003 and 2004 at Tumaini University and the rural Pommern Secondary School near Iringa. The objectives for the programming course included: (1) engaging students at the level at which they found themselves at the time, (2) the furtherance of application in the context of local needs for the benefit of local society, and (3) a gradual expansion of understanding from a basic mechanical knowledge of programming to an appreciation of the wider purposes of ICT and ICT applications. During the first part of 2004, we engaged in the course materials and the details of course content (see Section 4.2).

The preparation, implementation and follow-up phases of the course were analyzed separately by a Tanzanian ICT researcher and myself as a Western researcher. In analyses we underlined the meaning of the local context and relevance of the process for it (Section 3.1). As a joint categorization tool for this we used the CATI and its levels Import, Transfer, Apply and Contextualize developed earlier in the research (Section 5.1; PAPER III).

Table 12 shows the analysis of the course *preparation* phase based on the CATI model. The objectives of the course were evaluated on the contextual level, based on local sustainable background and goals. The global curricula had an effect on the course content preparations although the local content were revised a number of times. This part was located at the application level. A problem with the course material design and manufacturing was the lack of balance between Western staff members and local participants.

Table 12: Evaluation of the course development process before the Contextualized Programming course 2004-2005 (cf. PAPER V)

Preparation activities	**CATI level**
Setting up objectives	Contextualization
Course content preparations	Application
Development of the course materials	Transfer

As development researchers, we adapted the course *implementation* activities based on the limited ICT background of the students who were going to enroll the course. One of the main elements in this work was to extend the students' knowledge of the uses of modern forms of technology because most of them had little knowledge of the potential inherent in current technological development. Apart from the lectures and exercises with contextual materials, we introduced students to the concept of the learning diary so that they would become accustomed to contextualize their ideas by keeping local background and needs constantly in mind. As teachers we tried to be as sensitive as possible to problems, difficulties and hesitations on the part of students as we strove to provide them with a deep learning experience and a thorough comprehension of the content. We also arranged that all course projects would be undertaken in secondary schools or focusing on them because it was the ambition of all the course participants that they would eventually teach in secondary schools. The teaching and learning elements of the course were located in the application level. (Table 13)

What was missing in these activities was the contribution of the local teacher. All our preparations and plans were based on an understanding of equal contribution of a local and a foreign ICT teacher. The local teacher was to be the contextual expert and the foreign one the global subject area expert. This way the contextual relevance of the course would be best fulfilled. It is only at the transfer level that the value of the contribution of the teaching staff can be evaluated.

Our digital learning materials were designed based on the metaphor of the community-based learning *village* – a metaphor that was readily comprehensible to all our students (Section 4.2.2). A missing element in the material was the lack of the local experts' participation in material production and updating. The material was based on a local server and it was easy to update. The course-forum was free-ware. The digital learning materials were evaluated to be in the application level.

Although the activating, supporting technologies were to support learning, they also presented us with a sustainability problem. While it is difficult to determine the current and future availability of I-Blocks used for concretizing technology, the visualization tool Jeliot is always freely available (Section 4.2.2). Problems relating to the use and availability of this technology during that time located the component at the *transfer* level.

Table 13: Implementation of the course in terms of the CATI levels (cf. PAPER V)

Implementation	**CATI level**
Teaching activities including exercises, learning diary and projects	Application
Teaching staff	Transfer
Digital learning materials	Application
Activating technologies	Transfer

I define the *follow-up phase* as the phase where innovations and supplementary activities were introduced after the course 2004-2005. In 2005-2006, we introduced no substantial or far-reaching changes to the course content. One of our sustainability problems was that the courses were taught only by a Western teacher in 2005-2006. This disadvantage was somewhat reduced by the fact that students who had passed the course of the preceding year supervised the students' projects for the succeeding year. Some of the projects were also carried out in a context of a rural hospital. While this contributed to a reinforcement of capability building and a contextualization of student projects, it did not solve the sustainability problem of teaching staff for the coming years. This absence of the local engagement, the missing *pull effect,* was evaluated as part of the transfer level (see Section 1). (Table 14)

The Western partners in this project were committed as they exerted themselves in their efforts on behalf of course implementation and development. They also focused on the supervision of students pursuing topics for their required bachelor thesis, as well as on the creative expansion of projects in the field, for example, to benefit hospitals, schools and other local institutions in the region, as well as the development of new devices and approaches relevant to these efforts. These activities were on the application level of the CATI model. It is even possible the Western partners were too active in their involvement with, and support of, the project. If that was the case, they were inadvertently infusing the *push effect* into the collaboration (see Chapter 1).

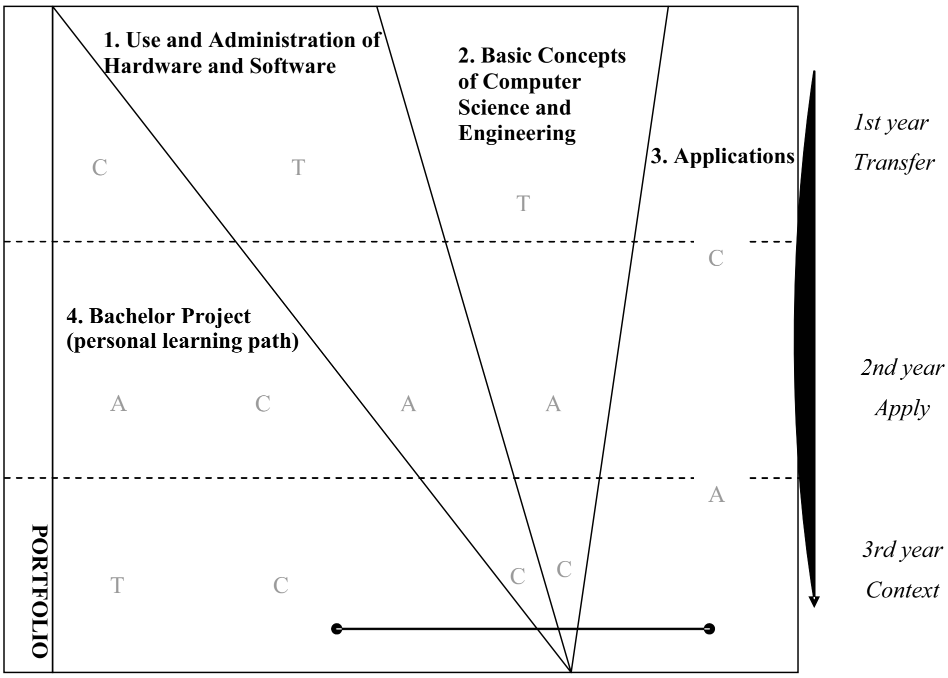
The overall usefulness and impact of the course implementation to the local university including the side effects and the spin-offs were evaluated to the application level. The student projects, for example, supported rural organizations by providing students' ICT expertise for them. They also provided a forum for the practice of participatory approaches such as constructivist pedagogical techniques (Section 2.3) and inspired novel projects such as the first East African Science Park, which was built in 2006. The IEEE International Technology for Education in Developing Countries (TEDC, 2006) workshop was organized at the Science Park including field activities in the Iringa region in July 2006.

Table 14: Follow-up phases described in terms of the CATI level (cf. PAPER V)

Follow-up phase	**CATI level**
Commitment of the local university	Transfer
Commitment of partners	Application
Usefulness for the university (and students)	Application
Spin-offs	Application

The course continued in quite the same way also in 2006-2007. There is an independent company that manufactures I-Blocks at the Science Park, and a localized IT bachelor programme will be started for the first time in September 2007 (Figure 19; PAPER VI). This bachelor program design has, from the beginning, placed a strong emphasis on community needs and local applicability. It also demonstrates the strength of Tumaini University's long-term commitment to the spirit of the project (*pull effect*).

To summarize, the data shows that although there are several contextual elements in the Contextual Programming course 2004-2005, a number still remain to be developed. If one considers the CATI levels, this indicates that the course was focused mainly on the application level as stated in detail earlier in this section. There will be a number of opportunities in the future to improve the transferred elements to better meet the context and concentrate more specifically on the approaching contextualization level with projects such as, for example, the implementation of the IT bachelor degree program (Figure 19). The research question answered by preparation (development), implementation and follow-up phase analysis is: *How was contextualization taken into account in the Contextualized Programming course?* (Q2) (PAPER I, IV, V; cf. PAPER VI).



Note: C=Contextualize, A=Apply, T=Transfer, I=Import

Figure 19: IT degree programme that focuses on the transfer, application and contextualization levels of the CATI model (PAPER VI)

5.3 Contextual outcomes of the Contextualized Programming course

Since the evaluation of the contextual outcomes of the Contextualized Programming course is a long-term project, this research concentrates on the identification and description of students' creative application ideas and opportunities they express. These thoughts may have a significant influence in the future. It is even possible that a totally separate research project might be devoted to long-term follow-up and the effects of the current intervention.

When I consider the general learning outcomes of the course, there were I-Block and Java project groups at the course, and the differences between the two groups were evaluated based on the final examination results. There were no significant differences. The exploratory clustering gave preliminary results that there were only a few I-Block project students in the weakest students' cluster of students based on exam results. An interesting results was that the students' points in the traditional programming exercises were not as good as in the most application-oriented I-Block question (sig. 0.000) respectively by Wilcoxon test. In general the student results indicated that they are still weak in basic programming skills, an effect also noticeable in their responses to the algorithm-related assignment in the questionnaires administered at the beginning and at end of the course. The good results that they obtained in their handling of the I-Block application questions nevertheless indicate that the students show a commendable level of skill and understanding in the application of their expertise and knowledge to practical projects. (cf. PAPER II)

There were significant, measurable changes in the students' awareness of ICT and its opportunities based on the mean changes detectable in the coded open questions between the questionnaires administered at the beginning and at the end of the course. The overall change was indeed meaningful because of the 0.002 significance in the sum factor by paired samples t-test (Table 15). This indicates an overall change in student awareness of ICT opportunities and potential for applying ICT to the local context. It is this kind of awareness that the intervention was designed to evoke in ICT students.

A CATI-based analysis of the data from the interviews also shows that most of the students attained the application level (Table 16). Even though the responses of some of the students show that they remain on the transfer level, various contextual elements are discernible in many of their answers. While it takes time for a student to make the move completely to the contextual level, it was nevertheless gratifying to note that even this short intervention inspired a number of impressive application ideas in the university setting and in the local society.

Table 15: The average number of application ideas identified at the beginning and at the end of the course (PAPER IV)

Question	No. responses (average) per questionnaire (Q'aire 1)	No. responses (average) per questionnaire (Q'aire 3)	Mean difference	Significance of the change
ICT awareness / ICTs in the students' environment				
1. Where is information and communication technology or robotics around you in your everyday life?	2.54 (SD 1.70)	3.12 (SD 1.14)	+0.58	0.053
2. Where could you apply programming or robotics skills in your society? How?	1.69 (SD 1.41)	2.12 (SD 1.24)	+0.43	0.086
Opportunities presented by ICTs				
3. What are the opportunities for ICT in your life?	1.46 (SD 0.99)	2.19 (SD1.02)	+0.73	0.005
4. What are the opportunities for ICT in Tanzania?	1.38 (SD 1.10)	2.00 (SD 1.10)	+0.62	0.015
Combined				
Questions 1, 2, 3 & 4 combined	7.08 (SD 3.53)	9.35 (SD 3.17)	+2.27	0.002

Note: responses of 26 students, SD = Standard Deviation

Table 16: Interview responses indicative of the general CATI levels (A), and the distribution of all quotations in the means of CATI levels (B) (cf. PAPER IV)

A. General CATI levels attained by each student			**B. Classification of quotations in terms of CATI levels for each student**		
Level	Amount	Percent	Level	No. quotations	Percentage among all quotations
Contextualize	-	-	Contextualize	15	7.9 %
Apply	17	63.0 %	Apply	94	49.7 %
Transfer	10	37.0 %	Transfer	75	39.7 %
Import	-	-	Import	5	2.6 %
Total	27	100.0 %	Total	189	99.9 %

The unexpected outcomes (called also spin-offs) of the course (see Section 4.2.4) are also contextual outcomes of the course. These are local institutional capacity-building projects and events, and they include international events like TEDC 2006 -workshop, authentic field project orientation, pedagogical development, and the Science Park establishment among others.

Taken together, the results answer research question number three (Q3): *What are the meaningful contextual learning outcomes of the students referring to applying ICT skills and knowledge?* (PAPER II, IV; cf. PAPER V, VI)

6 Conclusions and recommendations

In this research, I have:

1) established a basis for contextualized ICT and ICT education project implementation in developing countries such as Tanzania;
2) implemented and analyzed the Contextualized Programming course for undergraduate B.Ed. students at Tumaini University, Tanzania; and
3) analyzed the contextual outcomes of the Contextualized Programming course that was implemented for the first time in 2004-2005.

The reiterative and cyclical development research that I undertook between 2000 and 2006 has provided ample demonstration of how important it is to take *context* into account in ICT provision and education in a developing country such as Tanzania. The design and methodology of the intervention gave innumerable opportunities to remain sensitive to all aspects of the local context and thus achieve the outcomes that I had hoped for. It also gave an opportunity to show that an approach that focuses on local needs and context is able to lead to *sustainable development* and *reduction of the digital divide or gap* – two factors that are too often missing from development projects introduced into the developing world by sponsors from industrialized countries (Chapter 1, Section 2.1).

One of the paradoxical risks inherent in the contextualized approach is that the efforts to achieve contextualization might be so successful that a digital divide of another kind could become evident in the wake of a truly indigenous and successful approach to ICT (Chapter 1, Section 2.1). But local ICT operatives can prevent this from happening by ensuring that they remain familiar with global trends in ICT as well and that they relate these trends and innovations to their local conditions. By keeping in touch with global trends and developments and by applying them to local conditions and problems, it is possible for local people to enjoy the best of both worlds as they innovate and construct a unique local ICT culture in their own countries (Figure 20).

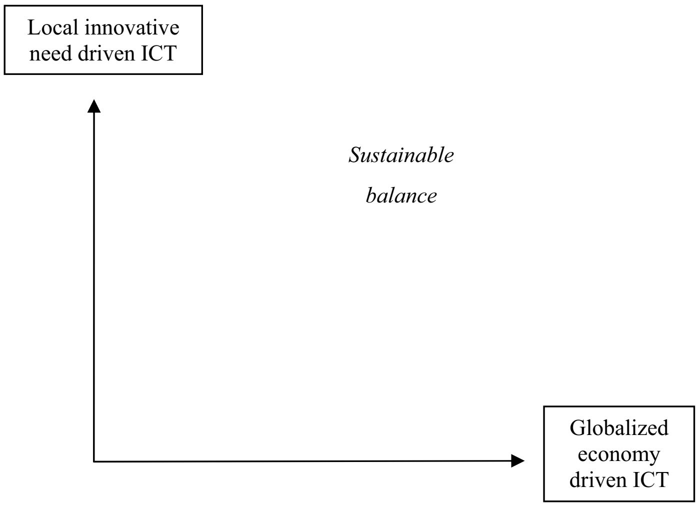


Figure 20: Sustainable balance between local and global ICT

The CATI model is advantageous for monitoring and guiding the transference of global innovations into the local ICT environment. Very little research on this kind of CSE has been carried out especially in East Africa (Section 2.2). Research such as this is therefore both necessary and relevant especially because foreign assistance to developing countries is often compromised and even rendered useless by insensitivity towards local problems and ignorance of local conditions, and approaches are lacking the human perspective and pedagogy (Sections 2.1, 2.3).

I decided to use a form of cyclical *development research* with ICT students at Tumaini University to answer the research questions (Sections 3.2, 4.1). If I had focused only on the conventional theory or practical projects, I would not have achieved the high level of ICT transference which the intervention ultimately achieved. The conditions and problems encountered in Tanzania, typical though they are of conditions in a developing country. They made my colleagues and me realize that adaptability, flexibility and sympathetic sensitivity to local conditions were all supremely important conditions for achieving anything of value in the project (Section 3.1).

"I did not use computer for education before came to Tumaini since I was not aware [of] any other kind of computer applications apart from emails"[4]

My research approach therefore strongly emphasized *flexibility* in adjusting to local needs and conditions as they arose. Because of our openness towards local conditions from the beginning and because of our respect for the local culture as we experienced it, our implementation activities became educative, not only for the students, but also for us as lecturers, teachers, facilitators and administrators as we were obliged to confront problems of challenge and resolution on a daily basis. We were convinced then, and are even more convinced now, that context-sensitive planning and implementation based on the CATI model increases a developing country's ICT capacity in a globalized market place. This research also gives us ample grounds for believing that a context-sensitive approach based on the CATI model provides a solid basis for future development and long-term sustainability in the ICT education field (PAPER III, IV, VI).

The intervention was a challenge to all those who became actively involved in it. Each member of the research and implementation team had to become an expert in the methodology and assumptions that scaffold context-sensitive ICT provision in developing countries. The challenge for all participants were: (1) to acquire a profound understanding of local culture and conditions, (2) to teach students whose background were very different from ours, (3) to construct CS/ICT knowledge and expertise while keeping a constant eye on context and response, (4) to master constructivist pedagogical theory and practice, and (5) to have a clear understanding of the requirements of development research. This all was also needed for a high standard analysis of the students' outcomes in a context related "joining together" manner.

Research methodology in this study nevertheless has certain limitations and restrictions: Development research is always time consuming when compared to most of the other research methodologies. Even so, had the research period been longer, it would undoubtedly have provided us with even more convincing data. Even though we had to set a cut-off point for this particular study, I am confident that the research that we were able to undertake between 2000 and 2006 provides us with a useful basis for further research in similar or parallel conditions. The

[4] *email from a year 2004-2005 student, 4th March, 2007*

time allocated to this research was longer than the average time allocated for research in most doctoral programs.

Had it been possible for me the researcher to remain in Tanzania uninterruptedly for a number of years, it might have been feasible to undertake even more participatory *action research* approach. A more fluent comprehension of local African languages, such as Swahili, would undoubtedly also have helped to facilitate deeper understanding between researcher and students – even though English is the *lingua franca* of higher level instruction in Tanzania. For Westerners in a developing context such as Tanzania, it is necessary to achieve and maintain a reasonable *balance* between being an outsider and being open and appreciative towards local culture, customs, languages and conditions. In spite of these requirements, every researcher needs to retain a sufficient degree of objectivity to remain true to the knowledge that he or she is importing while observing and analyzing whatever experimental data becomes available. This is only possible if researchers maintain some degree of distance from the local cultures and institutions. While knowledge and expertise need to become indigenized, it is counter-productive for a researcher to lose perspective and objectivity because of becoming uncritically immersed in local cultural conditions. Van den Akker (1999) calls this balance critical distance. While some members of our research team were born and brought up in East Africa, others had never even visited Africa although they are all competent professionals and experts in ICT.

The actual implementation and development of the Contextualized Programming course did not proceed as smoothly as we had expected it would when we were still in the early design stages of the project. Earlier research reports had led us to expect that we might encounter difficulties in securing commitment and establishing local partnerships, and this indeed proved to be the case (Sections 2.1, 2.2, 5.2; PAPER V). It was only in the context of the local culture that we achieved the best possible solutions to existing problems. Many of the problems that we encountered from the very earliest stages of the research arose out of deficiencies in the local ICT expertise and infrastructure. But these problems merely stimulated us to identify and implement solutions. One of the solutions that evolved in response to these problems became the IT bachelor degree that Tumaini University offers the first time in September 2007 (PAPER VI).

"The Internet from where I live is very far. [The] whole district [in which] I am living [does] not have Internet services and I am forced to travel about 80 kms to get the Internet."[5]

This research focused on the computer science side of ICT education. This limitation was made because of the domain of computer science, and also because of focusing on the authoring and developing ICT for future. This meant focusing on new innovators, in addition on end-users. While a further analysis of the teacher interviews might have been done, I decided to focus on the students and their future careers in the local society. I also had to bear in mind the limitations that the students would encounter in their own country in the future. Even though the present infrastructure is updating and improving, there are still deficiencies in it (Section 3.1).

There are some deficiencies and limitations in the included publications (PAPER I-VI). One of them is that the literature on development impacts might have been more thoroughly described in these publications; this has been done in Section 2.1.

PAPER I collated and analyzed the real needs of the students from their expressed opinions on the usefulness of our experimental approach and other techniques such as the use of I-Blocks to concretize learning. PAPER II applied quantitative measurements to the whole group of 27 students. An exploratory approach made the interpretation of results difficult. The subsequent publications provided more rigorous conclusions though. There are minor deficiencies such as spelling errors in PAPER II and PAPER IV. In PAPER II, some inaccuracies occurred such as the overoptimistic estimate that the gross national income (GNI) growth of Tanzania would be around ten percent instead of the actual between 6 and 7 percent in 2004.

While PAPER III was somewhat too technologically oriented for this research, PAPER IV probed far more effectively into the *human* problems and challenges inherent in ICT education research. The analyses of this publication could have been even deepened, but to cover the whole spectrum of this long term research process, the analyses were limited to the reported students' application ideas. It would also have been helpful if the analysis provided by PAPER V had been more solidly based on theory rather than on the practical approaches associated with the CATI model.

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[5] *email from a year 2004-2005 student, 6th September 2006*

Since the qualitative methodology of this research focuses clearly on context, it increases the *resonances* of the research while severely limiting its *generalisability* to the description of patterns and trends and to making recommendations (Section 4.1). The qualitative and contextual nature of this development research, imposed by local conditions, and its explorative design also excluded the possibility of any type of *control group* for comparative purposes in this study. The context-sensitive approach also gave an opportunity for misunderstandings and even a degree of disillusionment on the part of the researchers. Most of these difficulties were eventually surmounted as the researchers became more familiar with local conditions and as the intervention gradually began to bear fruit after a number of years of steady application.

Further research in this field might profitably pursue a community development line of approach by investigating the effects of the development process into the participants themselves. Valuable supplementary information might also be obtained from research that investigates the misunderstandings and conflicts that inevitably arise between active partners from developed northern countries such as Finland and Denmark and those from developing southern countries such as that of Tanzania.

Another valuable line of research is suggested by an analysis of the implementation of the local IT bachelor's degree offered at Tumaini University for the first time in September 2007. It would be very interesting to investigate the impact which the graduates of this degree make on the local development, business and industry in the future. Studies such as this would both supplement and extend the scope of the present research and continue the periodic reiterations required by cyclical research.

While there is obviously a need to evaluate further CATI-based approaches in developing societies, the application of the CATI model to conditions even in Western countries would be both instructive and interesting, and would doubtless extend both the range and utility of the present model. An extension might also include the subdivision of the CATI model levels (contextualize, apply, transfer, and import) into sub-categories in specific fields such as support services, infrastructure, business and education. This would make the model more focused and more widely applicable.

In the field of *policy* I recommend a continuation of long-term research and simultaneous practical implementation hand in hand. Such approaches should be squarely based on innovation and exploratory interventions in context-sensitive conditions. In my opinion, the best results will be obtained by avoiding small short-term projects and by focusing resources for the purpose of achieving continuous sustainable development in the field of capacity building. All this depends on the ability of researchers to approach as near as possible to the ideal of achieving an equal partnership with the beneficiaries of these initiatives. Although no partnership is ever entirely equal, it is not impossible to constantly strive for equality. The nearer we come to achieving equality, commitment and goodwill in partnerships, the more likely it is that developing countries such as Tanzania will be able to implement their own local solutions and even make creative and original contributions to the global ICT culture in the future. The more this happens, the more realistically will we be able to fulfill the WSIS vision of general access to ICT for all, and the more likely people from all over the world will be able to function not only as recipients but as active and equal participants – innovators and developers in information society.

"...to write different research and papers on ICT so that many people [Tanzanians] will get the knowledge [about] it and gain the benefit of ICT."[6]

[6] *email from a year 2004-2005 student, 6th September 2006*

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Publication PAPER I.

1

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I-BLOCKS for ICT Education Development, Case Iringa, Tanzania

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***Abstract*— The main aim of our research is to design and develop ICT education that would serve the needs of developing countries. Most of the present ICT tools are based on Western culture and logic and do not necessarily correspond to the ways of thinking in other cultures. We developed Intelligent Building Blocks (I-BLOCKS) to support learning by construction and, more specifically, to support "programming by building". By attaching a number of basic building blocks (each containing a microprocessor and communication channels) together, the user constructs an artifact which can perceive input, process it, and produce output. We had two "programming by building workshops" in Tanzania in October 2003 and April 2004 at Pommern secondary school and Tumaini University, Iringa University College. The students programmed with LEGO DUPLO covered I-BLOCKS. We evaluated their learning process and analyzed their concept maps, figures and written feedback.**

Keywords - ICT education, local context, I-BLOCKS, programming, developing countries

1. INTRODUCTION

Information and Communication Technology (ICT) is already almost everywhere, and it seems useful in many applications. In this article, we want to ask is it needed similarly everywhere and should it be taught the same way everywhere.

Our research is located in Tanzania, Africa. We are endeavoring to find out what are the local and specialized needs for promoting high level knowledge of ICT for development. At the same time we are developing tools to help students understand the basic foundations of ICT.

We developed Intelligent Building Blocks (I-BLOCKS) [1] to support "programming by building". By attaching a number of basic building blocks (each containing a microprocessor and communication channels) together, the user constructs an artifact which can perceive input, process it, and produce output. This method introduces learners to the basic principles of technology and the basic Western logic of programming. After understanding the basics of those, it is easier to continue by using more abstract tools and programming languages.

We had two "programming by building workshops" in Tanzania, the first in October 2003 and the second in April 2004 both at Pommern secondary school and Tumaini University, Iringa University College. The students programmed with LEGO

DUPLO[1] covered I-BLOCKS and evaluated their learning process by developing concept maps and figures, and by giving written feedback. We observed their learning processes and outcomes.

The focus in this case-study research is to analyze the contextualization needs and usefulness of I-BLOCKS in supporting learning of the first steps of programming and new technology for development in local context.

2. ICT, EDUCATION, AND THE LOCAL CONTEXT

Only 5.8 % of children enroll in secondary education and less than 1 % enroll in tertiary education [2]. Very rarely do schools have ICT education in Tanzania, and especially the public rural schools do not have computer laboratories at all. The ICT curriculum for secondary schools from 1996 is mostly out of date. [3] The curriculum raises the question of whether these students should study computer literacy or computer science, too.

There is a lack of well-qualified teachers and professionals in ICT. The University of Dar Es Salaam is the only meaningful University level institution, which provides Computer Science education. However, the capacity of it is limited. [3,4]

As is generally known, the local culture and context in Africa is quite different than in Western societies. Since our work began in Tanzania in 1995, we have noticed that the ICT curricula in Tanzania are very similar to the curricula in Western societies. Questions about the curricula and ICT education has been raising:

- Do the curricula meet local needs?
- Are the local curricula needed?
- What kind of learning support is needed?

Our approach teaches computer science in a manner which supports understanding and prepares students to use and develop the new technologies. The vision is that they are the innovators and developers of the future in Tanzania.

3. DEVELOPMENT OF ICT EDUCATION AND LOCAL NEEDS

The National Information and Communication Technology Policy of Tanzania [3] emphasizes human capital, local content, and ICT leadership as the developmental needs of the ICT field. The meaningful parts of those needs are the equal opportunities for development of human capital in addition to the development of teaching methods and curricula.

Among the ICT national policy [3] and our previous studies [e.g. 5], we are developing ICT curriculum in collaboration with the Tumaini University, Iringa University College. The focus is to develop the kind of curriculum which meets local needs and promotes local development. For that, different courses and starting points of education might be needed.

We have started by introducing programming. Instead of using a computer, we use concrete I-BLOCKS that enable non-expert users to construct ICT artifacts within an hour. By using I-BLOCKS, students become familiar with the basics of ICT and programming before they move on to actual programming. That kind of bridge should support the understanding of the basics of (Western) programming ideas.

[1] LEGO and LEGO DUPLO are trademarks of LEGO System A/S.

4. I-BLOCKS AND PROGRAMMING BY BUILDING

I-BLOCKS technology was developed in order to support our long term goal of allowing ”programming by building” [1]. In order to exemplify the concept of ”programming by building”, a series of intelligent building blocks (I-BLOCKS) were developed. Each intelligent building block contains processing power and communication capability. When two building blocks are physically connected they can communicate to each other and process the received information from neighbors. The initial I-BLOCKS were housed in LEGO DUPLO bricks, and each was equipped with an electronic circuit containing a PIC16F876 28-pin 8 bit CMOS Flash microcontroller and a number of serial two-way connections, two connections on the top and two connections on the bottom of each building block (Fig. 1).

In a typical set up, each building block will receive input on its communication channels, process this input, and then send the output of the processing procedure as output to the communication channels. A construction of such building blocks will have functionality defined by the physical construction (i.e. the topology), the input, the processing procedure in the individual building blocks, and the communication scheme. If input, processing, and communication are pre-defined, the user of such a system can decide the functionality of the system exclusively by manipulating the physical structure. However, in extensions of such a system, it may be desirable to allow input to be decided at run-time, for instance, through the inclusion of sensors.

a) b)

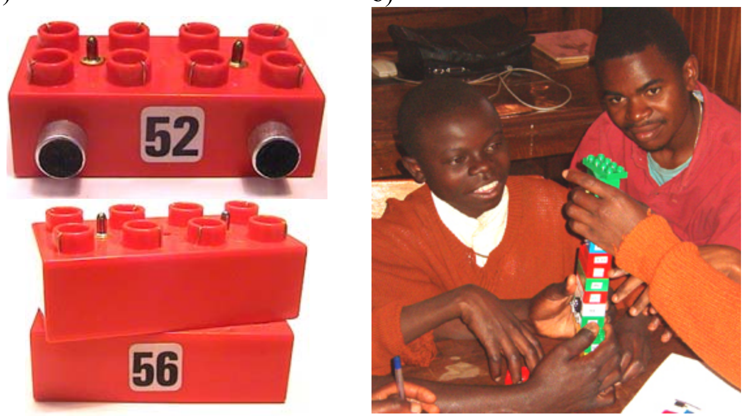

Figure 1. Intelligent building blocks implemented in LEGO DUPLO a) 52: sensor building block with two microphones, and 56: motor building block that contains a servo motor (Copyright 2002, H. H. Lund); and b) students building by I-BLOCKS in Tanzania.

There are input building blocks (LDR, microphone, IR, touch sensor, etc.) and output building blocks (motor, sound, display, etc.). Also, there is a rechargeable battery building block and a battery building block for standard 9V batteries. Further, for the second workshop in Tanzania, based on the wishes by the Tanzanian students during the first workshop, we developed radio communication I-BLOCKS, accelerometer I-BLOCKS, and ultrasound sensor I-BLOCKS.

With these I-BLOCKS, it is possible to construct a huge variety of physical objects with various functionalities. The processing in the physical construction is distributed among all the building blocks, and there is no central control opposed to traditional computerized systems (e.g., traditional robots). The distribution of control is obtained by allowing processing within each individual building block.

Importantly, the I-BLOCKS provide a continuous process of building and observing action responses from the ICT artefact construction. This contrasts other robot construction kits, such as the most commonly known LEGO Mindstorms robotic construction kit. With LEGO Mindstorms and other similar robotic kits, the building, programming and observation of response is split into separate processes. First the users build a robot, then they program on a host computer and transfer the program to the physical artefact (the robot), and then they observe the result. [6] We found that such a split into separate processes may be unfortunate, and that building and understanding of ICT artefacts can be more intuitive if the processes are better connected. With the I-BLOCKS, we integrate these processes, so that the users are continuously receiving the feedback from the actual system while they are constructing the system. They do not have to do abstractions in a programming language on a separate host computer.

For the workshops, we used four applications, namely I-BLOCKS for emotional constructions, I-BLOCKS for mathematical training, I-BLOCKS for language grammar training, and I-BLOCKS as free tools for developing artefacts. Some of these applications can be used for free, explorative play, whereas others were used in a more direct educational setting with a more direct subject aim (i.e. math or language). The development work of these has been done with V. Palma from P. Marti's group at the University of Siena [7].

The main idea behind the I-BLOCKS for emotional construction is the implementation of a system that allows the user to construct different emotional models by the different physical constructions of I-BLOCKS systems. The arithmetic blocks include blocks for addition, subtraction, multiplication and division, sensor input blocks for setting input values, and output blocks to present output values. In the linguistic scenario we transfer a well-known task used by speech therapists to the I-BLOCKS, in order to give more feedback and more sensorial information to child. [7] The fourth kind of I-BLOCKS tools were developed that provide possibilities for the end-users to define their own problem domain, rather than to work with a specific, pre-defined problem domain as were the cases with I-BLOCKS. The I-BLOCKS for this kind of free activity include inverter blocks, threshold blocks, memory blocks, etc. [8]

Based on the experience and evaluation of the first workshop in Tanzania, we also implemented, together with L. Pagliarini and J. Nielsen, a simple, graphical programming environment that would allow the students to modify the contents of the individual I-BLOCKS, in order to move one step further in opening up the black box and towards the understanding of programming.

5. First Steps of Develoment

5.1. Methodology

We had two parts of the whole I-BLOCK / "programming by building" workshop. The first workshop was held in October 2003 and second one was held in April 2004. The workshops were at Tumaini University and Pommern Secondary School, Iringa region, Tanzania.

Basically, the workshops started with free play with I-BLOCKS. Next, we had students do basic programming tasks. Additionally, the second workshop included final project work and abstract programming tasks that were carried out using the Jeliot visualization tool for learning Java [9].

The first workshop was mostly for testing the usability of I-BLOCKS in context. The second workshop was more for going deeper into the theme and for using more complicated tools than were used in the first workshop.

We conducted workshop I for 7 hours at Tumaini University and for 4 hours at the rurally located Pommern Secondary School. We had 27 university students of journalism, aged 21-42, and 11 secondary students, aged 15-25. During the second part of the workshop, we had 11 students at the University for 8 hours and 12 students at the secondary for 4 hours. For workshop II, all of the university students except one, were participants in the workshop I; most of the secondary students were new. Ages of the student were quite similar as in the first workshops.

We collected mostly qualitative data by using questionnaires, concept maps and figures, and by observing students' constructions and actions. The written data was sorted, classified, and categorized. The classification was reviewed and affirmed by other researchers. [10]

5.2. **Workshop I**

We started the first workshop by asking the students to freely make constructions using arithmetical and emotional I-BLOCKS. Students worked quite fast and built a variety of working "towers" using the I-BLOCKS. The constructions they built were quite traditional, but the group work was very intensive and a couple of groups seemed to have fun too. Next, the students used language blocks. Using language blocks was very easy for the university students.

The university students were able to build what they intended to build. Most of the students did not have major difficulties using I-BLOCKS. Some minor difficulties were that the I-BLOCKS were a bit hard to join together or that for instance it was difficult to make them emit specific sounds.

When we asked the students to relate what the I-BLOCKS or the building process using I-BLOCKS resembles in the Tanzanian context, the most frequent response was that using the I-BLOCKS resembled building, especially the process of house building (TABLE I.). Other answers were that the I-BLOCKS resembled certain things/tasks, robots, computers, the system of the society, toys, or electronics.

The largest amount of the house building responses changed our assumptions of localized I-BLOCKS. Before this workshop, we thought that LEGO DUPLO covered I-BLOCKS should be contextualized by changing, for instance, the form of the blocks. The feedback told us that these blocks are also suitable for the Tanzanian context. On the other hand, the answers show a mechanical view of I-BLOCKS.

The other interesting answer category was that the process of using I-BLOCKS was similar to the processes and systems of society. As one student's figure (Fig. 2a) shows, the student's interpretation is that the government cannot work without the citizens who are the batteries. The I-BLOCKS need each other to be able to work together to accomplish an overall plan; each of the blocks has a special role and the location.

TABLE I. THE ANSWERS RELATED TO "WHAT DOES I-BLOCKS RESEMBLE?"

Name of the category	**Sub category**	**Composed from k-amount of comments**
Building		*27*
	building houses	*(17)*
A thing / task		*19*
Robots / automation		*12*
Computer		*10*
	input-output system	*(6)*
Society / communication		*7*
Toy		*4*
Electronics / electricity		*4*
No category		*12*

Students thought that I-BLOCKS are useful for education in Tanzania and that I-BLOCK related applications could be useful in the fields of industry, entertainment, and for instance in airport and cargo services.

The students stated that they felt that they had learnt how to make constructions by using I-BLOCKS, and got basic ideas of how does a computer work, what is programming and what is the background of the technology. One example of how students explained their learning of inputs and outputs is visualized in Fig. 2b. Anyway they were not yet totally mastering the concepts. In general, the results indicated that the basic goal of the workshop was fulfilled and it is worth continuing development of this type of education.

a) b)

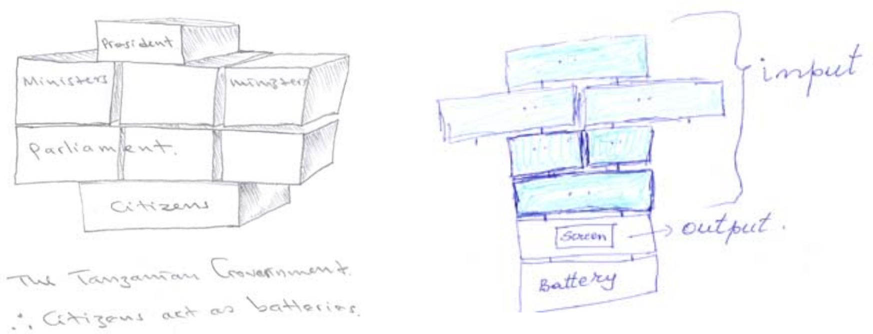

Figure 2. Students figures explaining a) the ideas of I-BLOCKS in society and b) input-output concepts.

5.3. Workshop II

The groups started workshop II by analyzing the complex actions of each I-BLOCK. After that, the groups made constructions using different I-BLOCKS. They modified the contents of the blocks a bit through a computer programming interface. Finally, we collaboratively decided on a project idea to be built and programmed. At the university, as a final task, we asked the students to utilize their skills by doing Java programming via Jeliot, a Java programming visualization tool [9].

Basically, the university students understood that the I-BLOCKS are controlled by humans. They learned that the person gives the I-BLOCK commands and the I-BLOCKS carry out the commands like robots. This represents the background ideas of programming and new technology. The secondary students designed objects like intelligent homes by using movement, sound, and light sensors when asked to create something related to their daily life.

For the final project, the university group decided to build a car alarm system by using I-BLOCKS. One group built a sensor-transmitter system and the other group built a receiver system. Their projects seemed to work. The planning and building of the car alarm system was evidence of success for us given the short amount of time involved. Especially, we noticed how the students were able to work together as two groups, building a common project which involved fairly difficult concepts related to sensory input (ultra sound sensors, flex sensors, accelerometer); output (motor, sounds); and communication (radio communication) between the car alarm and the receiving device that provided the output.

We continued the workshop by moving onto more abstract formats of programming with the university group. We used Jeliot visualization, which uses Java language. We gave the students some basic, mostly mathematical, tasks to do. We observed that the students understanding of inputs and outputs helped them use this written language. They were also able to do some small programs relevant to the local context and they understood the variable concepts (Fig. 3).

```
import jeliot.io.*;

class papaya {
public static void main() {

int papayaPrice = Input.readInt();
int pineappleprice=Input.readInt();
int papayaprice=Input.readInt();
int quantity = Input.readInt();
int product = papayaPrice * quantity;
Output.println(product);
            }
}
```

Figure 3. Jeliot program "papaya" made by students.

At the end of the workshop, the university students were asked to evaluate the state and future of ICT in Tanzanian. The students thought that ICT education should be developed with the assistance of Western people, but they also thought that the local authorities should be responsible for that. They also thought that ICT skills and opportunities should be available everywhere in the country.

6. CONCLUSIONS AND PROCESS TO CONTINUE

The preliminary, explorative results indicate that the I-BLOCKS may be a suitable tool for technology education in the Tanzanian context. We recognize that the results are very preliminary and that our method has been mainly explorative, so far. New innovations and uses related to those presented here are of course needed, but the use of the I-BLOCKS already looks promising for teaching the ideas behind modern technology and the basics of programming.

The next step will begin in October 2004 when we start the 'Introduction to Programming' course for the bachelor of education (mathematics) students at Tumaini University. We will start it with an I-BLOCK–Jeliot workshop and continue by using Java as programming language. Throughout the course we have connections to localized I-BLOCK ideas. We will finalize the course by another workshop.

Using these ideas with teacher trainees is very important, because they can learn to teach their own students to understand and apply technology. Their students could be future innovators and developers of the country. Indeed, as part of the programming course, students will perform teaching workshops at Pommern Secondary School teaching I-BLOCKS technology and programming to secondary school pupils.

The work will proceed by analyzing the course content of the fall 2004 semester and by analyzing student outcomes. This will be the basis for the next courses and the basis for the development of local ICT curriculum at Tumaini University.

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2

In Search of the Point-of-Contact: Contextualized Technology Refreshes ICT Teaching in Tanzania

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Abstract

Meaningful learning of Information and Communication Technology (ICT) requires students to understand ICT concepts in their own cultural or societal context. In this study, we hypothesized that grounding ICT education in the local context and using concretizing tools, like programming visualization and Intelligent Building Blocks (I-BLOCKs), would benefit students. We investigated this hypothesis by first developing an introductory ICT course in programming, which applied these strategies, and then by analyzing the results of the course. The course was held at Tumaini University, Iringa University College, Tanzania, in the fall of 2004. Altogether 27 teacher-trainees participated in the course. The outcomes of the course showed that the students understood the main concepts that were taught. They were also able to apply the methods of creative problem solving that were taught in the course. It was also found that students' algorithmically-oriented understanding was not at the desired level and that the course, as well as the future curriculum, needs further development in this particular area.

1. The role of information and communication technology in Tanzania

The development of Tanzania has been especially rapid lately. Although the statistics from 2002 say that less than 3 % of the population use internet [1], that amount is already much higher. The estimate is that 25 % of the population have theoretically the internet available representing 7 % of the area of the country. Also, the unofficial estimate for gross national income (GNI) for 2004 indicated a 10 % increase, which is much higher than the 5.6 % increase in the previous year [1]. Mobile phones are becoming increasingly common.

Information and Communication Technologies (ICT) like computers, mobile phones and computer applications are generally imported to Tanzania. Since much of the higher ICT education is also imported, the ACM/IEEE curriculum [2] is often used directly, without modifications.

There are only a few institutions in Tanzania that offer higher education in the field of ICT. The Tanzanian ICT education approach is mostly theoretically-oriented or concentrated solely on the use of a particular piece of software. One example of this is the Tanzanian national computer syllabus for secondary schools [3]. Most often the literature related to higher education ICT development in Tanzania is connected only to the University of Dar Es Salaam (see for example [4]), although there are also other institutions which are developing in the ICT field.

2. Technology and teaching in context

We have noticed through our work and previous studies in Tanzania that the majority of the ICT education in Tanzania is based on methods and materials from Western countries. When those methods and materials are combined with traditions of rote learning, the result is that students only gain mechanical skills, which do not meet local needs. Also local ICT strategy documents like The National Information and Communication Technology Policy from 2003 [5] point out the need development of methods in education.

Despite globalization, there are *cultural differences,* between and within countries. Cultures will not change. The globalization of culture is often like *homogenization*. The effect of homogenization is that Western culture has a large influence on other countries and cultures. The third view is cultural

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hybridization, which promotes the retention of elements of local culture and interaction with the multicultural world. [6]

Our *contextualized approach* [7] emphasizes using local flavour in learning materials. Contextualized ICT education should relate education to real life, even in theoretical parts of the ICT curriculum. Concretization with robots or visualization is a way to bring the contents of the ACM/IEEE computer science curriculum [2] alive and to make it relevant within the context that it is applied to.

It is our hypothesis that methods like creative problem solving [8] in the context and using concretizing blocks [9] will give students a better understanding of programming and ICT. Those will also give them greater possibilities to apply their skills within a particular context compared to traditional pedagogical methods. Those methods will also develop their creativity and provide them with the option to use their abilities for the development of the region.

3. Participants and setting

We designed and organized an introductory ICT course, which concentrated on programming, at Tumaini University, Iringa University College. Iringa University College is a ten-year-old higher education institution in the southern highlands of Tanzania [10].

The participants of the programming course were 27 second-year teacher trainees in a bachelor's program in mathematics and computer applications education. There were 11 females and 16 males. The average age of the participants was 35. On average, the students had almost ten years experience in secondary school teaching. Their previous experiences with using computers involved only the limited use of basic computer applications, like word processing or web browsing software.

The assistant teacher of the course was a local expert from Tumaini University who also participated in the development process of the course.

4. The research question and the aim of the study

In our research we wanted to get an answer to the following question:

How does the contextualized approach support learning and understanding of ICT in a particular environment?

When developing the programming course and analyzing the content of the previous programming course at Tumaini University, we found that the pedagogical strategy had been to teach a large number of concepts. This probably resulted in superficial learning by memorizing.

By having an experimental course in programming and robotics at Tumaini University, we wanted to explore the possibilities of the contextualized approach by using concretizing technology (I-BLOCKs) [11] and creative problem solving to apply knowledge and skills simultaneously, within context.

The contextualization of this was realized by relating materials to the local environment. We also collected feedback to develop the materials further for the future. The project portion of the course was carried out to apply skills to local needs.

5. Concretizing technology

In terms of concretizing technology, we used I-BLOCKs. These Intelligent Building Blocks are physical artifacts to support learning by construction and, more specifically, to support "programming by building." By attaching a number of basic building blocks, each containing a microprocessor and communication channels, together, the user constructs an artifact that can perceive input, process the input data, and produce output. [9] We had pre-tested these blocks several times in the local context and collected feedback for their further development [11]. I-BLOCKs are developed by the Adaptronics Group, at the University of Southern Denmark. [9]

Figure 1. I-BLOCK top and bottom view

Each 2x4 I-BLOCK, embedded in a LEGO Duplo® brick, can be connected to and communicate with up to 4 other I-BLOCKs (Figure 1). The blocks are powered through an adapter or through a 9-volt battery. Up to 20 I-BLOCKs can be powered by a single battery. We developed a number of standard I-BLOCKs with the features mentioned above and also developed some that have actuators, such as DC-motors, servos, light, LCD-displays and sound, built-in. We also developed I-BLOCKs that include sensors, such as LDR resistors, microphones, flex sensors, touch and ultrasonic ranging. In addition, we have experimented with and built communication I-BLOCKs that use both infra red

(IR) and radio communication to facilitate structure to structure communication. [9]

Because each I-BLOCK includes its own microcontroller, the processing that goes on in a structure is truly distributed, and therefore the activity of the structure is directly dependent on the physical properties of the structure.

6. Course arrangements

The course consisted of six weeks of contact teaching. Each week had six compulsory lessons in the computer laboratory. Those included lectures and hands-on activities. In addition to lessons, we offered three hours of counselling sessions per week. Students contributed to their learning portfolios every week and did weekly exercises related to the week's theme (Figures 2,3).

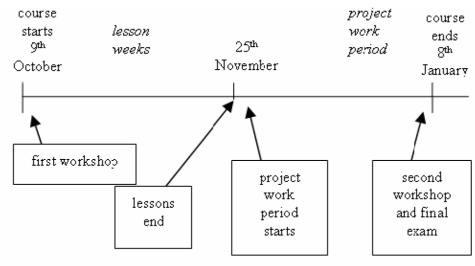

Figure 2. The schedule of the course

The course started with a one and a half day workshop in which students used I-BLOCKs for programming. After that, the students learned Java programming mixed with occasional I-BLOCK-related activities. Finally the students did project work in groups. Four groups worked on Java projects; three groups continued with I-BLOCKs and also taught an I-BLOCK theme for secondary students at a nearby rural secondary school. At the end of the course there was a day long final workshop set aside to present the outcomes of the course, to reflect, and to get feedback for further development. The course also had a final exam.

The first question on the exam was related to important concepts of computer programming and required the students to explain how to apply concepts in Java. Questions 2..5 were related to programming and algorithms. The last question was a creative problem solving assignment based on I-BLOCKs.

The final grade of the course consisted of the final exam (50%), project work (25%) and weekly exercises (25%).

7. Data and Analyses

We collected data from a variety of sources. We gave out questionnaires which also included some exercises in the beginning of the course, in the middle of the course and at the end of the course. We also collected data from weekly exercises, learning portfolios, and from the final exam. We observed students during workshops and interviewed all students at the end of the course (Figure 3).

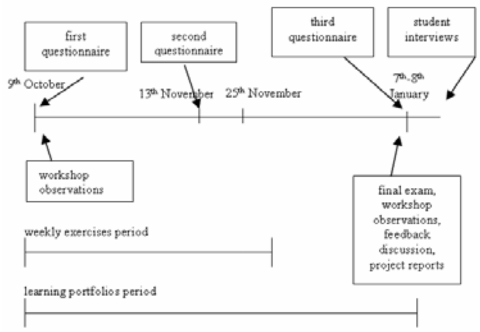

Figure 3. Data collection during the course

We analyzed the possible performance differences between the I-BLOCK and Java project groups for each of the six questions of the final exam, the total points of the exam and the final grade of the course. The statistical method that we used to compare these groups was a nonparametric analysis, Mann-Whitney U. We used Wilcoxon signed ranks test for paired samples to compare results on each question of the final exam. We also examined the correlations between exam points and final grades. To triangulate results we also did a qualitative analysis of text collected from the interviews.

We conducted exploratory cluster analyses to find underlying student categories in which students were grouped into four clusters according to their performance during the course (exercises, project, exam and final grade). We used the RLS algorithm [12]. The similarity within a cluster was maximized while the similarity between clusters was minimal. We performed six clustering procedures using the various combinations of the course outcomes.

8. Results

When comparing the Java and I-BLOCK project groups the statistical analysis showed (TABLE I) that the only difference nearing statistical significance was in performance on the final exam exercise 1 (sig. = 0.011). The Java project groups had got slightly better points in this concept explanation exercise. Otherwise there was no significant difference between the I-BLOCK and Java project groups' results on the exam.

Table I. The variation of the results of the final exam and final grade of the course between I-BLOCK and Java project groups (Mann-Whitney U).

Exercise / points	e1	e2	e3	e4
Asymp. Sig.	.011 *	.665	.880	.762
Exercise / points	**e5**	**e6**	**exam**	**Final**
Asymp. Sig.	.801	.099	.514	.920

e1-e6 = points of the exercises 1-6,
exam = points of the final exam,
final = final grade of the course
significance p:

* *p<0.05 almost* statistically significant
** *p< 0.01* statistically significant
*** *p<0.001 highly* statistically significant

An interesting observation is that the students got the highest points on the first and last exam questions. On the first question, the students gave incorrect answers in the part of the exercise related to applying Java concepts. Programming questions 2..5, which were the questions most aligned with the ACM/IEEE curriculum, were the most difficult for the students. The students got the highest results on the final question, which was most related to creative problem solving. The difference between exercise 1 and 2..5 (pair 1) is almost statistically significant (sig. = 0.012). The points of the exercise 6 and 2-5 (pair 3) differ at a high level of statistical significance (sig. = 0.000) level. (TABLE II)

An interesting finding is also that the points of the exam exercises 4 and 5 have the highest correlation to exam points and final grade (correlation > 0.8, sig. < 0.001). These are the exercises that are based on the students' own computer programming. This indicates that the students who had learnt to do programming by themselves completed the course well by themselves, too. On the other hand, exercise number 1, which was term explanations, had the lowest correlations with final points on the exam and with the grade of the course.

Our cluster analysis consisted of four categories (TABLE III). The clearest categories are the group of best performing students (cluster 4) and the one of the lowest performing students (cluster 1). It is interesting that only one of the I-BLOCK project students were in the lowest performing group (cluster 1).

Table II. Paired Wilcoxon test on the difference between the results of exercises of the final exam.

	Compared pair	Significance	
Pair 1	e1s - e2e5s	.016	*
Pair 2	e1s - e6s	.057	
Pair 3	e6s - e2e5s	.000	***

e1s & e6s = standardized result of exercises 1 and 6
e2e5s = standardized average result of exercises 2-5
significance p:

* *p<0.05 almost* statistically significant
** *p< 0.01* statistically significant
*** *p<0.001 highly* statistically significant

TABLE III. Four cluster model grouping the students according to the course results.

Cluster	Java project students	I-BLOCK project students	final points of the course	standard deviation
1	4	1	55.30	2.54
2	6	6	66.12	4.74
3	5	0	68.90	5.27
4	2	3	81.54	4.63

The results of the qualitative analysis indicated that the course caused students to think about the ways that they could apply their newly acquired skills to their school and to society. It also indicated that some of their expectations were unrealistic. For example, one student stated, "we will solve the administrative problems of our school by using Java programming."

9. Discussion

Programming exercises were the most difficult for the students. This conclusion is also supported by data collected from the questionnaires: no one was able to solve a small programming question that demanded creativity in the beginning of the course and only a few students were able to solve it at the end of the course. Especially those exercises that students' own programming divided the students in terms of their final grades. The process of creating a program needs own initiative and problem solving skills. The results we got with this small group supports the belief that the basic logical understanding required in programming is difficult for most students. In the development of the course, we have to focus more on this point.

The finding that students did best on the creative problem solving question is very promising. Students also became more open to apply the contextualized and concretized pedagogical approach in their own teaching. Almost all students stated that they will use the skills that they learned in their future work. Students reported that a potential problem in the application of their skills is the lack of ICT in Tanzanian schools.

Some of the students were rather unrealistic when it came to using Java to solve problems of their schools. A more effective tool for those problems could be for instance a spreadsheet application. These kinds of unrealistic expectations are quite normal; they indicate that the students have had limited experience with technology.

The preliminary, positive result – that there were not so many I-BLOCK project students in the lowest performing students' group in the final results – is promising. Hands-on technology might give students a better understanding of the more complex aspects of technology.

10. Future research

One group of students at Tumaini will continue with the development of the pedagogical approach and materials for teaching algorithms and logic. Another group of students will apply I-BLOCK technology with children at a local hospital.

We will continue the development of our contextual approach. At the moment, we are working with the course described in this article, but in the future we will develop a whole contextualized, undergraduate degree curriculum with and for Tumaini University, Iringa University College.

Acknowledgements

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Publication PAPER III.

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3

Contextualizing ICT in Africa: The Development of the CATI Model in Tanzanian Higher Education

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Abstract
In many parts of Africa the application of information and communication technologies (ICTs) in higher education institutions offers a particularly interesting research problem. This is because of the far-reaching consequences that information and communication technology (ICT) services and education have on the university graduates during their careers in African societies. Our extensive and well-documented experience of utilizing ICTs in a Tanzanian private university has lead us to propose a four-level approach, called CATI model, that can be used as the basis for implementing new ICTs, for evaluating how ICT is used, and for planning ICT education in developing countries. We conceptually categorize the four levels that we use in our model – contextualize, apply, transfer and import – as an *ethnocomputing* approach. This four-level model enable educators to use ICT services and ICT education in African universities in a way that will prepare university graduates to make a positive contribution to their own societies. The success of this model is attributable to the emphasis that we placed on local needs and creativity and on applications of ICTs that were sensitive to local culture, conditions and understanding.

Keywords: contextualized teaching, ethnocomputing, ICT education in developing countries

1. Introduction

The vision of the World Summit on the Information Society (WSIS) [1] is that all people throughout the world be given the opportunity to use information and communication technologies (ICTs). The vision specifically makes a plea for schools and other educational institutions - whether rural, urban, rich, or poor - not to be excluded from the benefits of ICTs. The WSIS vision thus addresses an issue that is both topical and important: *inequality in the use of new technologies*. While the pervasive effects of globalization and the sharing of ideas and new technologies constantly create new needs and opportunities in highly developed societies, the benefits of such opportunities are seldom disseminated in developing countries. One of these needs (one that is especially topical in Africa at present) is the need to integrate new ICTs with educational philosophies in such a way that the synthesis thus created harmonizes with local cultures and environments.

The WSIS action plan [2] also encourages the development of content and technical conditions that facilitate the presence and use of all world languages on the Internet. While the advantages of such a development are fairly obvious, there are real problems that have to be identified and addressed *before* we can ever hope to see ICTs making a truly beneficial impact of local conditions in developing countries. The advantages that ICTs confer in developed societies are fairly obvious. They enable an easier dissemination of knowledge, increased and varied social interaction, more efficient economic and business practices, political empowerment, better access to independent and diverse media, better education, a heightened awareness of health issues, improved health services, and diversified leisure and entertainment possibilities. The main focus of our work has been on developing ways for information technologies and ICT education to support local development without any sacrifice of local identity – especially in higher education institutions.

We have therefore moved away from a merely linear process of importing technology and education from industrialized to developing countries and seek instead to create a novel synthesis between technology, education, and culture that represents a balance between an alien but global technology and local needs. This kind of synthesis, we have found, fertilizes the inherent creativity that is always present in local communities. It also creates a learning community that utilises global technology while remaining uniquely local in style, method and content. Local creative learning communities are not restricted to classrooms. They contribute directly to the everyday lives of the learners and local society. By applying ICTs to everyday tasks and concerns, our students retain strong links with local society. They learn to apply their knowledge in the service of others in their immediate environment rather than become self-obsessed consumers of technological novelty in the constantly changing conditions of global information culture.

We undertook this research partly in response to reports on the extent to which Millennium development goals [3] had been achieved. These reports showed that Sub-Saharan Africa still lagged behind other regions in the world and that recent developments in this region had failed to meet the expectations of the WSIS [4]. The expansion of ICT that has lent wings to accelerating economic, environmental, and social development in Western countries has not had the same effect in African countries. Since a key WSIS principle is an “information society for all”, one might expect the introduction of ICTs would foster an equal rate of development in all societies. But this has not happened in most countries of Sub-Saharan Africa. What this suggested to us was that it is naïve and simplistic merely to take a foreign technology developed in alien circumstances, introduce it into a local culture and then expect the same benefits to accrue to that culture – which is different in many important ways from the culture in which the technology was originally developed.

While globalization has in some ways contracted the world culturally, it has not eradicated cultural differences between or within countries. One of the effects of globalization is often a kind of international cultural homogenization in which predominantly Western cultural elements and artifacts supersede local elements in non-Western cultures [5]. While cultures are never static, they change (ideally) along different lines and at a different pace. Our preference in these circumstances is for cultural hybridization [5] rather than homogenization. Cultural hybridization promotes the retention of the elements of local cultures and the expectation that it is possible to blend local culture with globalised cultural elements so as to produce a hybridized local style that is unique to its country of origin. There is no inherent reason why technological change should subvert local identities. Our experience has proved that it is possible to use new forms of technology to enrich rather than diminish local knowledge and culture.

Our contextualized approach [6] emphasizes using a knowledge of local realities, concerns and conditions to build ICT infrastructure and to develop ICT in education. Contextualized ICT should relate ICT infrastructure and education to local needs and everyday life.

Our research projects aim at non-zero-sum development. The benefit to us is that we extend our practical and theoretical knowledge and test technologies in an environment that differs enormously from our own sociocultural environment. The benefit to our partners is that they gain technological know-how and theoretical understanding from ICT education and from using technological tools. And all those involved benefit from the realities of international, interdisciplinary network. We selected Tanzania as our main target area because it became apparent to us that it had not benefited from ICTs to the same extent that many other countries had, and because ICT development had occurred only sporadically in Tanzania which, according to UN reports, is one of the least developed countries (LDCs) in the region [7].

It soon became apparent to us that it was not going to be easy to implement a developmental theory in practice – however well designed and carefully constructed it may have been. It is not a straightforward procedure to introduce and integrate globally functioning but foreign concepts and infrastructure into a society in a manner that is harmonious and that takes respectful cognizance of that local culture. From our perspective, we needed to leave enough room for local initiatives and activities so that they could co-evolve in harmony with foreign concepts. Our department runs a number of interconnected research projects, each of which employs a different set of methodologies. Most of our research approaches – such as participatory action research, problem-oriented research, and longitudinal development research – are based on techniques that belong to the ethnographic tradition. This article describes the origins, progress and outcomes of a number of our research projects. Our analysis of these projects and their practical and theoretical implications and concerns contribute to an approach that can be used in the planning, implementation and analysis of ICTs in higher education in developing countries. Since the focus of our research is somewhat narrow, we recognize that our particular approach may not be applicable to all situations at all times. We nevertheless maintain that it remains pertinent to a large number of cases of the kind we are dealing with much of the time.

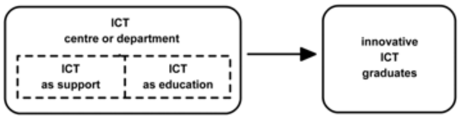

Figure 1: The Dual Role of ICT in a Higher Education Institution.

ICT in higher education institutions serves two functions (see Figure 1). In the first instance, ICT is needed as part of the *support infrastructure* that maintains an institution as a functioning entity. ICT is necessary in a modern tertiary institution for carrying out teaching and research. Secondly, ICT should ideally be taught as part of *a distinctive discipline* in its own right to both students and staff. Both these functions are necessary for the education of graduates who will apply ICT in their future professions. Some smaller colleges or universities in Africa tend to have a dedicated ICT centre or department that organizes all ICT services and training rather than one centre for support and another for academic activities (Figure 1). This kind of arrangement is also applied in Western countries where many universities begin with a computer centre before differentiating it into a support centre and a department of computer science at an opportune moment.

It is also generally accepted nowadays that graduates who have not specialized in ICT studies should nevertheless be sufficiently well trained in to use ICTs in their own fields in a competent manner. Students who graduate with a mastery of ICT will be in a far stronger position to advance their careers than students whose computer literacy is limited to a few standard applications.

The fact of the two roles or functions of ICT in higher education institutions is also evident in the WSIS key principles for an information society for all [1]. Table 1 shows that each WSIS principle needs to be addressed either by ICT support or by ICT education. Consider, for example, *capacity building*. Functional ICT support, such as an efficient library system, is a prerequisite for capacity building. Another important point is that all the WSIS principles are *context sensitive*. By this we mean that the *cultural context* of the user community needs to be taken into account when a principle is applied. Thus, for example, successful access to information and knowledge depends on the skills, attitudes, and values of the people who are in the need of information. It follows from this that both ICT support services and ICT teaching in higher education institutions need to be contextualized.

The implementation of key WSIS principles depends on long-term *strategies.* This makes them amenable to short-term planning (such as that which is based on three-month periods). Strategies are difficult to describe in rigid detail because their success and failure depend on long-term changes and variations such as those

Table 1: The Key WSIS principles

Key WSIS principles	***ICT support***	***ICT education***	***Context sensitive***
1. The role of governments and all stakeholders in the promotion of ICTs for development	√	√	√
2. Information and communication infrastructure	√		√
3. Access to information and knowledge	√	√	√
4. Capacity building	√		√
5. Building confidence and security in the use of ICTs		√	√
6. Enabling environment	√		√
7. ICT applications: benefits in all aspects of life		√	√
8. Cultural diversity and identity, linguistic diversity and local content		√	√
9. Media		√	√
10. Ethical dimensions of the Information Society		√	√
11. International and regional cooperation	√	√	√

Table 2: Educational Institutions that offer ICT Degree Programs in Tanzania (May 2005) [13]

Higher Education Institution	***Degree***	***Student Enrolment / Academic year***
Institute of Accountancy, Arusha	Advanced Diploma in Computer Science	41 / 2004-05
Institute of Finance Management, Dar es Salaam	Advanced Diploma in Information Technology	378 / 2004-05
Mzumbe University, Morogoro	B.Sc. in Information, Communications and Technology Management	33 / 2003-04
University of Dar es Salaam	B.Sc. and M.Sc. in Computer Science	400 / 2004-05

that occur in local "grass-roots" socio-economic and political changes, national plans and campaigns, and fluctuations in the global economy. The strategies that we implement in our projects are essentially local-level strategies that arise out of the needs of a university. Their implementation is correspondingly dependent on local circumstances such as the availability of resources (e.g. personnel, electricity, building material) and sociocultural factors (e.g. styles of teaching, learning, administration, decision making).

In the following sections we describe our work in more detail. Section two contains an overview of the role of ICT in Tanzanian education and especially in the Tanzanian higher education system. Section three describes the case study of Tumaini University, Iringa University College. Section four analyses the work detailed in section three within the framework of the CATI model. Section five explains how this project serves as an excellent example of what we have called *ethnocomputing* [8].

2. The role of ICT in Tanzanian Higher Education System

As Mkude et al. [9] state according to the *Progress and Financial Reports of University of Dar es Salaam*, Africa has been afflicted with every kind of social, political and economic woe over the past two decades and many countries are even now staggering under the burden of domestic and international conflicts, disease (especially HIV/AIDS), poverty, corruption and the effects of natural disasters such as drought. Since the 21st century is a ime of increasingly globalization, African universities that hope to perpetuate some kind of international reputation will have to be managed by strict discipline and new and more stringent strategies for implementing change. Many African universities, especially those in what the United Nations designates as "least developed countries" (LDCs), will have to further improve the capabilities of their graduates if the universities are to continue to maintain even their current share of the local and international labor market.

Strategic planning in Tanzania is currently guided by a document known as *Development Vision 2025* [10]. This document is, in effect, a blueprint for Tanzanian progress. It details what planners think is feasible for the future of Tanzania in terms of education and all the other amenities of a modern and progressive country. *Development Vision 2025* stipulates that information and communication technologies represented a primary means for realizing the terms of the vision. *Development Vision 2025* shows how much importance Tanzania's rulers attach to the part that ICTs will play in the development process in Tanzania. Tanzania has also its own specific ICT policy [11]. This document describes the key areas in which development in ICT is expected to take place.

Tanzania has no well-established ICT professional profiles – even in terms of its own ICT policy [11]. Neither are there any standardized procedures for evaluating or certifying ICT courses. Access to online and distance learning is limited. Opportunities for training are confined mostly to a few urban centers, and the country's official Secondary School Computer Studies Syllabus is outdated. While private urban schools offer the best opportunities for ICT education, there is no program for training ICT teachers. Universities and other higher education institutions lack computers and ICT amenities. Even in those cases where they do have computers, connectivity is severely limited. Internet access bandwidth for all these institutions was less than 512 kbps for the whole institution in 2003.

Bakari et al. [12] studied ICT in higher education in Tanzania from the security management point of view. While their study indicates that higher education institutions in Tanzania are currently developing ICT strategies, our observation is that

Table 3: Frequency of Computer Ownership and Number of Internet Users in Tanzania (1999, 2002 and 2003) [14]

Indicator	***1999***	***2002***	***2003***
Population, total (millions)	32.9	35.2	35.9
Personal computers (per 1,000 people)	2.5	4.2	5.7
Internet users (per 1,000 people)	0.8	2.3	7.1

most ICT strategies lack security management. In cases where ICT strategies make provision for security management on paper, such measures are not enforced in practice. This lack of security management in institutions and in national policy planning implies that ICTs are not currently serving the best administrative, research, and educational interests of the country.

There are four higher level education institutions that offer ICT degrees in Tanzania. These are (1) Institute of Accountancy in Arusha, (2) Institute of Finance Management, (3) Mzumbe University and, (4) University of Dar es Salaam (Table 2). [13]

Computer illiteracy is widespread in Tanzania and access to ICT facilities is on the whole extremely limited. The World Bank Group's [14] data profile for Tanzania lists the number of computers and Internet connections in Tanzania (Table 3). Nearly all of these are concentrated in urban areas. The latest available figures (from 2003) show an increase in the number of computers and Internet connections in Tanzania.

3. ICT at Tumaini University, Iringa University College

Tumaini University was founded in 1996 by the Evangelical Lutheran Church of Tanzania (ELCT) as a major contribution to higher education in the country. Tumaini University consists of four colleges: Iringa University College (IUCO), Kilimanjaro Christian Medical College (KCMC), Makumira University College (MUCO), and Waldorf College in Dar es Salaam. IUCO, the largest college at Tumaini University, is situated on the northern side of the town of Iringa, the capital of the Iringa region. While the total population of the region is approximately 1,5 million, Iringa municipality has a population of 350,000.[15] In 2004, the college consisted of four faculties: Arts and Social Sciences (including the Department of Journalism and the Department of Education), Business and Economics, Law, and Theology.

The case study described in this section took place between 2000 and 2004 at IUCO. The documented data includes the email databases of one of the authors, Jyri Kemppainen, and a number of official documents from Iringa University.

The student body of the college increased by about 30% annually in the years between 2000 and 2004, with 670 students enrolling in the academic year 2004-2005. Students come from every region of Tanzania as well as from other African countries such as Botswana, Burundi, Kenya and Malawi. The percentage of female students is approximately 40%. This is significantly higher than the 27% female average in government universities in Tanzania in 2004 [16].

As a private university, Tumaini University received neither funding nor infrastructure from the Tanzanian government in 1999-2004. Since its inception, IUCO's main donor has been the Evangelical Lutheran Church in America (ELCA). Another major cooperative partner for IUCO has been the Finnish Evangelical Lutheran Mission (FELM). ELCA and FELM have supported IUCO in a number of direct and indirect ways. They have financed construction activities, funded the recruitment of contract teachers for teaching at Tumaini, paid the salaries of administrative staff and volunteers for service in the college, initiated and financed scholarship programs, and arranged for the donation of educational materials such as books and second-hand computers. FELM has included some of IUCO's projects in the Program for Development Cooperation of Non-governmental Organizations, which is funded by Finnish Government. IUCO's plan to develop ICT teaching and ICT facilities for teaching constitutes an important part of the projects funded by the Finnish government.

Two former business students from IUCO completed their M.Sc. degrees in computer science at the University of Joensuu in 2002. One of them was subsequently appointed as head of the ICT Department of IUCO in 2003. In 2004 IUCO appointed a Tanzanian ICT expert who had recently completed his B.Sc. studies in computer engineering at the Espoo-Vantaa Institute of Technology, Finland. [17]

Figure 2 shows what will follow in this section. We shall begin by introducing the ICT strategies at IUCO and then proceed to describe the implementation of these strategies. Description of the implementation will be divided into: (1) ICT support and infrastructure, and (2) ICT education and training (see Figure 1). This arrangement will help us to analyze the Tumaini University case study in terms of the contextualization that we shall discuss in section four.

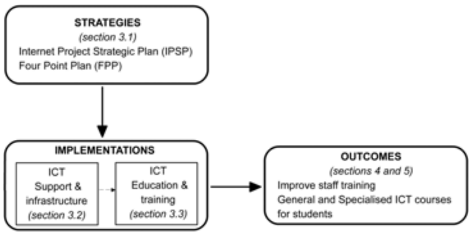

Figure 2: ICT at Iringa University College: From Strategies to Outcomes

3.1. Strategies

Internet Project Strategic Plan (IPSP)

Since 2004 IUCO has been engaged in implementing the *Internet Project Strategic Plan* (IPSP). This plan defines the general vision, goals, and objectives for all the ICT activities that IUCO plans to establish in its pursuance of an improved learning environment [18]. Because the IPSP vision emphasized the use of the Internet and computers as vital components in an effective learning and teaching environment, IUCO's key task was to get IUCO connected to the Internet.

IPSP arose out of a collaboration between members from FELM, ELCA, and IUCO, and was divided into the following three areas: (1) *human resource development*, (2) *institutional capacity building*, and (3) *infrastructure development* (Figure 3). The aim of *human resource*

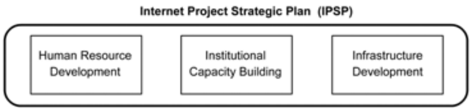

Figure 3: Three Foci of the Internet Project Strategic Plan (IPSP)

development was to train all members of IUCO (faculty, staff, and students) to use ICT facilities in their work as effectively as possible.

Institutional capacity building referred to the development of five areas: the library, curricular exchange, Internet-assisted courses, the Computer Science Department, and language skills. *Library* development aimed to modernize the catalog system, to establish cooperation with other university libraries in matters such as an interlibrary loan program, to increase the use of CD-ROMs, and to help students to get access to on-line journals, books and databases. *Curricular exchange* development covered distance learning and curriculum development activities in cooperation with other universities. *Internet-assisted courses* development was focused on providing IUCO students with a distance teaching option that would operate outside of classrooms. *Computer Science Department* development was predicated on the idea of establishing a new department of computer science. *Language skills* development included the use of the Internet and CD-ROM technology to enhance student language acquisition.

The third area of IPSP, *infrastructure development*, covered five initiatives: local linkage, regional linkage, disciplinary consortium, African studies, and local service. The *local linkage* initiative included cooperation with local educational institutions in activities such as the donation of old computers to local schools. The *regional linkage* initiative extended the local linkage to other universities and colleges in Tanzania and had the aim to sharing information. The *disciplinary consortium* initiative covered the same objectives as the regional linkage, but on a worldwide scale. The *African studies* initiative dealt with the idea of developing an African studies degree program under the faculty of Arts and Social Sciences in cooperation with other African universities. The *local service initiative* included a plan to start an Internet service provider (ISP) in Iringa and to develop short ICT courses for private clients.

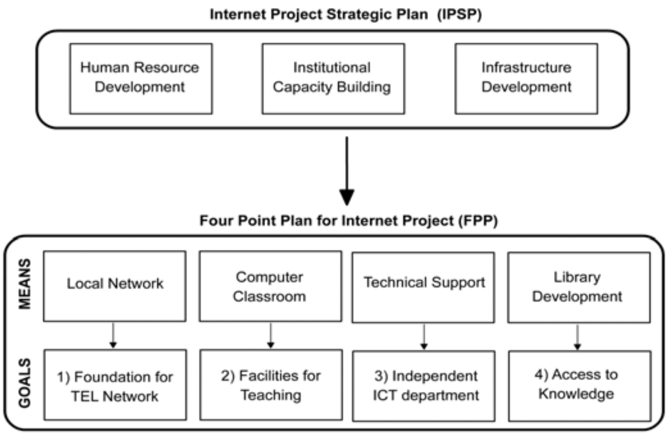

Figure 4: Four-Point Plan (FPP) and Its Implementation Goals for IPSP

The third area of IPSP, infrastructure development – unlike aspects of human resource development and institutional capacity building – was not really ICT-specific. It illustrated instead how ICTs could stimulate favorable developments in content and networking in education at Tumaini.

Four-Point Plan for Internet Project (FPP) as an implementation strategy for IPSP

The ideas introduced in IPSP on how to use ICT in education were difficult to put into practice because the IPSP strategy was too general. The strategy did not, for example, take into account the lack of ICT facilities other than for Internet connection. Because of this gap between the IPSP strategy and the real ICT situation at IUCO, IUCO devised a new plan entitled *Four-Point Plan for Internet Project* (FPP) (see Figure 4). This FPP was created after IUCO had analyzed the ICT situation in three other East African universities (University of Nairobi, Sokoine University of Agriculture, and University of Dar es Salaam). The purpose of FPP was to clarify the short-term commitments and determine the priorities of the IPSP. [19]

FPP showed that the college had four aims: (1) Technology Enhanced Learning (TEL), (2) better facilities for teaching, (3) an independent ICT department with its own budget, and (4) access to knowledge for students and faculty. These aims were to be accomplished by (1) *the local network*, (2) *a computer classroom*, (3) *technical support*, and (4) *library development*.

The *local network* required the building of a local area network on the campus, connecting all computers to it, and training students and staff in its use. An additional long-term goal (which had already been introduced in IPSP) was to create a solid foundation for technology enhanced learning (TEL). *Computer classroom* referred to having a new ICT laboratory for teaching. Although a new room had just been built and opened for ICT teaching, the computers were all 486s running Windows 95 and Microsoft Office 95. These were connected by means of temporary LAN wiring and a second-hand HUB. New personnel were to be recruited for *technical support* to maintain the computers and to offer computer literacy courses. We also recommended to the administration that the university's ICT budget should make provision for one technician for every seventy computers. *Library development* was intended to solve two existing problems at the library. The first was that computerized catalogues would solve the problem of disappearing books. The second was that CD-ROM technology and Internet access should compensate for a shortage of learning materials.

3.2. Implementation: ICT Support and Infrastructure

The FPP was divided into four separate projects for implementation: (1) IPSP 2001-2003, (2) Internet connection, (3) ICT department and its budget, and (4) the library facilities improvement project (Figure 5).

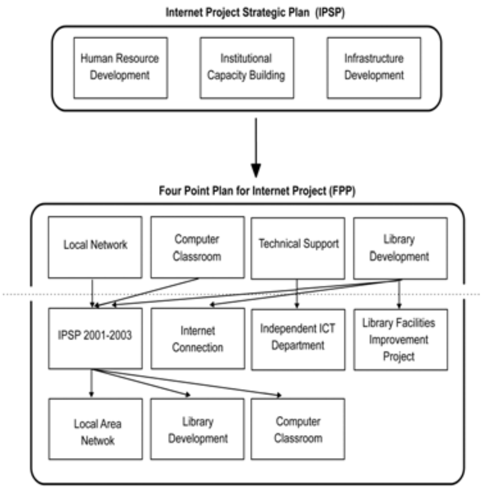

Figure 5: Implementation Plans for FPP as Derived from Its Key Areas

One of these, IPSP 2001-2003[1], included three subprojects. Because the scope of IPSP 2001-2003 was so wide, it was divided into three independent technical subprojects. The implementation order was based on the expected lifetime of the investments: the LAN wiring was expected to remain in a usable condition for longer than the life span of the new computers. The library management system was also expected to remain in use for longer than the new computers. The final scheme of IPSP 2001-2003 included the implementation plan for three out of the four areas defined in FPP, and these three areas were implemented between the years 2001 and 2003. They proposed:

- to build a LAN in two buildings
- to modernize the library by installing a library management system and by creating the facilities to use CD-ROM learning materials
- to refurbish the ICT laboratory so that it could be used for teaching

The role that an *Internet connection* would play was originally central to the IPSP, and the importance of an Internet connection is clearly delineated in IPSP's vision and goal. The first part of the IPSP consists of an analysis of the state of technical development at IUCO. This analysis is then followed by a consideration of several ways by means of which IUCO could be connected to the Internet. One of these possibilities – the suggestion that IUCO might establish and maintain its own Internet service provider (ISP) in Iringa – seemed both feasible and attractive. After the series of difficulties and challenges described in section four, an Internet connection (128/64kbs) that operated through the landline network of Tanzania Telecommunications Company Limited (TTCL), was eventually established at IUCO in August 2002, and any hope that IUCO might operate its own ISP was put aside for the time being.

An *ICT department* with its own budget was described as the goal in that part of the FPP that dealt with technical support. This proposal was a crucial subproject of the FPP, and the sustainability of an ICT department was considered to be a key question in the whole project. The development co-operation guidelines of the Finnish Government define *sustainability* as the "long-term functionality of developed systems" [20]. Sustainability may be said to be assured when the following factors are all accounted for: an adequate and secure economic and financial basis for long-term operation and maintenance; institutional capacity; the capacity to manage whatever systems are in place; sound socio-cultural accords and agreements, whether formal or implicit; reliable technical operations, and the maintenance of environmental impacts at an acceptable level. [20] Although there are a number of other definitions for *sustainable development*, of which the *Brundtland Report* [21] is perhaps the best known, the definition given here is best suited to our research because we focus on developing education and educational infrastructure.

There were two main obstacles that stood in the way towards the kind of long-term functionality envisaged by the FPP. Firstly, IUCO was not allocating funds for ICT development, and, secondly, IUCO had not organized ICT department. Possible solutions to both of these problems had been under investigation since the earliest stages of the project. IUCO administration then took two measures to compensate for the lack of funds. Firstly, the administration included in the university budget of 2002-2003 provision for the maintenance of ICTs [22]; secondly, they began to charge students a computer access fee for computer tuition. The major problem posed by the absence of an ICT department proved to be much more difficult to solve. There are very few qualified ICT professionals in Tanzania, and especially in Southern Tanzania. In the academic

[1]Note that *IPSP 2001-2003* is not the same as *IPSP*. *IPSP* is IUCO's overarching strategy that aims at developing the learning environment at the university. IPSP 2001-2003 is a project that implements parts of FPP.

Table 4: ICT Resources Available for IUCO Students and Staff (1999 and 2004)

Resource	***1999***		***2004***	
	Students	***Staff***	***Students***	***Staff***
Computers	30 (486)	18 (486)	73 (37 P4, 36 586)	72 (12 P4, 60 586)
Server Computers	none	none	2	1
Printers	4 matrix	6 matrix and 1 ink-jet	2 laser	2 laser, 6 ink-jet, and 4 matrix
Data/Video Projector	none	none	1	3
ICT Laboratories	1	none	3	none
ICT Teaching Laboratory	1 (14 computers)	none	1 (21 computers)	none
Internet Laboratory	none	none	1	none
ICT Service Centre	none	none	1	none
ICT Service Rooms	none	none	none	2

Table 5: Common ICT Resources at IUCO in 1999 and 2004

Resource	***1999***	***2004***
Internet Connection	none	128/64 KB
Server Computers	none	4
Computer Centre	none	1
Maintenance Room	none	1
Staff	1	8

year 2002-2003 the problem of ICT support and maintenance became much more critical when the last voluntary ICT teacher from abroad left the college. Although no official ICT organization existed at IUCO before 2003, there were two Tanzanians who worked with ICT in the academic year 2002-2003. One of these was an ICT teacher who worked for the university on an hourly basis. The other was a former secretary who had one year of ICT education.

The implementation of ICT support and infrastructure was based on the prioritized key areas of FPP. Table 4 and Table 5 show the increase in ICT resources between 1999 and 2004.

The *library facilities improvement* project was the fourth subproject of the FPP. Its aim was to supplement scarce print material in the library by means of electronic media such as the Internet and CD-ROMs. Since the implementation of this project is not part of the topic of this research paper, we shall omit any further consideration of it at this point.

3.3. Implementation: ICT Education and Training

Table 6, compiled from the course outlines and prospectuses of IUCO [23], shows the history of ICT education at IUCO. There are eight courses that focus mostly on computer applications. All of these courses were taught in the academic year 2004-2005. The four foundational courses, *Information Technology I*, *Information Technology II*, *Information Technology (Journalism)*, and *Information Technology (Business)*, remained basically the same between 1999 and 2004. Four newer courses were launched by the Department of Education at the beginning of the academic year 2002-2003. These were *Instructional Technology in Mathematics Teaching*, *System Support and Administration*, *Introduction to Computer Networks*, and *Computer Programming.*

Table 6: ICT-related Courses at IUCO

Course	***Introduced (year)***	***Target***	***Remarks***
Information Technology I	1994	All students	Reviewed 1999
Information Technology II	1994	All students	Reviewed 1999
Information Technology – Journalism	1998	Journalism	Reviewed 1999
Information Technology – Business	1998	Business	Reviewed 1999
Instructional Technology in Mathematics Teaching	2002	Education	
System Support and Administration	2002	Education	
Introduction to Computer Networks	2002	Education	
Computer Programming / Contextualized Programming Course	2002 / 2004	Education	Renewed 2004, Research Project

While most of the courses were quite traditional in design and intent, the *System Support and Administration* course was designed for student teachers who might in the future need to work with an inadequate ICT infrastructure such as that which is powered by current generated by solar panels for laboratory electricity.

Although there have been no major changes in courses, teaching facilities improved significantly between 1999 and 2004: 486 computers were upgraded to Pentium 4 computers, and Windows and Office were upgraded from 95 versions to XP versions. In 1999 the students were being taught how to use Internet facilities such as search engines and email without any real-time connection to the Internet itself. Teachers had to save all instructional material to a file, print it out on paper, or else show it to all the students together from one small computer screen because there was no data projector. By 2004 the ICT laboratory was connected to the Internet. Both software and hardware were up to date, and a data projector was a part of the equipment.

ICT training has been addressed by annual ICT courses for staff that have a strongly practical bias [22]. These courses covered the same issues as did basic courses for students. They taught basic office applications such as Word, Excel and PowerPoint, as well as some basic Internet skills such as sending and receiving email and searching for information. Between 2002 and 2004, IUCO's ICT trainers also developed and presented a series of courses for the staff and faculty. In 2003, for example, the Department of Journalism offered two courses in web publishing, one for faculty and the other for students. Both these courses were designed to give those attending an understanding of the structure, layout and management of a website. The course content and activities were alike for both groups and included the explanation of concepts such as hypertext, pixel/vector graphics, editors, animations and interaction. Course activities included an analysis of existent websites.

Since IUCO offers no degree program in ICT, courses are nearly always related to computer applications, and computer science courses are rare. *Computer programming*, the course that is most typical of a computer science degree syllabus, was introduced in 2002. The method of teaching the course before 2004 was strongly based on the kind of teaching method one would find in Western universities where most of the students have already had extensive experience of ICTs of one kind or another even before their university studies commence. The course content was also out of date. Thus, for instance, programming was being taught by means of Qbasic. A more recent pedagogical strategy has been to teach a large number of difficult concepts such as trees and stacks by using C language [24]. One cannot help noticing that because students were being taught data structures and algorithms even before they had any knowledge of even basic programming concepts, the chance of them having learned anything beyond what they could memorize by rote without any real understanding was unfortunately close to nil.

IUCO was interested in continuing to develop ICT education on the basis of the program outlined by IPSP, and collaboration with foreign institutions was already well established. In 2004 IUCO introduced a *contextualized programming course* for B.Ed. students in collaboration with the University of Joensuu (Finland) and the University of Southern Denmark. The course featured problem-based learning and made use of local examples, project work, interaction between university and school students. There was also a strong emphasis on activating tools such as robotics and visualization. The idea was to encourage the students to contextualize their emerging ICT skills in their everyday context, and to use creative problem solving to apply knowledge and skills simultaneously within a familiar context. [25]

3.4. A Summary of the IUCO Case

A comparison between the Four-Point Plan (FPP) and the implemented projects shows that the *key areas* of FPP and its short-term objectives were implemented during years 2000-2004 (Figure 6). IUCO modernized ICT laboratory for teaching (*facilities for teaching* in FPP), implemented LAN (*foundation for TEL network* in FPP), and acquired an Internet connection and a library system (*access to knowledge* in FPP). IUCO also established an ICT Department and allocated money for ICT in IUCO's annual budget (*ICT department and budget* in FPP). Two objectives of FPP were, however, not met. Firstly, IUCO did not establish a local Internet service provider because it would have demanded resources that IUCO did not have (original assets and human resources), and because at that time other ISPs had already become operational. Secondly, IUCO has not yet begun to offer ICT courses to outsiders because of the shortage of ICT staff at the college.

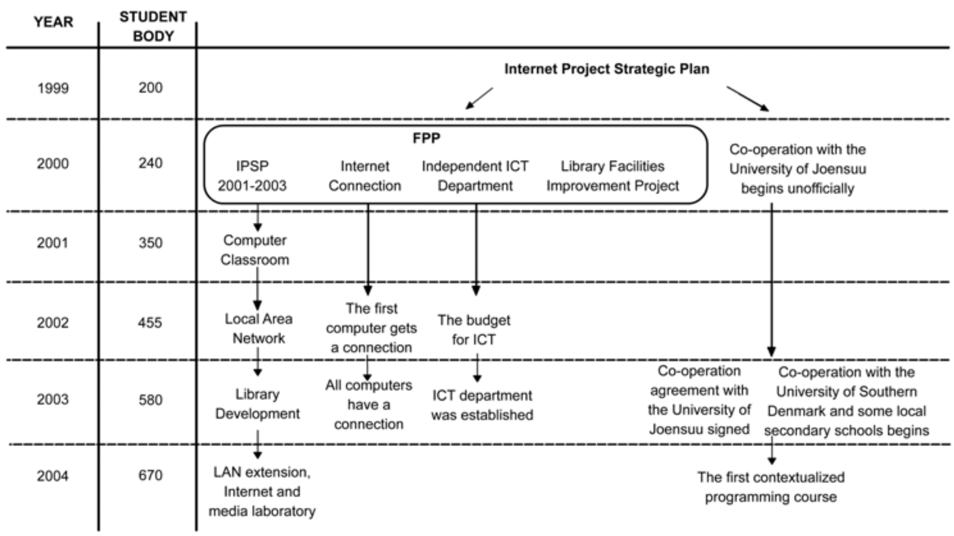

Figure 6: An Overview of the Projects Derived from IPSP and the Number of Students (by year)

4. Analysis

The contextualized approach to ICT in higher education can be represented as two parallel but opposite processes: *planning* and *implementation* (Figure 7). Our contextualized approach is based on our experience of carrying out the IPSP and other projects in Tanzania [6],[25-30]. We use the four levels CATI model – *contextualize, apply, transfer, import* – to analyze the planning and implementation processes (especially from the troubleshooting and constraints points of view). The planning process proceeds from contextualization to import, and the implementation process proceeds from import to contextualization.

It is important to note that the planning and implementation processes can interact with one another on all levels, and that the CATI model can be used with subprojects in continuous processes like the circle in Figure 7. A scheme of apply – transfer – apply would make sense in a situation where planning starts from an identified need of a particular application, which needs to be transferred for a user who needs to learn to use the application.

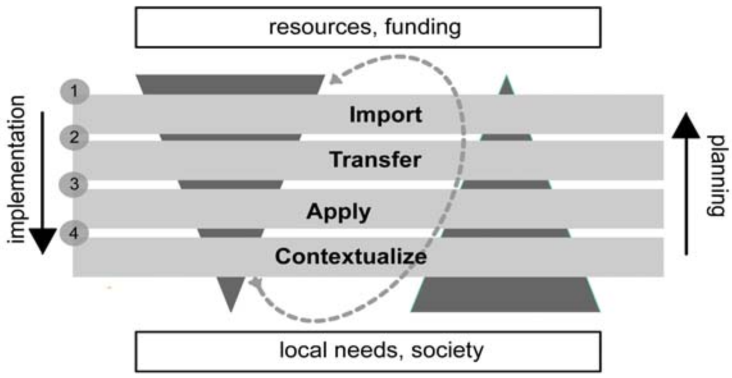

Figure 7: The Four-Level Model for Representing and Analyzing the Planning and Implementation Processes of ICT.

The four-level model is a simple framework that provides practical descriptors or benchmarks that researchers and providers can use to identify the difficulties that arise from the use of ICTs in developing countries and to analyze the cause of such difficulties. The planning and implementation processes are visible in both of the two roles that ICT plays in a higher education institution: ICT support and infrastructure, and ICT education and training (see Figure 1 and Figure 2). We embark on our definition of the levels in the four-level model by considering the dictionary definitions of the terms *import*, *transfer*, *apply*, and *contextualize*. The dictionary we use [31] gives the following meanings for the four key words:

Import	to bring or carry in from an outside source, especially to bring in from a foreign country for trade or scale
Transfer	to convey or cause to pass from one place, person, or thing to another
Apply	to bring into nearness or contact with something; put on, upon, or to put into action
Con-textualize	to place (e.g., a word or an idea) in a particular context, where *context* refers to the set of facts or circumstances that surround a situation or event; "that which surrounds and gives meaning to".

We can now extrapolate meanings that are specifically relevant to ICT for each of these words. Note that ICT refers here to any kind of software, hardware, wiring, service, innovation, idea, and so forth.

Import	The technological applications of ICT (hardware and software) are available on site. But *warmware* – human knowledge and experience – is missing.
Transfer	Human and technological ICT resources become available to those who need them through transference. Most resources are transferred from outside a community into the community.

Apply	ICT resources are used or mobilized in action. A user can apply ICT to the task that for which it has been invented. The application of resources often happens in a context other than that for which resources were originally designed.
Con-textualize	ICT will only fulfill the needs of the local community only if ICT is adapted, appropriated, re-invented [32] and implemented in a way that enhances the local context.

From the *local point of view*, we can expand these terms in the following way:

Import	*Imported* things may be innovations such as tools, books or attitudes. All of these may be very useful and needed in themselves or in their original context. But mere *importation* here means receiving something from abroad without any prior analysis of local needs. This kind of importation means creating a strong possibility of non-sustainable development.
Transfer	While *transferred* goods or human capital may be accessible to their users and even potentially applicable in a local context, the accompanying analysis of local needs may be relatively weak.
Apply	In *application* the potential of transferred things and human capital are realized. This kind of use is not simply mechanical. Creative application requires the users' own initiative. Effective application requires basic contextual expertise. A user can thus apply office applications for his or her own purposes (e.g. assignments, project reporting) without a more extensive relevance to his or her environment.
Contextualize	*Contextualizing* is intrinsically related to the needs of the larger user community. Contextualized ideas or technology relate directly and effectively to the needs of a certain sociocultural context or environment. The one who performs this is from the area itself, and the need for the analysis is rooted in that area. Because of the tight bonds between a community's people and its needs, contextualized innovations have a far better chance of sociocultural sustainability than do applied innovations.

This four-level *CATI model* can be utilized for:

- developing sustainable ICT solutions in collaboration between developed and developing countries
- analyzing the planning and implementation processes of ICT
- evaluating a person's ability to apply learned knowledge in an educational setting

What follows below is an analysis of the planning and implementation of the project at IUCO that we described in section three. We will pay particular attention to the problems that we encountered on the way – especially those that hindered a shift from one level onto another. Several problems were caused by technology-driven implementation that took place at the expense of context-based planning. In our case, our starting point was the expertise that was available among the Tumaini University staff. We used their IPSP and FPP analyses as our basis for development.

Planning

Figure 8 labels the FPP strategy that we described in section three as a *planning* process in the four-level CATI model (the *planning* process is marked by the arrow on the right hand side of Figure 7). The FPP strategy was born at the moment when the staff at Tumaini University accepted that they wanted to be able to utilize ICTs in education. The FPP started in Tanzania, in Iringa region, at Tumaini University – all these places define the *context* (4). The planning was then carried out by *applying* (3) the ideas in FPP (see Figure 4). This resulted in the division of FPP into four subprojects. These subprojects were: IPSP 2001-2003, Internet connection, ICT department, and Library facilities (Figure 5). The process continued with *transferring* (2): this is a movement from ideas to practical plans. The last phase was evident in the need to *import* (1) infrastructure and funding. Both needs were concretized in 2000 as a funding application.

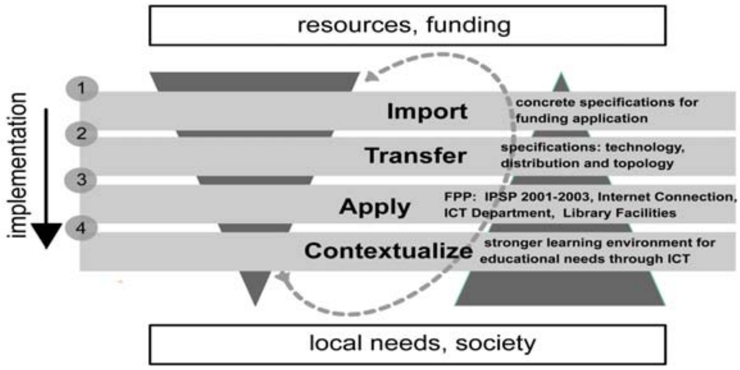

Figure 8: Planning of Four Point Plan (FPP) to Use ICT at IUCO

In the subsections that follow, we continue to analyze the implementation of FPP's four subprojects (*IPSP 2001-2003*, *Internet connection*, *ICT department*, and *library facilities*) on the *implementation* side of CATI model (the *implementation* process is marked by the arrow on the left hand side of Figure 7).

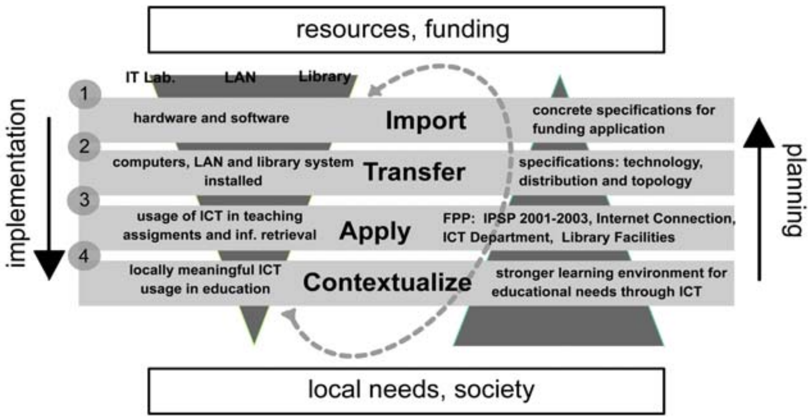

Figure 9: Implementation of IPSP 2001-2003

Analysis of FPP subproject 1: IPSP 2001-2003

Although the planning of IPSP 2001-2003 was carefully carried out, the implementation process was accompanied by several problems. The project required us to set up an IT laboratory, build a local area network (LAN), and develop the library facilities. The first problem that we encountered in the implementation of IPSP 2001-2003 (Figure 9) was on the *import* level (1). The problem was that it was difficult to obtain the right materials and machines. This problem compelled us to exercise patience because certain (often unexpected) difficulties such as long waits for the required materials are simply part of the reality of everyday working transactions in a developing country. But, even then, once we had got hold of the right technologies and material, we found that they could not be *transferred* (2) into use or operationalized immediately because of a number of practical reasons. The desks, for example, were not strong enough; water gushed into the building from outside; the earth leakage electrical system did not work; power cuts were frequent; there were no local fiber optic cable or companies with the necessary skills who could perform maintenance, supply spares or offer expert advice; the cooling system was inadequate, and so on. These problems are typical of developing economies. But once again, we solved these problems by exercising our imagination and by taking local conditions and possibilities into account. Before they could *apply* the ICT (3) that they had acquired, the staff needed to be educated. Fortunately, there were a number of courses for the staff that imparted computer literacy. These are noted in IPSP's *human resource development:* see IPSP in Figure 3. *Contextualization* (4) required us to exercise a great deal of imagination and ingenuity in our consideration of the local context. This level was at least conceptually met by the contextualized programming courses that we started at IUCO in 2004. These courses are the first components of a contextualized B.Sc. degree program in ICT.

Analysis of FPP subproject 2: Internet connection

Our intention in the beginning was to set up the Internet connection within four months. But our timetable was too optimistic because there were no suitable ISPs available in the region. This caused a two-year delay at the *import* (1) level (Figure 10). After two years had passed, ISPs were offering ADSL connections in the area at a reasonable price. Even so, the connection was not satisfactory. We had a problem at the *transfer* level because of the slow speed of the ADSL and also because of frequent interruptions to the connection (2). But the reliability of the connection gradually improved, and eventually, in some Internet-related classes, the local server was able to maintain a stable Internet connection.

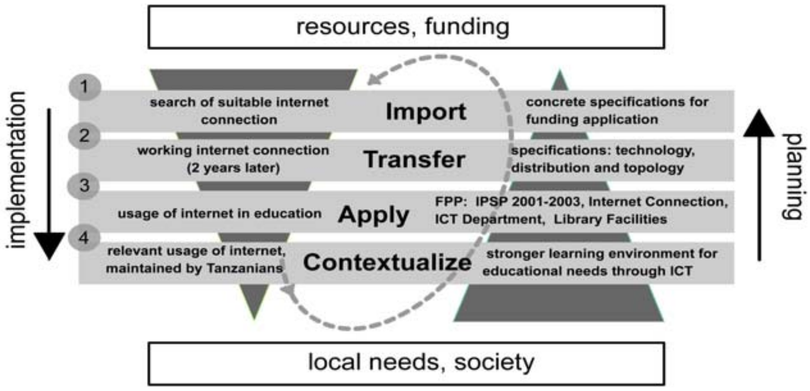

Figure 10: Implementation of the Internet Connection

When we reached the *application* level (3), we found that the number of Internet users was growing more quickly than bandwidth (128/64 KB). The cost of Internet connection also

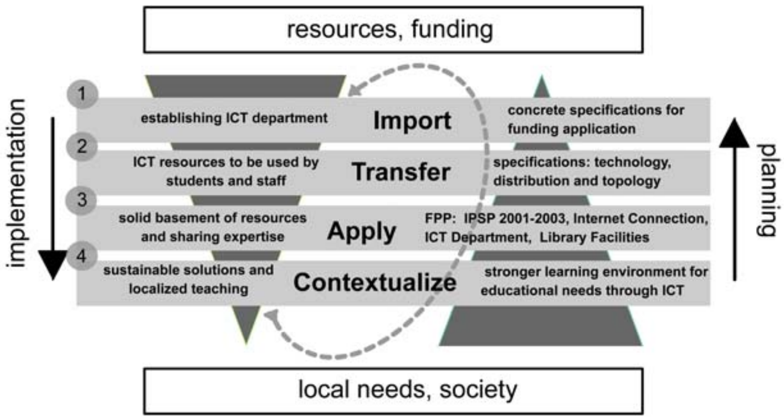

Figure 11: Implementation of ICT Department and Its Budget

remained high. Despite these continuing difficulties, the newly functioning Internet connection gave us opportunities to undertake *relevant* teaching to access necessary information (4). Such activities were among the main goals of the IPSP project. A number of IUCO's departments also at this time began to experience substantial benefits. Thus, for example, the Department of Business began regularly to get access to real-time information about national and international businesses; the Department of Journalism began to get access to national and international papers, magazines, and other media, and the Department of Education began to get access to databases and e-libraries. And by 2004 the LAN was being maintained by IUCO staff and by technicians from TTCL, a local Tanzanian company.

Analysis of FPP subproject 3: the ICT Department and its budget

In the early days of the project, the ICT Department was being run only by temporary staff. The department also had no solid funding on which it could rely. It became apparent to us that if *sustainable* development were to take place in the ICT Department, it would have to be properly organized. Obtaining (1) external funding and employing regular staff would open for IUCO opportunities to *transfer* (2) the technology that IUCO needed to function properly (Figure 11).

The shortage of staff was remedied when the department obtained the services of a few Tanzanians who had been educated in Western countries. This employment of trained, knowledgeable and capable staff members made the practical *application* of technology possible (3) (Figure 11). We found however that the new staff was not committed to innovative approaches to the teaching of ICT courses that were relevant to the local sociocultural context (4) because the local approach to education seemed to be based on modified nineteenth century Western models. In addition to this, the institution was also then not offering a competitive working environment, salaries or career opportunities.

Analysis of FPP subproject 4: Library Facilities Improvement Project

The Library Facilities Improvement project was the least ICT-intensive part of FPP. There again, the library project was strongly linked to the information needs of IUCO. The first part of the project involved the *importation* of second-hand books from abroad (1) (see Figure 12). Although this greatly expanded the library's book collection, some of the imported books were outdated or irrelevant. The consequence of this was that departments were asked to propose lists of the books that they needed so that they might benefit more specifically from the library as a resource. This represented *transference* of the benefits of the resources to those that needed them (2). The subsequent use of books in different fields of education moved the process onto the application level (3). It is pertinent at this point to ask how contextualized or relevant the material was. When students begin to use library resources for their own needs, library services begin to approach the contextualization level (4).

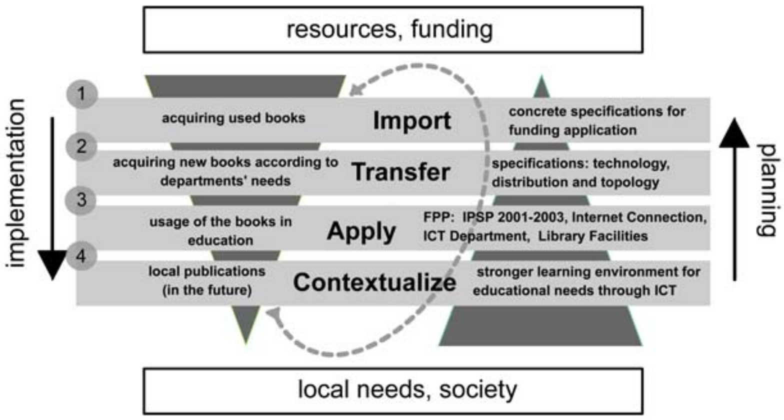

Figure 12: Implementation of the Library Facilities Improvement Project

5. Universal or Particular?

One of the main sticking points in the debate about technological development is the juxtaposition of *universal* and *particular* (this is also visible also in the above-mentioned *technology-oriented vs. community-based* development debate). This juxtaposition takes different forms in different contexts. In debates about the role of education, lines are often drawn between pure and applied, scholarly and professional, theoretical and practical, academy and industry, and abstract and concrete. The same antinomies are also evident in debates about knowledge – about whether knowledge is universal or particular, global or local, objective or subjective, transcendent or situated.

This debate is also central to our work. As we worked with the technologies and technological education that supports Tanzania's Vision 2025, we were constantly faced with questions such as, “Which elements and aspects of technology and education should be localized? Which should not be localized? Which elements of local knowledge contribute to our own understanding of technology and education?” Like most practitioners operating in this field, we have adopted an intermediate position between these two poles: we believe that a considered dialectic between universal and local creates a viable synthesis.

During our work in Tanzania, we gained a great deal of insight into the world of Tanzanian students, the university administration, as well as local and national government. Our experience leads us to maintain the position that it is imperative for us not to present computing merely as a scholarly, theoretical, and abstract activity that is removed from any kind of context. We also do not focus only on tools (i.e. on the practical, concrete, and the applied). Throughout this project we constantly sought a balance between the theoretical and practical, a balance that we believed would satisfy all parties equally.

In support of the national Vision 2025 and IUCO's strategies we built local networks and computer classrooms. This first aim – the construction of infrastructure – made it clear to us that it was important for us to understand the theoretical aspects of ICT while at the same time being able to adapt to and harmonize with local conditions. It is not enough simply to know how to build a computer laboratory. One also has to understand and be able to accommodate oneself to local customs and modes of operation in matters such as appropriate and reliable channels for funding, the levels and social meaning of bureaucracy, the ways in which local people organize themselves, channels of influence, risks and possibilities, strategic emphases, limited resources, and degrees of sustainability and commitment.

Our work in realizing our role in the second part of the major visions and strategies, *human resource development*, began with developing appropriate levels of ICT literacy in the faculty and students. Teaching basic computer literacy is a demanding task in a developing country, and we had to learn how to make the necessary compromises and adjustments along the way. Students and faculty in general had very little experience or understanding of any kinds of advanced technological equipment such as computers and their peripherals. Instead of imposing some kind of “universal approach”, or simply trying mechanically to transfer the content of some elementary textbook about computers, we supported the local approach by starting with a consideration of the needs of the students and the faculty.

We therefore approached the situation by working together with students and faculty firstly to identify and analyze the problems that faced us (by reference to the analyses made earlier by IUCO). Secondly, we identified the technical tools that would be appropriate for a solution of the problems that had been described. Thirdly, we enumerated the kinds of skills that would be needed for the various tasks that were facing us. We continued to defer respectfully to the local approach by accepting that teaching should not be merely theory-oriented imposition but that it should rather reflect a judicious combination of practical concerns and the subject matter that would be needed by students and teachers. Only once these matters had been settled did we give the theoretical implications of these practical issues the consideration that they needed.

Here we hit another series of problem. Because of Tanzania’s severe shortage of ICT professionals, we had to extend our range of teaching from computer literacy courses to courses in computer science because theory is indispensable to an understanding of computer science. In spite of this faultless analysis, the same question confronted us when we came to teaching computer science: should our teaching be pure or applied, theoretical or practical? Or, more specifically, what combination of both would respect local custom but yet support the unavoidable needs of the teaching process? A solution was closer to hand than it might otherwise have been because together with many authorities in the field of computing, such as Knuth, 1991 [33], we believe that abstract and concrete considerations are inextricably linked in the teaching of computer science. We consequently emphasize the fact that ICT professionals constantly face not only theoretical and technological limitations, but also economic, ecological and geographical limitations – not to mention cultural, social, and philosophical barriers [30]. While theoretical and technological limitations may be universal and non-culturally specific, the other limitations are very real too, and ways to cope with them cannot be learned from textbooks.

Our goal was (and is) therefore to teach computer science that has meaning, programming that is based on sound empirical premises, and problem solving that is concerned with real problems [34]. Both content *and* context are important in ICT education. *Content* represents pure, scholarly, global and theoretical considerations while *context* represents the applied, the professional, the practical and the local. Content is hardware, context is the uses to which hardware is put. We believe that if technology, technological know-how, computer applications, and ICT education are all imported and uncritically accepted, the country that imports them will remain on a digital leash as a mere consumer of ICT. An uncritical acceptance of foreign technology is precisely the syndrome that has given rise to concerns about some of the more deleterious and sinister aspects of the process of globalization.

In contrast to being solely an uncritical importer, Tanzania could, if it were to nurture local means of production and local talent, become a country that develops ICT-specific education and a culture of ICT that is peculiarly Tanzanian in spirit and identity. In the process, it could also support local development, contribute to meeting WSIS goals, and create for itself a role as a producer of and contributor to ICT. One need not locally produce all that is needed for computing. It would be folly to attempt to compete in an already saturated international hardware markets. But if it were to bypass hardware production and move directly on to less material modes of production, Tanzania could well gain a share in global markets.

In we will continue our work in future by retrospective analysis of the skills that students have learned during the computer science courses. Our main focus in that case will be on the *application* of ideas and the skills that students invent and learn during or after the courses. This will give us important information about the future development of computer science education in Tanzania and in any other developing country. It will also guide us as we continue to remain interested in the development of a local (Tanzanian) degree in ICT.

6. Conclusions

In this paper we sketched the development of ICT usage and ICT education at Iringa University College of Tumaini University between the years 2000 and 2004. During this time, the utilization of ICTs and ICT education evolved from a shadowy half-existence to being the pride and showpiece of the college. The university has contributed to this success by allocating steady funding from its budget for ICT concerns. It has also succeeded in obtaining sustained external funding for maintenance and development. The functional and practical ICT know-how that students are currently offered prepares them not only for the Tanzanian labor markets, but also for global information sources and global markets.

The most important lesson that this project has taught us is the indispensability of local knowledge. Much of the knowledge that the success of this research has been based on is tacit, unspoken knowledge of the researcher, knowledge that has come together during years of living within the community. Yet there is a lot of overt knowledge too, knowledge that can be transferred to other similar projects. Examples of this sort of overt knowledge are, for instance, the necessity and difficulty of finding even slightly *qualified people* for support and maintenance, not to mention ICT teachers; the importance of getting a *firm commitment* from different levels of the university; and the *locally built sustainability* for the project: In order to be worth the investment, most of the development projects have to eventually become autonomous and self-reproductive.

Iringa University College's successes in the development of ICT support and infrastructure as well as ICT education and training, its continuous channels of funding, ongoing human resource development, co-operation agreements, and its production of own, contextualized ICT-courses are all indicators of a very strong tendency towards autonomy and self-sustainability. Because the development steps taken during this project have all been locally managed and not imposed by outside experts, sensitivity to the world of the students and faculty has been maintained. Furthermore, neither teaching nor planning have been based on standard Western strategies, but on local skills, attitudes, values, knowledge, as well as local limitations. As such, the teaching and planning both have a much better sociocultural fit than an imposed "standard" or "mainstream" strategy would have had.

Our experience with this project has led us to propose a four-level CATI model for ICT planning, evaluation, and training in developing countries.

These four levels, *contextualize, apply, transfer* and *import*, constitute three aspects of the ethnocomputing of a particular sociocultural setting: representation, utilization, and appropriation [35]. *Representation* consists of aspects such as conceptual models, mental models, and methods of teaching; *Utilization* includes aspects such as uses of technologies, diffusion patterns, and social attitudes towards technology; *Appropriation* involves aspects that break the mainstream mental models, such as using technology for non-standard purposes, job-creation through innovative business ideas, and the creation of ad-hoc solutions for technological obstacles.

We believe that an interaction between the implementation and planning-aspects of our approach can significantly help projects to achieve results that are sustainable, relevant, and autonomous as well as effective, productive, and influential. After all, no technology is ever used in a sociocultural vacuum: The power and significance of hardware and software comes from warmware, from people, from the fact that technology can help people in some way or another. If an ICT project lacks the know-how of implementation, progress is hard to achieve – and if a project lacks relevance in planning, seeming progress may not improve anything. But an insightful combination of implementation and planning can result in a real, decisive improvement in people's lives.

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Biography

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Publication PAPER IV.

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ETHNOCOMPUTING IN TANZANIA: DESIGN AND ANALYSIS OF A CONTEXTUALIZED ICT COURSE

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A crucial challenge in the teaching and learning of information and communication technologies (ICTs) in developing non-Western countries is the irrelevance of much Western learning content, materials, tools, and methods from the perspectives of local communities. Our approach for designing an ICT course is based on the concept of ethnocomputing — finding culturally suitable entry points for understanding, utilizing, and producing ICT in a relevant way. In order to study the feasibility of our approach, we designed a contextualized introductory programming course with Tumaini University, Tanzania, and offered it to second-year undergraduate students in teacher education in the academic year 2004–2005. The approach was to encourage students to create programs that would meet the needs of their own local communities. The course made extensive use of learning technologies, such as robotics, to concretize the first steps in understanding ICT. We applied an ethnocomputing-based analysis to three aspects: (1) the development process of the course; (2) the role of learning technologies in the course; and (3) students' contextual learning outcomes. First, representation, utilization, and appropriation appeared at various stages in the development of the course. These included unexpected spin-offs for local communities, such as the introduction of educational robotics to assist young patients in a rural hospital. Second, contextual relevance of learning technologies — digital learning materials, the robotic I-BLOCKs, and the Jeliot program visualization tool — was analyzed by the CATI model, and the results indicate their relevance at all the four levels of the model: Contextualization, Application, Transfer, and Import. Third, student learning outcomes were observed by using content analysis of questionnaires and interviews. There is evidence that students developed a contextual understanding of ICT, especially at the application level of the CATI model. Overall, the study indicates that an ethnocomputing-based analysis can be used for designing needs-based ICT education by analyzing its feasibility with various operationalizations of the ethnocomputing concept. Moreover, research results envisage new components and methods for an entirely contextualized undergraduate curriculum of ICT.

Keywords: Ethnocomputing; ICT education; Tanzania; development.

1. Introduction

One of the critical challenges facing those who attempt to introduce information and communication technology (ICT) in non-Western countries is its irrelevance from the perspectives of local communities. Conventional learning content, materials, tools, and methods are mostly of Western origin and do not necessarily address the needs of potential non-Western users of ICTs. Moreover, for most non-Western learners, ICT is a completely new subject field, and hence its contents cannot easily be built on the previously known. Teaching of ICT also mainly aims at certain skills, such as programming, and most teachers prefer to follow a path which exposes students to the area step by step. However, even if ICT education emphasizes skills, the learners find it very hard to apply them to real world tasks, especially at the beginning of their studies.

The term "Computing" refers to the family of closely related disciplines of Computer Science, Computer Engineering, Software Engineering, and sometimes also Information Systems Science. ICT can be understood to belong to this family as well, as a practically oriented subject, intended mainly for minor studies. Nearly everyone who works in Computing Education Research (CER) uses the universal ACM/IEEE Computing Curricula (ACM & IEEE, 2001) to anchor her/his understanding of what students should learn, and on which basis learning outcomes should be measured. Although such an approach might be justified on purely *conceptual* grounds, it might attract a researcher to ignore the *realities* of the learners' background in those cases where the cultural assumptions of learners are radically different from those of learners who have grown up in so-called Western cultures where ICTs are more commonly an integral and accepted part of everyday life.

One of the achievements of traditional universal computing education is that the teaching of programming has been designed and analyzed mainly from a point of view determined by the *syntax* and *semantics* of various programming languages and paradigms. An alternative *pragmatic* approach would be to begin the design process by making a careful study of what ICTs in general (and specifically programming) would look like if they were designed to accommodate learners whose social and cultural realities are very different from those of learners from highly developed countries, such as the US, Japan, Australia, and those in the European Union. We call such an approach *ethnocomputing* (Tedre, Sutinen, Kähkönen, & Kommers, 2006) because it strives to create a discourse of teaching and learning that frames computing as theory and of the practical use of ICTs in culturally relevant terms that are immediately familiar to local learners.

Because Computing Education is traditionally standardized, it provides us with an interesting perspective for studying the role of various cultural factors in different aspects of a course. This applies particularly to learning technologies as they represent both the content and learning tools of an introductory ICT course. This explains the choice of the three aspects of this study: (1) the development process of the course, (2) the role of learning technologies in the course, and (3) students' learning outcomes.

Most learning technologies that have to date been applied in, say, programming courses have been *theory-driven* (or course-driven or content-driven). For instance, students use a compiler to apply their knowledge as they build reliable and predictable programs, or they visualize them so that they can see how various syntactic structures function. The theory-driven approach builds upon an emphasis on the syntax and semantics of programming.

A *community-driven, needs-based* approach is an alternative to the theory-driven approach of learning ICT. It is consistent with the innovation systems approach for economic improvement that is emphasized in the recent report on achieving the Millennium Development Goals (Task Force on Science, Technology, and Innovation, 2005). Comprehensiveness, common to community-driven and innovation systems approaches, requires that multiple viewpoints can be taken into account simultaneously. The community-driven approach is based on the pragmatic focus of ICT education.

The key question in this study is "What is the design process of a community-driven ICT course?" A complementary question is "How can such an approach be feasible; that is, how can a community-driven ICT course make sense in its context?" This requires a feasibility analysis of the approach. These two aspects of design and analysis are closely related.

We will answer the first (design-related) question by describing the design and implementation of an introductory ICT course that was devised for second-year undergraduate students in the Department of Education at Iringa University College (IUCO) of Tumaini University in southern Tanzania. The course material and program were constructed to reflect the everyday life of local learners. Extensive use was made of learning technologies such as robotics to concretize the first steps in understanding the opportunities of ICT. The students were encouraged to create programs that took cognizance of the expectations, needs, and traditional concerns of their communities. This kind of approach to studying ICT reflects the essence of ethnocomputing which requires one to identify culturally meaningful entry points for understanding, utilizing, and producing ICT in a relevant way.

We will answer the second (analysis-related) question by presenting a feasibility analysis of our approach that consists of the three aspects of this study mentioned above. We based the analysis of outcomes on questionnaires and interviews. We classified the primarily qualitative data by using Atlas.ti software and interpreted the way in which students learned ICT by means of the CATI model's four levels of **C**ontextualization, **A**pplication, **T**ransfer, and **I**mport (Vesisenaho, Kemppainen, Islas Sedano, Tedre, & Sutinen, 2006).

In a study like this, it is important to recognize the limitations and reservations that the researchers' background might have on the actions and observations throughout the research process, as well as the comprehension and interpretation of its results. The researchers came from a Computer Science department of a Finnish university, but they have been in a regular working relationship with the Tanzanian university from the year 2000. This collaboration became even more intense

Table 1. Ethnocomputing approach to the design and analysis of an introductory ICT course in Tanzania (The numbered items refer to sections in this paper.).

	Design	Analysis
Development process of the course	2.2	4.1
Role of learning technologies	2.3	4.2
Students' learning outcomes		4.3

throughout this study, and the role of local teachers was crucial for improving and analyzing the course.

The overall research scenario is presented in Table 1. It is a conceptual test of the validity of ethnocomputing in developing community-driven studies in ICT. The structure of the paper follows the research scenario. Section 2 describes the context, including the course itself and the use of learning technologies therein. Section 3 presents the research method, starting from the three operationalizations of the ethnocomputing concept. Section 4 reports the findings of the study, with our interpretations. The results are discussed in Section 5, and Section 6 concludes the paper.

2. The Context

2.1. *Iringa University College, Tumaini University*

Tumaini University is a private university run by the Evangelical Lutheran Church of Tanzania. It consists of four campuses in different parts of the country. Its biggest campus, Iringa University College (IUCO), is located in the southern highlands of the country. Iringa itself, the capital of the region, has a population of 350,000 (The United Republic of Tanzania, 2002). IUCO, in which this study took place, consists of four faculties: Arts and Social Sciences (which includes Departments of Journalism, Cultural Anthropology and Tourism, and Education), Business Administration, Law, and Theology (Tumaini University, 2005).

The student profile of IUCO clearly reflects the demographics of a sub-Saharan African university in which students come from many different ethnic backgrounds in terms of both nationality and tribe. Because the University is a private one and charges relatively high tuition fees, a number of students are reliant on scholarships. Most students come from rural areas and have no tradition of academic study in their families. What this means in practice is that their prior experience of ICT is either nonexistent or very limited indeed.

Out of all the IUCO graduates in 2004, a total of 41% were female (Bahendwa, 2004) compared with a Tanzanian average of 27% (The United Republic of Tanzania, 2005). Although these figures are not directly comparable, they indicate that the gender division at IUCO is somewhat more even than it is in other Tanzanian universities. The student body at IUCO has been growing. It was 200 students in 1999, 670 in 2004, and more than 1,000 in 2005 (Tumaini University, 2005).

The 27 students who took part in the current study are representative of the student demographics referred to above. Their ages ranged from 24 to 44 years, with the average age being 35 years. There were 16 men and 11 women in the group. All except two students had preliminary teacher education. The group came from 16 different regions of Tanzania and from 17 different tribes. Most of the students' parents were farmers and housewives, showing that the University serves the whole community and not just the rich and privileged. About eighty percent of students had used computers for only one year.

The mission statement of IUCO (Tumaini University, 2006) includes a commitment to provide staff, facilities, and support appropriate to a university of the highest order, to promote research, its organization and application to the learning environment, and to support service to the community, region, and nation through the church, the government, industry, public, and private organizations. The mission statement reflects a contemporary understanding of the three main tasks of a university: teaching, research, and commitment to the community. The successful implementation of a mission statement such as this in the modern world requires a certain level of ICT efficacy. This also explains why IUCO places a strong emphasis on, and makes a clear commitment to, expanding the use of ICT in all its activities.

IUCO obtained its first second-hand computers in the mid 1990s. Even in those first years, the focus was already on including ICT applications such as word processing in the curriculum. In 1999, IUCO launched a strategic plan for ICT development (Ashford, 1999) that emphasized human resource development, institutional capacity building, and the development of infrastructure. This plan has since served as a solid basis for the use and implementation of ICT in education.

From the point of view of this study, it is important to pay attention to how ICT can help a teaching and research institution, such as IUCO, to fulfill its societal task. The teaching and learning of ICT need to be contextualized in terms of the local culture precisely because IUCO is committed by its ethos and mission to community service. Any kind of teaching at IUCO must therefore be seen to have such a focus. The expectation implicit in this kind of teaching is that students who have been taught in this way will take the lead in shaping the future of their country in a way that emphasizes service to the community. This perspective indicates also the relevance of this type of research beyond its original scope.

2.2. *Course description*

2.2.1. *Aims of the course*

The introductory course on ICT (known as the Contextualized Introduction to Programming) is a compulsory course for second-year undergraduate students in the Department of Education. The aim of the course is to help students to understand and appreciate the extent to which ICT can enrich and enhance human activities in authentic environments. Students who are trained in this way should be far more likely to use ICT as effective and efficient application tools wherever they can in their future jobs compare to those who are not trained in this way. Although most of the students from a group such as this will end up as subject teachers of science or mathematics in secondary schools, the purpose of the course is to give such teachers an in-depth appreciation of just how effectively ICT can be used in any typical Tanzanian community setting to serve the community itself. In addition, such teachers will be in a position to inspire their future students with a vision of just how constructively ICT can be used, so that the students themselves ultimately become intelligent consumers of ICT rather than hapless users.

The aims of the course determine its curriculum in terms of content, methods, materials, and activities. In this case, the course objectives emphasized *programming competence* at the cost of practical experience in learning how to use various types of office software. The idea was to equip these future teachers with a certain level of skill in programming so that they could resolve technical difficulties and use ICT for their own purposes, either by requiring more from ICT services or, in some cases, programming by themselves. We also felt that a technically orientated course would give teachers the practical wherewithal to inspire their future students with the excitement and potential inherent in ICT.

However, before the course evolved to this stage, it underwent an incubation period of almost five years. This period of incubation is described in the following section.

2.2.2. *A brief description of the history of the course*

Table 2 gives an outline of the various phases through which the course design process evolved. We began course development in the *Preparations phase* with two masters-level students from Tumaini University studying at the University of Joensuu in Finland. These students helped us to tailor the new ethnocomputing approach to ICT education that we proposed for their own local Tanzanian context. As a starting point, we invited them to engage in our Finnish ViSCoS (Virtual Studies of Computer Science) non-degree program which allows high school students to take first year, university level Computer Science courses over the web (Haataja, Suhonen, Sutinen, & Torvinen, 2001).

One of the two master's students went back to Tumaini after he had graduated. With him and other ICT experts from IUCO, we organized *Workshops* in 2003 and 2004 to evaluate the usefulness of robotics in ICT education (Vesisenaho & Lund, 2004). Our hope in doing this was that we might obtain new and useful ideas for developing contextualized ICT education at IUCO.

On the basis of the encouraging opportunities that we identified in the Preparations phase, as well as the feedback from the Workshops, we launched a more serious *Consultations* phase in which we planned to launch a completely revised and redesigned Introduction to Programming course. When we analyzed the implementations of the programming courses of 2002 to 2004 that had been held at IUCO, we noticed that this course, targeted at novices, included, in its earlier stages, an introduction to the BASIC programming language and, later on, the implementation of advanced data structures and concepts such as stacks, queues, and trees

Table 2. The five phases of contextualizing the Introduction to Programming course.

Phase	Time	Objective	Partners	Contents and/or Activities	Learning Technologies
Preparations	2000–02	To get ideas on how to contextualize basic Computing concepts in the Tanzanian setting	UJ	Two IUCO BBA graduates at UJ studying for MSc in CS	The Finnish version of the first year virtual CS studies, ViSCoS
Workshops	2003–04	To identify the role of robotics in an introductory ICT course	SDU, UJ	One-day workshop with students who were building and programming robots	I-BLOCKs
Consultations	2003–04	To create a syllabus for a new, contextualized ICT course	IUCO, SDU, UJ	Analysis of IUCO's existing programming course	
Course I	2004–05	To design and analyze the first version of the course	IUCO, SDU, UJ	Workshop, lectures, assignments, project, examination	I-BLOCKs, Jeliot, ViSCoS.tz
Course II	2005–06	To implement a new, improved course	IUCO, UJ	Workshop, lectures, assignments, project, examination	I-BLOCKs, Jeliot, ViSCoS.tz

IUCO = Iringa University College of Tumaini University; SDU = University of Southern Denmark; UJ = University of Joensuu; I-BLOCKs, Jeliot and ViSCoS.tz are explained in Section 2.3.

in the C language. Students who did this course did not have any programming experience before the course began.

We continued to hold consultations between Tumaini University and its partner universities (the University of Joensuu and the University of Southern Denmark) in the first half of 2004 on the basis of what we, by then, knew to be the requirements of the local programming course. At the same time, we began to develop the course materials and structure. During this design process, we occasionally returned to the course structure of previous years. Part of the problem of negotiating a mutual understanding between ourselves and those at IUCO arose out of the necessity to define the general requirements of programming courses in terms that would be universally accepted and understood in the global Computing community. In the end, we reached amicable agreement about what the course content should be.

We launched the first newly designed course, referred to here as *Course I*, in October 2004 with an activating workshop based on robotics. A comparison with traditional programming courses will show that the syllabus of this course paid less attention to covering all the topics of a standard programming course and, instead, encouraged students to build their own programs and projects — even with incomplete knowledge. This course, as well as its successor, *Course II* (2005–2006), which was an improved version of Course I based on student feedback, ended with a concluding workshop in which the students presented the projects which they had partly carried out in local schools or hospitals.

2.2.3. *Content of the course*

The course that we agreed upon in this way included an introduction to the basics of computer programming. This introduction placed a special emphasis on Java which, because it is the lingua franca of the web, bridges the way to more technical tasks. Our first expectation was related to learning technical skills: the students should have a good general knowledge of the methodology of creating computer programs after they had successfully completed this course. They should also acquire a general understanding of robotics and modern technologies. The second expectation was more contextual: the students should appreciate the usefulness of programming and its application in their own society. Our long-term hope was that students could map their technical skills onto the needs of their surroundings.

From the point of view of technical content, the course was an unconventional hybrid of two topics seemingly far removed from each other at first sight: programming by building and the basics of Java. The first topic covered an introduction to robotics and mainly event-driven programming, and the second one covered procedural programming with control structures and applets. The course carried a weight of three local credits, which is equivalent to about four ECTS (European Credit Transfer System) credit points.

2.2.4. *Course I arrangements*

Course I was presented by two teachers, one from the University of Joensuu and the other from Tumaini University. Because the Tanzanian teacher had other responsibilities apart from teaching, he was only occasionally present. The actual teaching thus fell to the teacher from the University of Joensuu. The course consisted of the following activities:

- a workshop;
- lectures that were supported by weekly exercises (including a learning diary) and an optional tutoring session;
- a project assignment;
- a project presentation session; and
- a final examination.

The first part of the course consisted of a one-and-a-half day workshop in which students used I-BLOCKs (intelligent building blocks) for programming (see Section

2.3.2). After this, they were taught the Java language in a computer laboratory during six hours of weekly contact teaching over a six-week period. Each week's teaching program also included web-based exercises, a learning diary, and three hours of optional tutoring (Lund, Nielsen, Sutinen, & Vesisenaho, 2005).

During the course, each student received six sets of weekly exercises that were based on the six units of the course material. While such exercises gave students opportunities to practice their skills, they gave their teachers information about levels of understanding among the students. The weekly assignment also included a learning diary in which students were required to reflect on their learning and develop applications relevant to the local context. This exercise was also intended to make both students and teachers more aware of, and sensitive to, their local context.

For the purpose of projects, students were divided into groups that contained three to five members per group. Half of the groups undertook a project on teaching basic ICT skills to secondary school students by using I-BLOCKs. The other groups engaged in a Java programming project in which they had been asked to develop a program that would be beneficial to secondary school teachers or to students. The topic choices included the programming of a calculator, making a program that could create graphic representations of polynomial functions, making a program for a simplified Bao game, and the making of three different mathematical programs of their choice. All of these topics made sense for the future subject teachers of mathematics.

2.2.5. *Changes in course arrangements for Course II*

The objectives of Course II were the same as the objectives of Course I in the previous year, except that there was less focus on robotics and I-BLOCKs because the I-BLOCKs had been temporarily misplaced after the first course. We also set aside less time for workshops than we had done in the previous year and extended the completion time for the whole course. The students in this year had better access to printed reference material because the books they needed had finally reached the library. In all other respects the course was the same.

For programming projects, two groups of students taught secondary school students about ICTs by using I-BLOCKs. In another group, the students introduced orphan children to the potential of ICT by making use of I-BLOCKs and A-BLOCKs (African I-BLOCKs), a newly created set inspired by the feedback from a special project related to Course I with hospitalized children. In the Java projects, students were given the freedom to develop any program that might be beneficial to teachers or students in secondary schools in Tanzania. The topics chosen for those projects were: a $2 * 2$ matrix program, solving integration of exponential functions, and a statistics program for analyzing student scores.

The teacher from the University of Joensuu was effectively the only active teacher of the course. The reason for this was that the new local ICT teacher had to be engaged elsewhere in teaching other courses. He also had an onerous workload as a technician and simply did not have time to update his own programming skills as well as plan and attend the lessons. He was nevertheless kept informed about what was happening in the program as a whole. The four best students from Course I were selected as assistant teachers so that they could supervise projects during the course. The idea was to train them, so that at least one of them would be able to present the course in future with only online support from the University of Joensuu.

2.2.6. *Spin-offs*

The contextualized ICT courses we organized benefited various Tumaini University students and communities in the vicinity of Iringa in some unexpected ways. First, three students from Course I were selected on merit to undertake special projects in ICT as part of their studies. The titles of the projects they were given were:

- the influence of teaching strategies on students' achievement in learning computer programming in Tanzanian secondary schools;
- an investigation of the role of computer programs in the teaching and learning of mathematics: the case of Java and Maple 9; and
- an investigation into the application of I-BLOCKs in a Tanzanian context.

In addition to this, one Course I student was awarded a five-month grant to continue her studies in Finland. Second, the University of Tumaini has begun to build the Tumaini University Science Park, the first of its kind in East Africa. Successful prototypes of A-BLOCKs have been developed and are due to be produced in the Science Park. Plans for an ICT bachelor degree with a strong local-content curriculum are also getting underway. The Technology for Education in Developing Countries Conference (TEDC 2006) was held at Tumaini University in July of 2006.

Third, student projects became seriously engaged with local concerns in the Iringa region and extended their activities in various fruitful directions. An interesting example of such a project in which course content and methods are used to further learning activities (in this case in local hospitals) may be seen in how students have been using ICT to produce therapeutic aids for hospitalized children (called the Ilembula Project).

2.3. *Role and use of learning technologies*

The learning technologies used in the Contextualized Introduction to Programming course can be divided into digital learning materials and activating tools. Since the design of the course was guided by the principles of ethnocomputing, we stipulated that learning technologies should comply with the following requirements:

- Digital learning materials should be presented in such a way that students should feel comfortable, rather than culturally alienated, while studying any new topic in this field. The presentation should be culturally adapted that students will find it easier to come to grips with the material.

- Activating tools should equip students to express themselves in terms of the new concepts of programming that they are learning. These tools should also stimulate students to create new and exciting ways of applying ICT in their own communities. In order to learn skills and get technical competence, one has to practice; that is why it was crucial to have activating tools in addition to more or less static learning materials.

2.3.1. *Digital learning materials*

The main course material, called VisCoS.tz, formatted as light web-based material in HTML, was developed by researchers at the University of Joensuu with assistance from a lecturer from IUCO. We used Flash for navigation animations. We had Java applets in the materials and then made the most of programming code locally available to the students because the limited Internet capacity made downloading, or even browsing, slow. We also used other web-based materials because books were only available on a limited basis and web-based material is easy to deliver and update. We also circulated most of the web-material in the form of printed handouts to students because they had only limited access to computers that were connected to the University's LAN. We also ordered a few textbooks on Java, entitled *Java for students* and *Introduction to Java,* for our students. The simultaneous use of web material and printed course materials was a novel experience for the students at that time.

We published the course material for each week (comprising six units) in the local server. The metaphor of the instructional interface was a village (Figure 1).

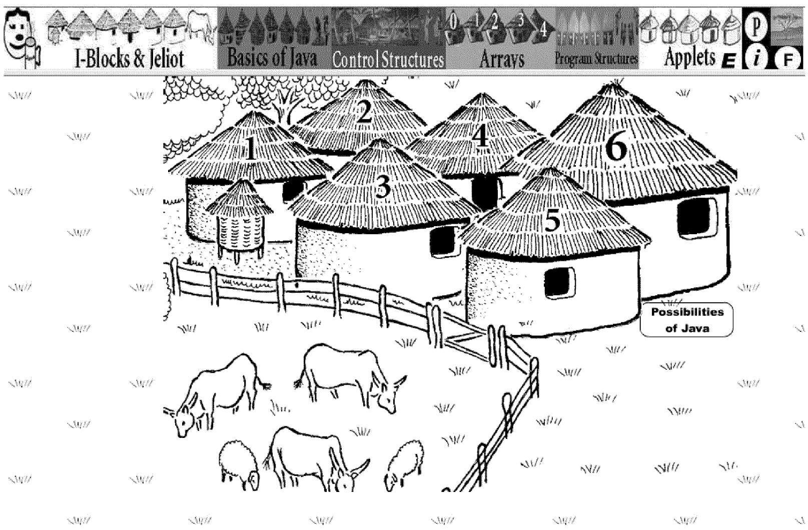

Fig. 1. The learning village as a graphic metaphor of the course material.

Students using the site could obtain the information they needed by clicking on the huts and the people in the village. We used this symbolism deliberately in order to demonstrate that computer programming does not have to be presented in obscure "high tech" Western-specific formats, but it can be made easily grasped if it is taught by means of imagery and concepts that are entirely derived from the local social and cultural context of learners. It was, of course, interesting to see how students received our graphical representations of their own context.

We included programming examples that students could download and modify. Even though they were given weekly problems to solve, they were also encouraged to come up with their own ideas and plans for making programs. The course also supported four PHP-based forums: question–answer, project work, general information, and free discussion.

2.3.2. *Activating tools*

Since the course was a hybrid of two complementary approaches to learning programming, we felt that it was necessary to support each of these approaches with an appropriate activating tool. We were also keen to find out how these tools could be integrated into the overall design of the course and how they might further be developed by means of feedback from our learner group. We hoped that because our learners had not had much exposure to ICT, they might be able to offer some original, ingenious, and stimulating suggestions for modifying our existing tools.

I-BLOCKs (Figure 2) allow users to build a program by connecting together blocks of three different kinds (Lund, 2003):

- *input blocks* with a sensor or mechanism to set a value;
- *output blocks* producing a tone, displaying a value, etc.; and
- *operator blocks* for arithmetic or logical operations.

Their modular design makes it easy for learners with no prior programming skills to use I-BLOCKs to assemble, say, a program that produces an alarm (by an output block with a sound synthesizer) when it recognizes a touch (by an input block with a touch sensor). We used I-BLOCKs to introduce programming concepts because these I-BLOCKs teach students the fundamentals of modern technologies while they

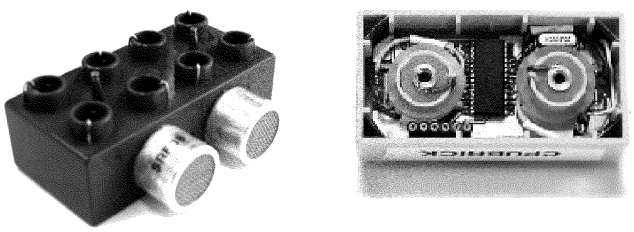

Fig. 2. I-BLOCKs with microprocessor and communication channels (Lund, 2003).

use them in various arrangements to construct an assortment of devices. The University of Southern Denmark also developed a simple programming interface called I-BLOCK Application for the course. This interface allowed students to program I-BLOCKs for different functions in an easy manner. The QEL Micropro program was used for downloading programs to the Microchip inside the I-BLOCKs.

We were particularly intrigued by two aspects of the use of I-BLOCKs by our students. The first was how I-BLOCKs inspired students to come up with new ICT-based innovations that were relevant to their own communities. The second was how familiarity with I-BLOCKs enabled students to make valuable suggestions about ways in which they might be further developed and refined.

Jeliot program visualization software allows students to follow each step of what happens in their Java programs (Figure 3). It has been shown to be particularly helpful to students who are new to programming (Levy, Ben-Ari, & Uronen, 2003). Jeliot is also useful for illustrating the behavior of the basic control structures and arrays. In some ways, it functions much like I-BLOCKs. It is a hands-on tool that allows students to experiment with code and see the otherwise inaccessible configurations of a running program.

One of the main challenges when using any visualization tool is how to make it an integral component in the course design. Visualizations that may look quite appealing to teachers might make little sense to learners. The ethnocomputing approach requires us to ask how exactly any visualization tool has been culturally adapted to facilitate the learning process. *Adaptability* in this context means the extent to which learners can adjust the visualization to suit their cultural preferences. An adaptive system adapts automatically to the user's profile. How cultural adaptation may be distinguished from cognitive adaptation is addressed in various places in the existing literature about program visualization.

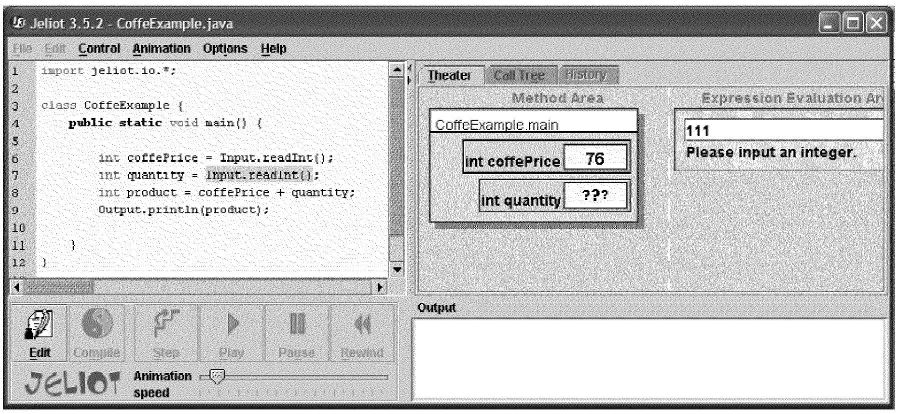

Fig. 3. Screenshot of Jeliot visualizing a program. The code is in the left window, its dynamic visualization in the right one.

3. Methods

The first question in this study focuses on what happens when a learning technology takes the cultural background of learners into account in order to make learning possible. We will answer this question by describing the design process of the course.

The second question about the feasibility of the design can be answered by presenting an analysis of the three aspects of the learning outcomes as they became evident in the students' application of ideas for ICT. Successful ideas for the use of ICT that were culturally relevant to local communities were considered by us from the very beginning to be indicators of successful course design.

In this section, we will describe the methods that we used in the study. The general framework of our analysis is rooted in the concept of ethnocomputing which is described in Section 3.1. At this juncture, our analysis will explain how we deliberately incorporated certain cultural adaptations into the design of the Contextualized Introduction to Programming course. We used the CATI model to operationalize the concept of ethnocomputing (Section 3.2). This model ensures that an ICT is culturally *sustainable* or *rooted* in a community because it tests whether or not the ICT concerned complies with the four stages designated by the CATI model (Contextualize to Apply to Transfer to Import). The CATI model can be used to analyze both the design of the course and its learning processes or outcomes. The analysis of the learning outcomes requires a content analysis, and we will return to this in Section 3.3. The research scenario is represented in Figure 4. The arrows show which operationalizations of the ethnocomputing concept are used to analyze each of the three aspects. Learning technologies, for example, need to be analyzed both in terms of ethnocomputing and the CATI

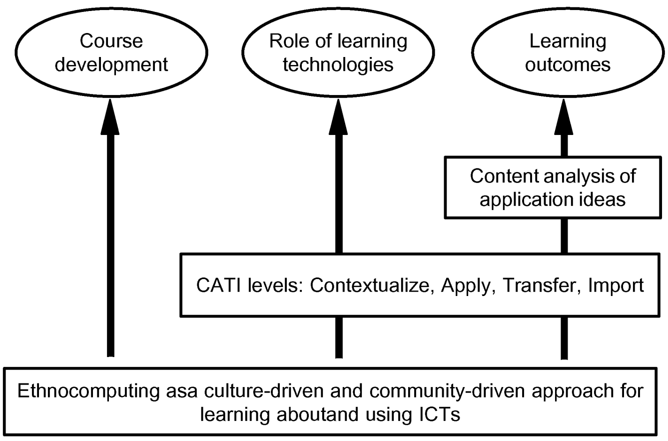

Fig. 4. The overall research scenario.

model. We will analyze the course development process in Section 4.1, the role of learning technologies in Section 4.2, and the learning outcomes of the students in Section 4.3.

3.1. *Ethnocomputing as an explanatory framework*

Ethnocomputing (Tedre *et al.*, 2006) refers to an approach that makes it easier to understand, use, and apply ICTs and the theory of computing. This can be done by interpreting such ICTs in terms of the *particularities* and idiosyncrasies of an ICT user's own culture rather than in the terms that were developed and that are usually regarded *universal* in the developed world. While the universal language of computing discourse cannot be set aside, the difficulties of translating computing theory and methods for using ICT into terms that ordinary people can understand, constitutes a clear failure of the computing community to transfer the extraordinary benefits of its expertise to those who desperately need it.

We have begun to compensate for this serious omission by teaching community-driven or culture-driven computing in the spirit of the UN Millennium Goals (United Nations General Assembly, 2000) that call for no person to be excluded from the benefits of this science. In our practice of ethnocomputing, we teach the subjects that comprise the Computing family to student populations from previously disadvantaged communities that have had little or no exposure to modern ICTs. In ICT education, *ethnocomputing* refers to any approach to the learning and teaching of computing theory and of ICTs that is mediated by a discourse that has been specially adapted to make it familiar and user-friendly to those whose culture is different from the industrialized culture of developed countries. Ethnocomputing emphasizes the need to create culturally meaningful entry points for learners to understand, utilize, and produce relevant ICT.

Ethnocomputing in any given sociocultural setting can be analyzed from the point of view of representation, utilization, and appropriation (cf. Eglash, 2004). *Representation* refers to conceptual models, mental models, and methods of teaching. *Utilization* deals with the various uses of technologies, diffusion patterns, and social attitudes towards technology. *Appropriation* refers to creative initiatives that challenge our mainstream ideas about what should be happening. These include the use of technology for nonstandard purposes, job creation that is stimulated by innovative business ideas, and the creation of effective ad hoc solutions to technological problems.

In this case, as we are using ethnocomputing to analyze the design process of a particular computing course, it can be applied at the different stages of the course's lifespan. An analysis of this kind would include:

- analyzing the needs that gave rise to the course in the first place and identifying the reasons why the course was created;
- establishing the objectives, goals, and aims of the course;

- organizing the course (this includes teacher allocation, methods, scheduling, etc.);
- developing the learning materials;
- designing and testing the learning technologies;
- evaluating the learning process and outcomes; and
- taking note of whatever unexpected spin-offs the course may give rise to.

We will analyze the Contextualized Introduction to Programming course from the point of view of representation, utilization, and appropriation (Section 4.1). This will give us a broad understanding of the design process that the course underwent. For a more specific analysis, such as an analysis of the role of learning technologies or that of learning outcomes, we will need a more accurate model. The following section explains how we used the CATI model (Vesisenaho *et al.*, 2006) to apply the principles of ethnocomputing.

3.2. *The CATI model as the analysis method*

The CATI model allows us to determine how sustainable and viable a particular ICT solution or course is by applying the four levels of the model — Contextualization, Application, Transfer, and Import. The CATI model (Figure 5) can be used for developing sustainable ICT in developing countries, for analyzing the planning and implementation processes of ICT, for education, and for evaluating a particular person's ability to apply previously acquired knowledge.

Let us now define each of the levels in the four-level model. We are particularly interested here in how the model can illuminate and serve the *local needs* of the population for which it is intended.

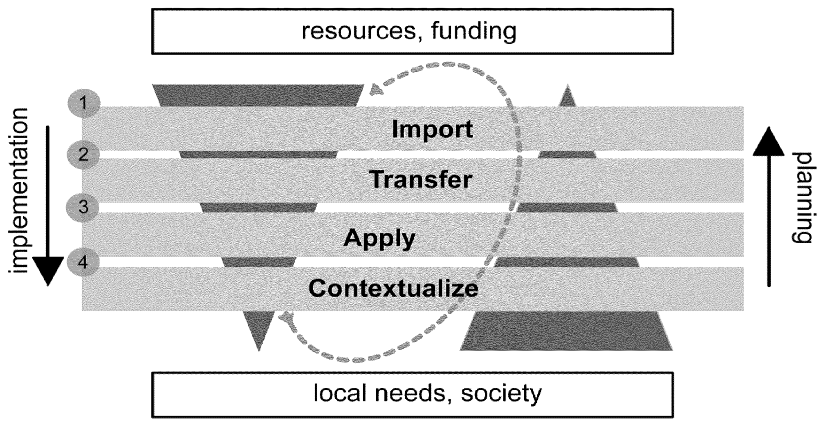

Fig. 5. The four-level CATI model for representing and analyzing the planning and implementation processes of ICT (Vesisenaho *et al.*, 2006).

- *Import*: Importation refers to any situation in which an innovative technology is imported from abroad before any local needs analysis has been undertaken. Importation may thus by implication also indicate a situation in which non-sustainable development is offered to local people.
- *Transfer*: Transferred innovations are those that are accessible to their users and potentially applicable in a local context. The analysis of local needs in such cases may have been weak, incomplete, or even nonexistent.
- *Apply*: Application means that the inherent potential of a transferred innovation has being realized. An application of this kind will not be merely mechanical in its implications. It will contain elements that show that users have exercised their own initiative to apply the ICT.
- *Contextualize*: Contextualizing means that users have thoroughly integrated ICT with the needs and concerns of their community. For a developing country, the development and application of contextualized innovations, with its origin in the country, is essential so that the innovations could benefit the country by meeting its particular development needs. If ICT is to be sustainable, it needs to be contextualized to serve the local community.

Although these four levels of the CATI model sum up the three constituent parts of ethnocomputing (representation, utilization, and appropriation), it can also be fruitful to use these two dimensions independently of one another for purposes of analysis. The mere importation of ICT might lead to the creation of new jobs — and that would be an indication of the appropriation of an ICT. Representation is also present in all ICT teaching, independently of its CATI level.

The levels of the CATI model allow us to determine the *sustainability* of a learning technology at the level of design in any given ICT course (Section 4.2).

When we analyze the learning process or outcomes of a particular ICT course, the focus of our CATI analysis is on the extent to which students have elaborated the ideas and skills they obtained in a particular course. The content analysis required for this is offered in the following section.

3.3. *Analysis of the learning outcomes*

In this article our operational ethnocomputing approach in ICT focuses on education that would be relevant to students' background knowledge, to the state of ICT in the local country, and to the local development in globalizing world. Relevant use of ICT also requires awareness of application opportunities.

Our approach to learning outcome analysis is two-fold. We gathered data by questionnaires and interviews (Figure 6). In the first phase, the learning outcomes were measured in terms of how students' ideas for applying ICT changed during the course. Therefore, questionnaires were designed to indicate how aware students were of ICT and which opportunities they saw in it. The questionnaires were administered in the beginning and end of Course I, in early October 2004 and January 2005.

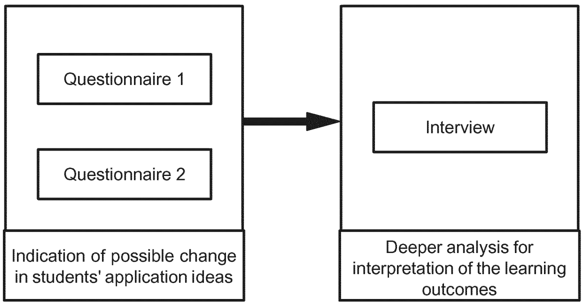

Fig. 6. Research approach to the analysis of students' learning outcomes: data collection and analysis.

The thematic interviews were conducted at the end of the course in January 2005, to give a deeper picture on the students' acquired understanding of ICT in terms of the CATI levels. We analyzed the learning outcomes of the students of Course I by using a content analysis approach with prefixed categories (Neuendorf, 2002). We used Atlas.ti software to classify the qualitative data that we collected from these interviews, and we then interpreted the data we thus collected in terms of the CATI model. The CATI model thus functions as an explanatory framework that guides our content analysis, seeking evidence of learning and application in students' profession and in society.

In order to increase the inter-rater reliability and to examine the CATI model in this purpose, we had two independent coders carry out the coding of each interview. The coding was done twice and independently. One of the coders was a researcher who had worked in the Tanzanian ICT project since 2000, and the other was a MSc in Computer Science interested in cultural dimensions of ICT. The focus was on students' attained CATI level of each coding unit and the general CATI level across all coding units in an interview based on students' learning and application ideas.

Free-marginal Kappa, a chance-adjusted measure of agreement, was used to evaluate inter-rater reliability (Brennan & Prediger, 1981). There were no other courses which could have affected the outcomes, because there were no other theme-related courses held at the same time. As the students were, on average, 35 years old and had 9 years of teaching experience, we did not expect age or teaching experience to affect the results. We will present the analysis of students' learning outcomes in Section 4.3.

4. Analysis

The analysis that we present in this section is based on data from Course I (2004–2005) unless otherwise indicated. The first step is the overall analysis of the course development process, then the learning technologies, and finally the deepest

Table 3. Phases of the development process of the Contextualized Introduction to Programming course that are relevant for the ethnocomputing aspects of representation, utilization and appropriation. For phases, refer to Table 2.

	Representation	Utilization	Appropriation
Analyzing the reasons for the course	Preparations	Workshops	Consultations
Setting the objectives, goals and aims of the course	Course I	Preparation, Workshops	Consultations
Organizing the course (teacher allocation, methods, scheduling, etc.)	Consultations	Workshops	Consultations
Developing the learning materials	Preparations, Course I	Preparations	Course I
Designing the learning technologies (support tools)	Preparations, Workshops, Course I	Workshops, Course I, Course II	Workshops, Course I, Course II
Evaluating the learning process and outcomes	Course I, Course II	Course I, Course II	Workshops, Course I, Course II
Identifying the unexpected spin-offs of the course	Course II	Course II	Course I, Course II

insight is on students' learning outcomes, focusing on their application ideas of the course content and ICT (Figure 4).

4.1. *Course development process*

We will analyze the development process of the Contextualized Introduction to Programming course (Course I) in terms of the ethnocomputing aspects of representation, utilization, and appropriation. Table 3 shows how each category was taken into account at a different phase of the development process and at a particular stage of the course. In the Consultations phase (see Table 2), for example, the teaching methods of the course were at least partly agreed upon. This is indicative of *representation*. The analysis clearly shows how the course development process strongly reflected the ethnocomputing design approach.

The course design and implementation process was also analyzed using the CATI model (Vesisenaho, Duveskog, Laisser, & Sutinen, in press). The application level was most often reached in practical operations. Objectives were evaluated with respect to the contextual level. Joint activities were based on the transfer level.

4.2. *The role of learning technologies*

If we use the description in Section 2.3 of how learning technologies should be used, we can illustrate the extent to which these technologies complied with the ethnocomputing approach for the design of Course I by using the levels of the CATI model. The analysis is summarized in Table 4. It shows that the role of learning technologies indicates cultural relevance. That is to say, all of the three applied and

Table 4. The CATI levels of the learning technologies used in the Contextualized Introduction to Programming course.

	Contextualize	Apply	Transfer	Import
Digital learning materials	The visual design of the materials indicates that students can use ICT in their communities.	The material is rich in exercises. It encourages users to create their own programs.	The material is available to users at IUCO even though they may not have access to the web.	The core contents of the course comply with the globally standardized CS curriculum.
I-BLOCKs	Students can continue to refine the design of I-BLOCKs so that they become even more useful and valuable in their contexts.	I-BLOCKs inspire students to invent and create prototypes of ICTs that can be used in their communities.	I-BLOCKs are easy to use and make. They make programming accessible even to those who have no prior expertise in the field.	The I-BLOCKs were designed abroad (in Denmark), and were imported into the situation.
Jeliot	Using Jeliot challenges students as well as teachers to come up with ideas for cultural adaptations of program visualization.	Jeliot opens the black box of computer operations and inspires learners to think about program applications.	Jeliot permits users to create visualizations with their own programs.	Jeliot was imported into the situation.

Table 5. The frequency of references to learning technologies in the interviews of students.

Learning Technology	Contextualize	Apply	Transfer	Import	Total
Digital learning materials	0	3	0	0	3
I-BLOCKs	2	19	15	4	40
Jeliot	1	7	3	0	11
Total	3	29	18	4	54

Note: For each student, multiple references to a learning technology in a certain CATI level were counted as one reference only.

analyzed technologies also represent the Contextualization and Application levels of the CATI model.

While Table 4 represents the *potential* of each learning technology in terms of different CATI levels and thus reflects the Western interpretation of the researchers, we studied how students regarded the relevance of these technologies with respect to the CATI model. Table 5 shows the number of references to each technology in terms of a certain level in interviews of students.

It is understandable that most coding units were from the application level. The large number of the I-BLOCK related coding units (40) and the significant number of these at the application level (19) indicate the major role of application in the learning process, as well as in understanding the concept of programming and ICT. Some of those answers also refer to the contextual problems of I-BLOCKs; they are not so far available in Tanzania and are not especially Tanzanian-made.

> *Yeah, I think the importance of I-BLOCK ... is that ... this when you learn something by manipulating or by using hands you learn better than just thinking abstract ... yeah, so that was, I find that ... to learn something that you touch and try to make experiments what is going to happen, I find that it is good ... So also the important, other important that ... I-BLOCKs can be used to teach students of low level, for better understanding.*
>
> *Yeah, I realize that there's a need of I-BLOCKs and Java because in I-BLOCK is where you are starting to know how the program works and how the structure of the program is and the parts of how the each other, when we are talking about output and input in processing, through I-BLOCKs can understand the whole structure and thereafter you go to the Java but my (...) is, the course is, there are a lot of things to do in just course but the time is not so (...) the whole coverage because it make you to be to rush quickly, not to have enough time to think about not (...) how to practice, how to do more things because the time is not enough.*

Jeliot was mentioned only 11 times, probably partly because Jeliot and Java programming were very much related in the course. An interesting point is that J-Creator was mentioned much more often, although it is only an editor, but is was of course used very often.

> *Yeah, in Java ... it has two categories. One is founding, using Jeliot, so in Jeliot you find that what is going on (...) going on in the process are seen in the, are seen in the, so you say in easy for visualization, so you see the display of the what you have been doing ... and another in J-creator you find that ... that one is the most ... is above this Jeliot because you find that it performs complex programs ... and these are put in the (...) or in the applet.*

The digital learning materials of the course were not referred to very often (3), and so it is quite difficult to evaluate the contextual usefulness of them. When compared to the printed part of the material, the digital material included more examples, exercises, and animations. The village structure of the digital learning environment was to link it to students' everyday life, and a coding unit seems to support our idea of it. It also tells how novel the computers are for these students.

> *... let me tell you something, where I come from ... it is the first time to touch computer here, no computer because my schools is in the village ... I started touching the computer first time here ... but now each of the villages, which come in front of me is a new and I am happy to know it, for example, this Java it is the, the (...) I had there when I am making a work, a workshop of (...) two days, now since (...) new course, actually I am happy very much, not only*

to me either my other friend in the class, I hope if you ask them such a question they are going to tell you such thing, we are very much with this course.

4.3. *Students' learning outcomes*

We started tracking the changes in the ICT application ideas of the students right from the beginning of Course I. Section 4.3.1 presents awareness of ICT and ideas of its contextual opportunities that students had at the beginning and end of the course. The learning outcomes of the students are analyzed by qualitatively based content analysis of their interviews in Section 4.3.2.

4.3.1. *Application ideas as awareness of ICT and its opportunities*

We devised questions (Table 6) focusing on the kind of ICTs students identify in everyday life (1), where they could apply robotics and programming (2), and how they could identify the opportunities of ICT personally (3), and in the society (4). We divided these into two dimensions: changes in awareness $(1, 2)$ and identifying opportunities $(3, 4)$. These results show a definite progression in the application ideas during the course. Especially, the combined variable (paired samples t-test) shows that the students were more aware of ICT and more able to identify its opportunities in the end questionnaire than in the beginning questionnaire ($p = 0.002$).

In the awareness question (1), the biggest increase was on the realization of ICTs in institutions such as schools, hospitals, and the police; also that technical devices and mechanical aids are part of everyday life. The other awareness question (2) gave a positive view to application in education, as the students are becoming teachers. Examples of the major additions in responses in detail per question are in Table 7.

In the opportunities of ICT (3), the interesting increase was in the fields of personal and economical development. In question 4, students also identified important social and economic opportunities increasing the pace of development and improving communication in their country by means of a more general and creative use of ICT in society at large.

The questionnaire-based data shows that the number of responses increased and that very many of the student application ideas were outside of school life. The deeper analysis of the state of application ideas by an interview-based CATI analysis is taken up in Section 4.3.2.

4.3.2. *Application ideas in profession and society*

In this section, we present a CATI analysis of the thematic interviews administered to students after the course had ended. The focus on analysis was to define students' CATI level based on their learning in terms of their application ideas in their own profession and society in general. Each coding unit of each student was coded with

Table 6. The average number of application ideas identified at the beginning and at the end of Course I.

Question	No. of Responses (Average) Per Questionnaire (Q'aire 1)	No. of Responses (Average) Per Questionnaire (Q'aire 2)	Mean Difference	Significance of the Change
ICT awareness/ICTs in the students' environment				
1. Where is information and communication technology or robotics around you in your everyday life?	2.54 (SD 1.70)	3.12 (SD 1.14)	+0.58	0.053
2. Where could you apply programming or robotics skills in your society? How?	1.69 (SD 1.41)	2.12 (1.24)	+0.43	0.086
Opportunities presented by ICTs				
3. What are the opportunities for ICT in your life?	1.46 (SD 0.99)	2.19 (1.02)	+0.73	0.005
4. What are the opportunities for ICT in Tanzania?	1.38 (SD 1.10)	2.00 (1.10)	+0.62	0.015
Combined				
Questions 1, 2, 3 & 4 combined	7.08 (SD 3.53)	9.35 (3.17)	+2.27	0.002

Note: Responses of 26 students; SD = Standard Deviation.

a CATI level. Also, a general CATI level was defined for each student. In all, there were 189 coding units.

The following question themes were coded:

- Could you describe what you have done during this programming course?
- Could you apply your skills somehow in your coming work? If yes, how?
- Do you think the things that you have been learning or that have been taught during the course will benefit society somehow?
- Is there a relation between I-BLOCKs and Java, as you have studied both of those in the course? If yes, what kind of relation?
- What have you learnt? Describe your learning. What do you think was the most important learning experience during the course for you?

Our analysis, based on interviews coded in terms of the CATI model, shows (Table 8) that most of the students attained the application level (17). The second largest number achieved the transfer level (10). No students attained the levels of importation and contextualization. It should, however, be noted that 15 students' responses indicated contextualized elements whereas only five indicated elements of importation (Table 9).

Table 7. The major increases in ICT opportunities and awareness ideas.

Question and Categories	Answers in the Category (Questionnaire 1)	Answers in the Category (Questionnaire 2)
1. Where do you see examples of robotics or ICTs around you in your everyday life?		
Institutions (schools, hospitals, police)	4 (6.1%)	12 (14.1%)
Technical devices including (computers, cars, ships, trains, etc.)	9 (13.6%)	18 (21.2%)
Mechanical aid (carrying, moving etc.)	3 (4.5%)	5 (5.9%)
Others	50 (75.8%)	50 (58.8%)
Total number of answers	66 (100%)	85 (100%)
2. How could you apply programming and robotics skills in your society?		
Education (learning, teaching)	15 (34.1%)	21 (37.5%)
Mechanical aid (carrying, moving etc.)	5 (11.4%)	7 (12.5%)
Others	24 (54.5%)	28 (50%)
Total number of answers	44 (100%)	56 (100%)
3. What opportunities do ICTs give you in your life?		
Getting, delivering information, communication (inc. education)	17 (44.7%)	25 (42.4%)
Poverty reduction, econ. development, competitiveness	3 (7.9%)	10 (16.9%)
Personal development (e.g., creativity)	1 (2.6%)	4 (6.8%)
Others	17 (44.7%)	20 (33.9%)
Total number of answers	38 (99.9%)	59 (100%)
4. What opportunities do ICTs extend to your society?		
Getting, delivering information, communication (inc. education)	10 (27.8%)	13 (24.5%)
Poverty reduction, economic development, competitiveness	10 (27.8%)	18 (34.0%)
Others	16 (44.4%)	22 (41.5%)
Total number of answers	36 (100%)	53 (100%)

Note: 27 students altogether.

Most of the students are at the application level, although many students still functioned only on the transfer level. This indicates that they seem to be stuck on a conceptual level where learning application is still largely based on the uncritical memorization of information.

As half of the coding units reflected ideas on application, we hope that students will develop along these lines and progress toward higher levels. Of course, it may take students a long time to move from memorizing to application.

The following interview responses illustrate how we derived the level of student attainment, and they offer insight into how difficult it sometimes is to derive the correct level from a particular coding units.

Table 8. CATI levels in general.

Level	General CATI Levels Per Person	
	Number	Percentage
Contextualize	—	—
Apply	17	63.0
Transfer	10	37.0
Import	—	—
Total	27	100

Table 9. Distribution of coding units at different CATI levels.

Level	Coding Units at Different CATI Levels	
	No. of Coding Units	Percentage of all Coding Units
Contextualize	15	7.9
Apply	94	50.0
Transfer	75	38.9
Import	5	2.6
Total	189	100.0

Yeah, it will benefit if the ... If we have this computer program of Java, the society would benefit very much. (*import level*)

This comment and its implications do not refer to or address any real-life situations or contexts although the student uses the word society. We derived an *import* level from this coding unit.

Yeah, my, my teach in case my school can introduce such a course at my school, I am able to teach, I can teach how to program in Java language because I have a mastered the important (*course*). (*transfer level*)

The coding unit clearly shows an example of *transfer*. The student explains what he will do; he can teach a similar course without any change.

Okay, an important learning experience from the course. I have been interested in geometrical structures because I can transfer the knowledge of Java programming to my mathematics course such as on drawing different structures or graphs and other many things. (*application level*)

The application of ideas means that one uses one's own understanding and knowledge to *apply* an idea. In this case the student intends to apply it in her mathematics teaching.

I can use these programs even now to teach the students because nowadays we have many things to teach the students, let's say for example in Java programming. Always we just deal with how to educate the students on budgeting.

> *Therefore I can use this program to show them that if you need to do something, before doing it just go to the computer and just see if you can manage. Therefore I think it is very useful.* (*contextualization level*)

The level of contextualization is the most difficult to actualize in practice. This student reported on how he would apply and *contextualize* his teaching by using Java, and applying ICT for budgeting teaching (a new initiative) in his Tanzanian school.

The inter-rater reliability for the analysis of 189 codes by CATI levels was moderate; the value of Kappa was 0.62. The overall inter-rater reliability for students' general level CATI coding (27 codes) was high with a Kappa value of 0.81, giving a positive general insight of the similarity of the coding results and applicability of the content analysis method.

5. Discussion

Our analysis shows how the Introduction to Programming course developed and the role that its learning technologies played in its conceptualization, design, and successful implementation. In addition, the analysis of the design of the course shows how learning to use ICT can be successfully based on community and context-driven principles. This emphasis has become stronger during the development process as teachers and students began to notice the challenging (and often unexpected) opportunities for applying ICT in their local region.

It was encouraging to notice how readily our students devised application ideas. This is reflected in the many constructive comments that students made in the interviews about applications. Their enthusiasm gives us reason to hope that these students will continue to develop along these lines and progress to higher levels of application and contextualization. Of course, it is no easy transition to move from memorization to application. But a start has been made. The ultimate success of this kind of advanced education and the quest for sustainable development requires us to retain our long-term goals and perspective as we continue to strive for results that would eventually lead to development. The level of contextualization is the most difficult to attain. It was vitally important that at least some of our students should break through into this level. That some did is a cause for satisfaction.

Another interesting consequence of our work was that the course development and outcomes created several spin-offs in local communities. One example was that our students created educational robotic devices for some young patients in a local rural hospital. In addition, there was the opening of the first East African Science Park at IUCO, a newly established forum in which university and business collaborate to meet local needs, the TEDC conference, the first international conference to be organized on the premises of IUCO, and, finally, plans for a localized undergraduate program in ICT. It is therefore most important that skilled teacher trainees are encouraged and supported to continue their work in this field with new application ideas and skills.

We are aware of the risks of using the concept of ethnocomputing as both the design and analysis method of a course. But the analysis shows that ethnocomputing can serve as a viable, precise, and creative framework for guiding a design process of this kind so that representation, utilization, and appropriation are taken into account in a way that encourages learners to contextualize their learning process.

6. Conclusion

We applied an ethnocomputing-based approach to the design and analysis of an introductory ICT course at Tumaini University, Iringa University College, Tanzania. The emphasis of the analysis is on the development process of the course, the role of learning technologies in the course, and the contextual learning outcomes of the students. This study indicates that an ethnocomputing-based analysis can be used for designing needs-based ICT education by analyzing its feasibility with various operationalizations of the ethnocomputing concept.

The design process of the contextualized programming course reflected several perspectives of ethnocomputing. The student responses focused especially on the usage of I-BLOCK technology to support learning and understanding ICT. The digital learning material and Jeliot visualization tools did not seem to be so important for the contextual learning experiences. On the other hand, students' application ideas increased, and the digital learning material was designed to support these. There were a couple of students who reached the contextualization level elements based on the CATI model in the learning outcome analysis. The most frequent were application level ideas. Spin-offs in context and students' thoughts and ideas of application in a wider Tanzanian context were promising.

We developed and tested the use of the CATI model for a *community-driven* approach in its use of learning technologies. The model seems to support this approach to development, but the descriptions of level and divisions still need to be elaborated. The division of the application and contextualization levels to a greater level of detail, such as people, environment, and technology, requires further analysis.

The process of creating a contextualized ICT course is time-consuming and requires a great deal of patience and circumspection, as this case study from Tumaini University shows. Our work in Tanzania continues. One goal would be to create a contextualized Bachelor of ICT degree program at Tumaini University. But this task will require further elaboration of the ethnocomputing concept itself, as well as the design and analytical methods that accompany it locally.

Another issue related to the curriculum is that there might be a need for a more general ICT degree curriculum that specifies the content of Computer Science, Computer Engineering, Software Engineering, and Information Systems Science in a developing country. There could also be a need for a mixture with Engineering Sciences. This also refers to general needs of experts with a wide spectrum of understanding and skills in the theory of Computer Science and practical understanding of technology.

Tanzania is currently in the state of using ICT that existed a couple of decades ago in Western countries. Meeting the real needs with novel ICTs can also mean development of new business opportunities. Much good work can yet be done.

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5

Designing a Contextualized Programming Course in a Tanzanian University

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Abstract - **Tumaini University has been developing the use of information and communication technology (ICT) in education since the mid-90s. Their first systematic ICT development project called Internet Project Strategic Plan (IPSP) focused on obtaining infrastructure for accessing information; instilling ICT skills into staff and students, and installing and servicing computers to support learning activities. With this in mind, we developed the CATI model (Contextualize, Apply, Transfer, Import) to support sustainable ICT development projects on the basis of our evaluation of the IPSP project and our previous experiences in contextualized ICT education. During the past few years we have focused our efforts on contextualizing ICT education. One of the outcomes of this initiative was a contextualized Introduction to Programming course (2004-2005). In this paper, we analyze the course design and implementation by using the CATI model. We found that the basic elements and ideas of the contextualization in terms of learning materials, practical project components, and exercises were concentrated on the application level. The course has created promising spin-offs in local Tanzanian communities. The main weaknesses of implementation are that practical elements such as teaching on the campus are still dependent on the presence of Western teachers.**

Index Terms – CATI model, contextualization, development, ICT education

Introduction

Iringa University College (IUCO), a college of Tumaini University, has been developing information and communication technology (ICT) for educational purposes since the mid-90s. After an initial phase in which they used second-hand computers and office software, the staff of the university launched Internet Project Strategic Plan (IPSP), their first systematic ICT development project, designed to run between 1999 and 2004. The strategy that informed this program was that staff and students and other accredited university personnel should have access to ICTs, that staff and students should be educated in the skills necessary for operating and using ICTs, and that ways and means should be devised for using computers and other ICTs to support learning activities in the university. The implementation of this project made it clear that contextual solutions in ICT development were of the utmost importance. It became clear, in other words, that if any ICT program were to be sustainable at IUCO, it would need to take into account both the societal and cultural environment of the recipients of this program as well as the possibility of creating a sustainable infrastructure.

Our evaluation of the IPSP project and our previous experience of applying ICT to education in Tanzania led us to develop a CATI model (Contextualize, Apply, Transfer, Import) that would enable us (1) to support sustainable ICT development projects in the identified context, (2) to analyze the planning and implementation phases of the projects, and (3) to evaluate the relevance of the ICT curricula and applications. [1]

In the past few years we have focused our efforts on contextualizing ICT education. We have been doing this ever since we realised that contextualization represents (so to speak) the missing piece of the puzzle that makes sense of all our work in Tanzania. We were and indeed still are convinced that without contextualization – or the framing of ICT education in the context of local culture, attitudes and development needs – there can be no successful transference of the benefits of ICT-related programs to the local population. We therefore accept (as part of our methodology) that the mindset and cultural assumptions of the Tanzanian students with whom we work are very different from our own. [2] Part of our mission is therefore to become as sensitized as we can to the local African environment and cultural assumptions and to remain sensitive and aware in all our contacts with our Tanzanian students and collaborators.

One of the outcomes of this initiative was a contextualized Introduction to Programming course (2004-2005) which we subject to a CATI-model analysis in this paper. By undertaking this analysis, we identify the constituent elements of this undergraduate course (preparations, implementation, and follow-up), and we place ourselves in the position of knowing whether the identified elements either support or hinder learning about and applying ICTs from the point of view of the learners' socioeconomic and cultural context.

The World Commission on Environment and Development defines *sustainable* development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [3] The Finnish Ministry for Foreign Affairs interprets this to mean a long-term functionality (sustainability) in the systems that are developed: an adequate economic and financial base for long-term operation and maintenance, institutional capacity and capability to manage the systems, a socio-cultural interface that respectfully takes account of local conditions, beliefs, customs, attitudes and assumptions, reliable technical operation and maintenance, and acceptable environmental impacts. [4]

We should consider the term *contextual design*. We take it to mean that all development products are subjected to a design process that makes them harmonious with customer's (in this case, the local university's) expectations, attitudes and cultural assumptions. [5] This is a term that is used in usability engineering as well as participatory design.

For researchers like ourselves, research designs have to be scrutinized very carefully indeed because the factors that influence design are cultural ones that only become evident in the contextualization process. If we want our developmental work to be successful, we need to subject all our research designs to the most exhaustive analysis on all levels and from all points of view over a period of years. Our purpose is to understand what we might call *the deeper learning ecology* of the matrix within which we work. This matrix is a complex interacting system that functions as the product of numerous varied elements to support learning. [6] The research approach we use is called *development research*, which aims for practical and scientifical results. This method incorporates a preliminary investigation, theoretical embedding, empirical testing and production of relevant documentation, analysis and reflection on process and outcomes. [7]

In this research we concentrate on analyzing the programming course, its design and its implementation and their effects on local development.

COURSE DEVELOPMENT PROCESS

I. Preparations for the Course

We started the Introduction to Programming course development in 2000-2002 with two master-level students from IUCO at the University of Joensuu. These students were engaged in tailoring the kind of ICT education we proposed for their own Tanzanian context. They looked first at virtual basic level studies in computer science for Tanzania. [8]

Our plans at that stage did not include an action phase. One of these two master's students went back to IUCO after he had graduated. Through him and other ICT experts from IUCO we organized a series of programming-by-building workshops for 2003 and 2004. [9] By doing this we hoped to obtain some new and useful ideas for developing contextualized ICT education at IUCO. Our analysis of the only programming course that had ever been held at IUCO revealed that the course had included, firstly, instruction in Basic, and, secondly, tuition in some very difficult data structures and concepts such as trees, queues and stacks in C language. The students who did this course had no previous programming experience before the course began.

We continued to hold consultations among IUCO and its partner universities, the University of Joensuu (UJ) and the Southern Denmark University, in the first half of 2004 on the basis of what we by then knew to be the requirements of the local programming course. At the same time we began to develop the course materials. During this design process, we occasionally returned to the course structure of previous years. In the end, we reached amicable agreement about what the course content should be.

Objectives and content of the course

The course that we thus agreed upon included an introduction to the basics of computer programming. Our expectation was that students would have a good general knowledge of the methodology of creating computer programs after they had successfully completed this course. They would also have a general understanding of robotics and modern technologies and would appreciate the usefulness of programming and its application in the society. Our long-term hope was that such students would be able to develop ideas for new technologies and programmes that could enrich life in their context.

The following topics were included in the course materials: programming by building – introduction to robotics and programming, the basics of Java, control structures, arrays, program structure and applets. In addition to this, there was also a programming project, a workshop at the end, and a concluding examination. Student competence in the course was evaluated by adding performance grades obtained from the final examination (50%), the weekly exercises (25%), and a Java or I-Block school application project (25%).

Course materials

The main course material was developed by researchers at UJ with assistance from a lecturer from IUCO. It was given the format of light web-based material in HTML. For navigation animations we used Flash. We used Java Applet examples in the materials and made the programming code available to most of them because the Internet capacity in Tanzania was very limited. We used web-based materials because books were scarce, and because web-based material is more interactive, and easier to update and deliver than books. But we also prepared additional handouts for students because their access to computers could be very limited. The forum was php-based (phpBB). The material was intended for installation on the local server because of restricted internet connectivity. We also ordered the course books *Java for Students* and *Introduction to Java* for our students.

We published each week's course materials (comprising six units) to this site. The instructional interface was a village. Students using the site could obtain the information they needed by clicking on the huts and the people in the village. This symbolism was deliberately used to demonstrate that computer programming does not have to be presented in obscure high-tech Western-specific formats but that it can be made easy to grasp from imagery and concepts that are entirely derived from the local social and cultural context. Although there were weekly problems to solve, the students would also be encouraged to come up with their own ideas and plans for making programs. This would gradually prepare them for the larger, more complex programming project that they were required to undertake towards the end of the course.

The course would be supported by four forums: question-answer, project work, general information and free discussion.

Teachers

The original intention was that there would be one Tanzanian teacher and one teacher from the UJ to teach the course in the second half of 2004. There would be only one local teacher who would teach the course with support from the UJ in the following year.

II. Implementation 2004-2005

Topics covered during the course and the course material

Everything in the course outline was covered by the course material except for the introduction to object-oriented design. This had to be left out because there was not enough time and because the students concerned were insufficiently informed at that stage about basic concepts of program structure. Although we intended to make the developed course material available not only on the Local Area Network but also on the World Wide Web, for practical and security reasons only parts of the course could be made available on the World Wide Web. But we also circulated most of the web material in the form of handouts to students. The course books also did not arrive before the first course had already ended. We made the Java 2 SDK, Standard Edition Documentation Version 1.4.2 by Sun Microsystems available to the students. The simultaneous use of web material and printed course materials was a new experience for these students at that time.

Teachers and course activities

The course was presented by two teachers, one from the UJ and the other from IUCO. Because the Tanzanian teacher had other responsibilities apart from teaching, he was only occasionally present and the actual teaching thus fell to the teacher from the UJ.

The first part of the course consisted of a one-and-a-half day workshop in which students used I-Blocks (intelligent building blocks) [9] for programming. After that they were taught Java language in a computer laboratory by means of six hours per week over a six-week period. Each week's teaching program also included three hours of voluntary tutoring sessions, and a set of exercises. While such exercises gave students opportunities to practice their skills, they also gave the teachers information about levels of understanding among the students. The weekly assignment also included a learning diary in which students were required to reflect on their learning and develop applications to local context to make both students and teachers more aware of local context.

For project purposes, students were divided into groups that contained 3-5 members per group. Half of the groups undertook a project on teaching basic ICT skills to secondary school students by using I-Blocks. The other groups engaged in a Java programming project in which they were asked to develop a program that would be beneficial to secondary school teachers or to students. The program choices included programming a calculator, constructing a program that could make graphical representations of differential equations, making a program for a simplified Bao game, and making three different simple mathematical programs.

The course ended with a project presentation workshop and an examination. The last question in the examination was a problem solving question related to I-Blocks. All the other questions were about Java programming and they were divided into the following categories: theoretical questions about basic concepts in programming, examples of code containing errors that students were expected to detect, examples of code that had to be explained by students, and, finally, questions which required students to write their own programming code.

Supportive tools and programs

I-Blocks were used to introduce programming because these I-Blocks permit students to learn the fundamentals of various forms of modern technology as they use them to build different structures. A simple programming interface allowed students to program I-Blocks for different functions in an easy manner. I-Blocks were used as teaching tools throughout the course.

The following programs were also used during the course: Jeliot – a visualization tool that allows students to follow in a step-by-step way what happens in their programs; JCreator – a text editor especially made for Java programming; and QEL Micropro – a program for downloading programs to the Microchip inside the I-Blocks.

III. The Follow-up Year 2005-2006

Changes in course arrangements for 2005-2006

In the academic year 2005-2006, the course had the same objectives as it had had the previous year. But there was a bit less focus on robotics and I-Blocks to be used as an entry point for the teaching of programming. The timeframe for the whole course had also been extended. But in this year the students had better access to printed reference material because the books they needed had finally reached the library. In other respects the material was same. Because of a huge increase in student numbers at IUCO, the computer laboratories were heavily occupied and students could not log up enough personal practice time per week in a laboratory. But because second-year students were allowed to borrow keys to the computer laboratory, they were able to use the laboratories in the evenings at times when they would normally have been closed to students.

As far as the programming projects were concerned, two groups of students taught secondary school students about ICTs with the use of I-Blocks. In another group, orphaned children were taught about ICTs with the use of I-Blocks and A-Blocks (African I-Blocks). In the Java projects, students developed a program of their choice for secondary schools in Tanzania. The topics they choose were: the 2*2 matrix program, the solving integration of exponential functions, the solving integration of exponential functions, and the statistics program for students' scores.

The teacher from the UJ was in practice the only teacher available to present the course. The reason for this was that although the new local (Tanzanian) IT teacher was the only one who possessed programming skills, he had a concurrent teaching schedule that prevented him from also teaching the IT course at IUCO. He had, in addition, an enormous workload as a technician and simply did not have the time to update his programming skills, as well as plan and attend lessons. He was nevertheless kept fully informed about what was happening in the program as a whole.

The four best students from the first course (2004-2005) were selected as assistant teachers to supervise projects during the course. The idea was that at least one of them should be able to present the course in future with only online support from the UJ. Three students from 2004-2005 were selected on merit to engage in special projects in IT as a part of their studies. The titles of these projects were: The influence of teaching strategies on student achievement while learning computer programming in Tanzanian secondary schools, An investigation of the role of computer mathematics programs in the teaching and learning of mathematics: the case of Java and Maple 9, and An investigation into the application of I-Block in a Tanzanian context. One of year 2004-2005 students was awarded a five-month grant to continue her studies in Finland.

Spin-offs

Our collaboration in programming course development has had several spin-offs. One is that the IUCO has started building the Tumaini University Science Park – perhaps the first of its kind in East Africa. Another is that the Technology for Education in Developing Countries (TEDC 2006) Workshop will be held at IUCO in July of 2006. Yet another is that successful prototypes of A-Blocks (African I-Blocks) have been developed and tested and are due to be manufactured in the Science Park.

Student projects have also been extended in several other directions. ICT as a Therapeutic Tool for Hospitalized Children (The Ilembula Project) is, for example, a new project that uses course content and methods to further learning activities in a local hospital. And now plans for a localized ICT bachelor degree curriculum are getting underway.

CATI MODEL FOR ANALYSIS

The contextualized approach to ICT in higher education can be represented as two parallel processes: planning and implementation (Figure 1). Our contextualized CATI model [1] utilizes four levels (Contextualize, Apply, Transfer, Import) to analyze processes when troubleshooting or when *constraints* emerge in any situation. The planning process proceeds from contextualization to import, and the implementation process from import to contextualization. It is important to note, however, that the two processes can interact with each other on all levels, and that the model also makes allowance for sub-processes.

This simple four-level model gives users a method for identifying whatever ICT-related difficulties might occur in developing countries and a model for analysing why these difficulties arose in the first place. The two processes of planning and implementation apply to both ICT roles in a higher education institution: to ICT support and infrastructure and to ICT education and training.

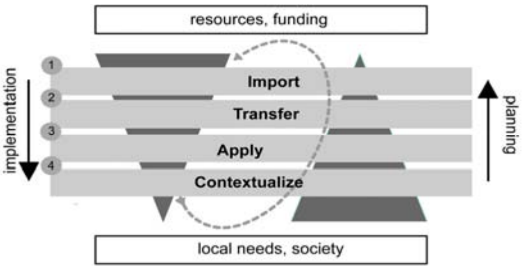

FIGURE 1.
THE FOUR-LEVEL CATI MODEL [1]

Let us now define each of the levels in this four-level model. We can characterise these terms from the point of view of *local needs* in the following way.

- IMPORT: Importation refers to a situation in which innovations are received from abroad before any local-need analysis has been undertaken. Importation will most probably create a situation in which non-sustainable development occurs.
- TRANSFER: Transferred innovations are those that are accessible to their users and potentially applicable in a local context. The analysis of local needs in such a case may be relatively weak or incomplete.
- APPLY: Applications mean that the inherent potential of transferred innovations has been realized. Such a usage is not merely mechanical in its implications. It will contain elements that will show quite clearly that users have exercised their own initiative in the application of a technology to their local conditions.
- CONTEXTUALIZE: Contextualizing means that a technology has been used to develop and establish a deep and permanent relationship to the needs of a more extended user community. Contextualized technologies are those that are being sustained in local cultural contexts. Because an active user of a technology comes from a particular region in which the innovation was introduced, the analysis is rooted in that locale.

The development of the course (including preparations, implementation, and the follow-up year) was analyzed by the means of the levels of CATI model (Table I). The evaluators are a Tanzanian IT education expert (M.Sc. in Computer Science) and the Finnish researcher whose special research interest was IT education in Tanzania. The elements of the course were evaluated on the basis of the needs identified by the local expert. The local expert and the Finnish researcher evaluated implementation by using the CATI levels. They also made recommendations for the future development.

TABLE I.
PARTS OF THE COURSE DEVELOPMENT PROCESS EVALUATED BY CATI MODEL (C=CONTEXTUALIZE, A=APPLY, T=TRANSFER, I=IMPORT).

	Element being evaluated	*Needs stated by the local expert*	*Implementation level evaluated by local expert and researcher*	*Justification for the level by local expert and researcher*	*Recommendation for the future by local expert and researcher*
Pre-course. Preparations					
1	Design	*Foreign curriculums are used as main frame of reference for local curriculum.*	A	Despite consultation, Finnish implementation.	More localization. Mainly local experts should be involved.
2	Development of the course	*Maximum local context, examples and terminologies.*	T	Still too many Western ideas, quick reviews by Tanzanians.	Include Tanzanians in material production.
2004-2005. Implementation					
3	Objectives	*Aim to provide ICT at contextual level to solve problems.*	C	Together found applicable objectives.	Place even more of the ownership on Tumaini University.
4	Course arrangements	*Take more time because of students' limited IT background.*	A	Good application opportunities. Full contextualization of elements did not materialize.	
5	Evaluation of students	*Examinations, homework, projects and practical training.*	A	Different levels, including contextual ideas of students.	
6	Teachers	*Need local teacher for localization and foreign lecturer for subject expertise.*	A	Local and Western teacher.	
7	Teaching arrangements	*Dictated by local schedule and standard credits.*	T	Teaching performed solely by Western teacher.	Local teachers with online support.
8	Web-based course materials	*Slow Internet connectivity. Need preparatory courses and simple navigation. Be as light to use as possible. Consider removable storage devices.*	A	Attempted application included changes made in the field to Western original. Light material based on local server.	Next version of the material can incorporate new elements as evaluated by students.
9	Exercises	*Make students aware of the environment and local problems.*	A	Content of exercises relevant to local environment.	Still needs further development. Ideas from students.
10	Learning diary	*To encourage students to explain how they ca use ICT. Local students are not used to doing this.*	A	While these contain many application ideas, there are few contextual answers.	This takes time, but it may be helpful.
11	Supporting software	*Software needs to be modified and customized. Disable confusing elements. Evaluate before purchase.*	A	Comprehensible – even though students needed some preliminary training; low cost; based on freeware.	
12	Concretizing tools used (I-Blocks)	*Local tools should be encouraged. Foreign ones should only be used if no local ones are available.*	T	Concept was pre tested. No local maintenance available for tools thus far.	Next version imminent. Tanzanian production about to start. Collaboration with technical education institutions.
13	Projects	*Problem-based projects should be developed locally in collaboration with local people.*	A	Done for work and/or in field practice. Tools still Western.	Continue field projects. Invite even more local involvement. Include different organizations.
2005-2006. Follow-up					
14	Sustainability of course implementation	*Local and foreign institute should be involved so that the project can be promoted to program level.*	T	Material is based on sustainable technology. Local maintenance lacking. Implementation still depends on Western staff.	Address staff shortage. A *local* manager of the organization is needed.
15	Commitment of the local university	*Foreign institutes should encourage commitment by advertising the importance of these projects.*	T	Local university did not appoint anyone to continue the work. In 2005-2006 there were only Western teachers. Participation of previous year's students in project tutoring was very good.	There is a theoretical but not a practical consensus. This needs to be thought through from the beginning once again.
16	Commitment of partners	*Working together to create ultimate goals, objectives, strategies, and the sharing of costs will sustain commitment.*	A	Trying to do their best although they fail to grasp the full importance of the contextual mindset. Perhaps they are too set in their own worldview.	Should keep local custom in mind and design practical (even slow) steps to completion.
17	Usefulness for the university (and students)	*Local relevance adds value to the community. Foreign partners create marketing value.*	A	Students demonstrate applicability for their work; new opportunities for the university.	Still more local input is needed – especially for the new degree curriculum. This could be good investment on an international level.
18	Spin-offs	*All stakeholders (in this case, various institutions, students and the community) need to be consulted.*	A	While there are numerous spin-offs, many of these are still Western-driven.	The spin-offs (such as, for example, the local Science park and business-university collaboration) are important for development.

The preparation phase of the course entailed general design and the development of the course elements. Implementation in 2004-2005 includes objectives, course arrangements, the evaluation of students, teachers, teaching arrangements, web-based course materials, exercises, the learning diary, supporting software, the concretizing tools that were used (the I-Blocks) and projects. The follow-up year (2005-2006) will be evaluated on the basis of the following elements: the sustainability of course implementation, the level of commitment on the part of the local university and the partners, the course's usefulness to the university (and students), and spin-offs.

RESULTS AND DISCUSSION

Our analysis of the course preparations, its implementation and the follow-up year for the period in which these events occurred shows that the effects of the course were concentrated primarily on the application and transfer levels. While application occurred most frequently in the practical parts of the course whereas, joint activities occurred mostly on the transference level. The consensus between local and foreign course organizes in those was only theoretical. While many elements were partly contextualized, full contextual implementation was not effected (Table I). It is important nevertheless to note that the joint objectives were confined on the contextual level.

Our preparatory phase included an emphasis on local development, although the first prototype of the course material was mostly prepared in Western countries. Because there were few local experts included in process, the state was evaluated to apply and transfer levels.

The implementation year 2004-2005 focused on the application level. While the students applied their ideas by programming in new ways, the most serious deficiency – attributable to a scarcity of available local teachers – was in the area of teaching arrangements.

There were great expectations for the follow-up year. These were undermined by the fact that Tanzanian teacher who had been part of the previous year's program became unavailable, and by the fact that the university did not appoint anyone in his place. Because of this, the sustainability of the course was evaluated at the level of transference.

A number of obstructions hinder the effective organization of the course. Among these is a scarcity of suitable local actors, which is also linked to the question of local commitment related to identified needs. Specially designed preparatory courses might be what are needed. But what we most need to remember is that contextualized ways of learning and the development process itself both require *time* to take root, grow and flourish.

CONCLUSION

The Introduction to Programming course contained the basic elements and ideas of contextualization in terms of learning materials, practical project components and exercises, all of which were designed to encourage the students to use their imagination and think of relevant applications. The objectives of the course were even evident on the contextual level. While the technology used is basically sustainable, maintenance might be a problem.

What diminished the impact of the course was the failure to analyze a number of course elements in terms of contextualization while the course was still in the planning phase. It may be clearly seen that while the results are often strong on the application level, there is a lack of full commitment on the side of all the partners. This design weakness strongly affects the sustainability of the course. Several elements of the course are still based on knowledge transfer rather than on contextualization. Unfortunately there is no local teacher who can service this need. The absence of commitment on the part of the local institution becomes quite clear when one looks at the situation one year later. This can only be remedied in the planning and implementation stages. One needs to plan to have a sustainable participatory project by taking the idiosyncrasies of the human context and local environment very definitely into account.

The bright side is that the course has created new spin-offs in local communities. Thus, for instance, students introduced educational robotics to young patients in a rural hospital. There is also the Science Park, the TEDC conference, and plans for a localized bachelor degree program. And it remains of the utmost importance that skilled teacher trainees be encouraged and supported to continue their work in the field with their new application ideas and skills.

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Information Technology Degree Curriculum in Tanzanian Context

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Abstract: Designing a meaningful curriculum for information technology (IT) studies presupposes a sensitive awareness and appreciation of the needs of the local society. Such a challenge in the context of a developing country is heightened by the nonexistent or very limited experience that novice IT students have of technology. The contextualized IT degree programme designed for Tumaini University in Tanzania is based on the CATI model which emphasizes early student compliance with local social expectations from technology. The degree programme follows six principles: contextualization, involvement in local problems as a starting point for student projects, a practical and interdisciplinary orientation, international recognition, and continuous research into the impact of the programme's formative development. The curriculum recognises the need for international academic visitors, not primarily as lecturers, but as experts and advisers who help students towards specific solutions to identified problems and the elaboration of such solutions for the benefit of local end users.

Keywords: Computer science education, Information technology education, curriculum, context, development, Tanzania

1. Introduction

Because computing is one of the fastest growing activities in modern times in both industrialised as well as developing countries, it is essential for employees to be able to offer commensurate information technology (IT) skills. This in turn has put pressure on higher education institutions to offer courses that will equip their students to function adequately in an IT environment.

Several IT programmes in African universities have been directly transplanted from other continents (specifically Europe and America) into African universities without proper precautions being taken to ensure that the content of the curriculum is suited to local needs. This failure to adapt course content to local conditions often means that much of the knowledge and skills acquired by students is irrelevant to the actual cultural and technological conditions prevailing in their own countries [1].

Because of this danger, it is essential for IT education to be adapted to the social conditions and technical opportunities in whatever countries it will be taught [2]. It is recent graduates who will be required to use modern technology to design applications that will be relevant and meaningful in the social and technological conditions of their society [3].

Since computer science education (CSE) is usually theory driven, it is rare to find constructivist learning principles being applied in IT or Computer Science (CS) [4]. Yet the situated constructivist principles will enable IT students to learn how to apply their knowledge for the benefit of the society in which they live. [5]

Puri [6] notes that even though it is vitally important to take the socio-economic, cultural and political contexts of students and their society into account, only few CS or IT projects in Africa have used context-sensitive or participatory methods. Elovaara, Igira, and Mörtberg [7] emphasise the crucial importance of needs' analysis based end-users' knowledge and ethnographic assumptions. The use of needs' analysis should be built into a degree curriculum and that it should be applied so that students become accustomed to a contextual and need-based approach that will have a long-term impact and will support sustainable development [8].

Because no holistic theory or model of technology transfer has as yet been devised, there is a clear need for the kind of long-term research and development that will produce such a theory. [9] Reliance on the imported technology and knowledge has also created an urgent need for local technological capacity. The application of technology to the problems of poverty requires a human-centred holistic strategy. [10]

In this paper, we report on a new IT curriculum in Iringa University College, Tumaini University. The curriculum is contextualized to the local needs of Tanzanian society. The university is a private, ten-year old higher-level education institution in Tanzania with a student body of 2,000. The institution has offered IT application courses since the mid-90s and focuses on the active development of IT education as an important part of its capacity building. One practical outcome of these developmental efforts is the Tumaini University Science Park, which was opened in July 2006.

The IT programme offered by the college is based on the following six principles. It is contextualized, based on problem-based projects, oriented to practice, interdisciplinary (Engineering and Computer Science with applications to the other domains), internationally recognized, and research-based. Since we have studied local IT education in Tanzania for several years, the goals and principles embodied in this programme arise out of the reiterative, spiral-like developmental nature of the research which takes account of both practical and scientific goals [1,11].

2. Background

We started our collaboration between Tumaini University in Tanzania and the University of Joensuu in Finland in 2000. The University of Southern Denmark joined this partnership in 2003. In 2000 the first two Tanzanian graduates arrived in Finland to complete their studies for a degree in CS. It was during their years of study in Finland that we collaborated with them to construct suitably context-sensitive IT courses for Tumaini University.

We continued in 2003 and 2004 with workshops to develop courses for beginners in programming at Tumaini University. For this purpose we used Intelligent Building Blocks (I-BLOCKs) in the workshops. I-BLOCKS are game-like artefacts that support learning by means of construction – and (more specifically) the learning of programming by means of building. [12] Analyses of the performance of I-BLOCKS in these preliminary workshops in 2003 and 2004 indicated that they had immense potential for furthering the kind of IT learning we hoped to be able to implement [13].

We started the first version of the contextualized programming course in 2004-2005 for B.Ed. students by arranging workshops similar to those mentioned in the previous paragraph. The purpose of these workshops was to familiarise students with the basic principles of robotics, programming and technology and to open their eyes to the potential for IT applications in their everyday environment in the society in which they lived. The materials, teaching, exercises and projects of the entire course were in fact constructed according to constructivist and context-sensitive principles [1].

An outcome of this collaboration was our development of the CATI model (see Figure 1 below), a model that is equally useful for developing sustainable IT in developing countries, for analyzing the planning and implementation processes required for IT, for IT education itself, and for evaluating the ability of a person to apply previously acquired knowledge. The four levels of the model are Contextualize, Apply, Transfer and Import. [14] Each level refers to a particular aspect or phase of development, and may be briefly explained from the technology and knowledge transfer point of view as follows:

- Import refers to any situation in which a technology is imported without any prior local needs analysis. While the technology may thus be completely locally available in the physical sense, it may be completely inadequate or unusable by local operators.
- Transferred technology or innovations are those that are accessible to their users and that may have some potential for application in the local context. Such a situation may be accompanied by a deficient and/or inadequate local needs analysis.
- Application means that the potential of a transferred innovation has being realized because someone has been successful in applying the technology in some or other way to local conditions and needs.
- Contextualizing means that users have become capable of integrating ICT with the needs and concerns of their local community. The local innovative approach is the basis of this level.

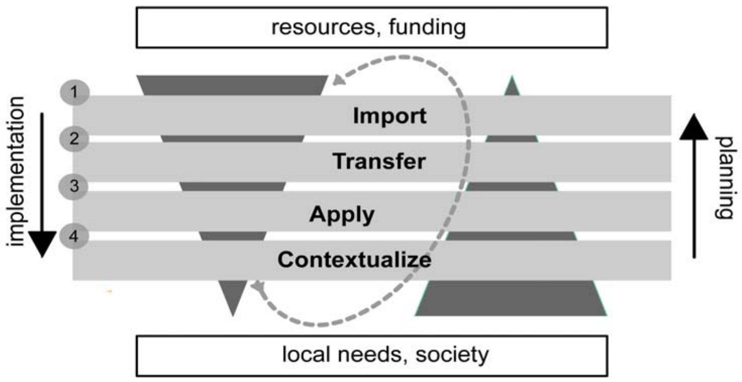

Figure 1: The CATI model for sustainable IT education development [14]

It was our analysis of the contextualized programming course that confirmed our conviction that it is the context-sensitive approach that makes this kind of technology useful and relevant in local societies in developing countries. Most students were able to demonstrate several applications of the IT to their school life and society. Their learning outcomes showed that most of them had attained the level of application, although some of them had approached the level of contextualization after they had completed the course. [1]

We also used collaborative teaching events to promote among students an image of computers as user-friendly transparent boxes that can be controlled and understood – rather than opaque black boxes that hinder progress and understanding. At the same time, the collaborative approach emphasized the relevance of IT to actual living conditions in local society and the applicability of learned content.

3. Plan for the New IT Degree Curriculum

3.1 Design Principles

When we began to design a context-sensitive IT curriculum, we devised principles with which the curriculum should comply – principles that would enable us to justify the decisions that we needed to make during the construction and implementation. The six design principles were that the curriculum should promote teaching that was:

- context-sensitive;
- based on problem-solving projects (problem orientation);
- orientated strongly towards practice and activity;
- interdisciplinary in design and implementation (CS and Engineering being the other fields of study that were incorporated);
- of the standard that would be internationally recognized; and
- based on research.

The most important principle of the programme is contextualization or sensitivity to local context, needs and conditions. Because of this it was necessary to identify regional challenges and idiosyncrasies and to construct the curriculum in such a way that students would be supported in their attempts to identify and solve the local problems engendered by such differences. An approach of this kind should encourage future local users of IT to pursue their own projects and to develop a distinctively local IT culture that is unique to its country of origin.

Another provision of the curriculum was that its courses should be project-based. This in practice meant that course content would be linked to the concerns and needs of local businesses, industry, health care, schools, and so on. Problem-based learning enables students to solve authentic problems and learn whatever theory they may need to solve a problem while solving the problem itself. This kind of practical activity gives students the kind of valuable experience they will need to start their own company or obtain employment after they have graduated.

The need for a practical orientation in teaching IT is readily apparent in Tanzania itself. Since the IT infrastructure in Tanzania is neither yet well developed nor established, IT professionals are confronted with serious practical problems on a daily basis. Students therefore need to become familiar with these difficulties and not merely with the kind of Western solutions that might be irrelevant to conditions in a developing country.

The principle of interdisciplinary linkages may be interpreted in two ways. Firstly, the curriculum includes courses in Engineering and CS. This is linked to the previous principle of practical orientation because IT professionals will undoubtedly be faced from time to time with conditions that demand knowledge of electronics. Secondly, supplementary courses are accommodated by other faculties because students need to understand how IT knowledge and skills can be utilized in other domains such as business and administration, education and tourism. Interdisciplinarity therefore also supports the need for future collaboration on the part of IT professions.

Because global markets maintain standards that are internationally accredited, it is necessary for any local degree to be recognized internationally. International recognition will also allow graduates to pursue further education outside Tanzania and so improve their qualifications. International accreditation requires that the standard of the degree be preserved at a suitably high level.

Because we understand that the currency of the degree needs to be re-affirmed from time to time, we are committed to maintaining our research into the successfulness of the programme itself as well as our research into the impact that the college's graduates make in Tanzanian society. We also plan to maintain our development research approach [11] and utilise a formative development method (FODEM) [15] with the intention of gradually improving the curriculum over a period of time.

3.2 Structure of the IT B.Sc. Degree in Tanzanian Context

We have identified four components of the IT degree for our purposes. These are: (1) the use and administration of hardware and software, (2) basic concepts of CS and Engineering, (3) application projects, and (4) bachelor's degree project and thesis. The degree process is summarised in Figure 2.

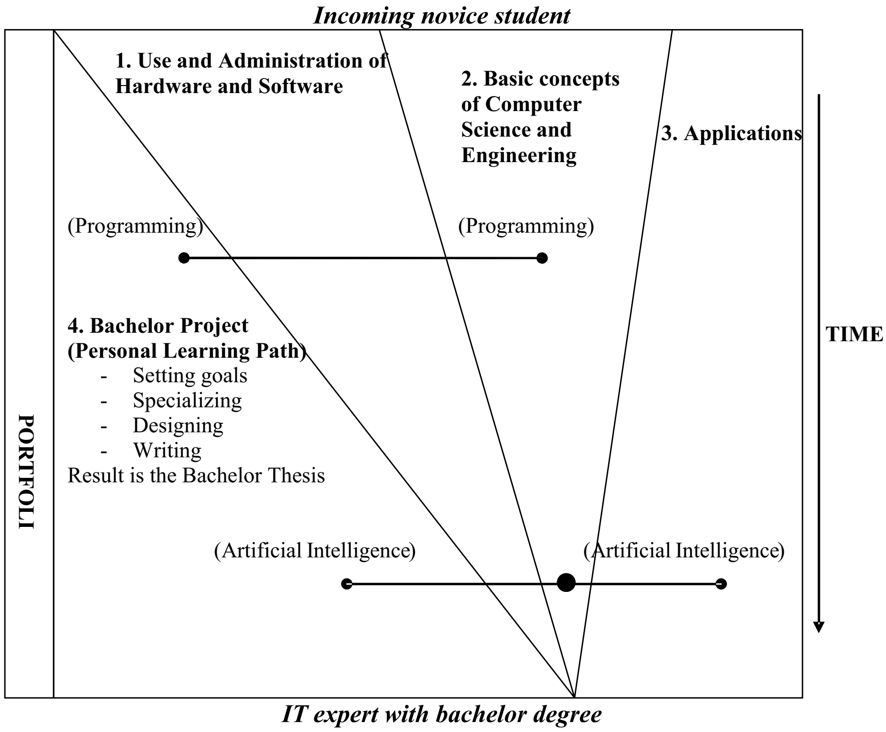

Figure 2: Allocation of different components during the degree programme

Because of prevailing economic and technological conditions in Tanzania, university students often encounter computers for the first time when they enter the university. The most urgent need of such students is therefore first to acquire basic computer skills and literacy. And because qualified IT personnel are scarce, it is the responsibility of the IT graduate in most cases to administer the computer systems (component 1). These goals are accomplished by the first component.

Because of the acute shortage IT teachers, we plan to implement the basic concepts of CS and Engineering (component 2) partly by using existing CS and Engineering courses by the collaborating universities. Thus, for example, we intend to use ViSCoS [16], an on-line CS programme, to support teaching the basics of CS. We further intend to ensure that this programme will be contextualized by engaging local co-teachers or tutors to present the content and take local conditions and culture into consideration.

Component (3), the application projects, is intended to be an important part of the degree. It is in the course of applying what they have learned in projects and by solving authentic problems that students will acquire important skills and knowledge. Students might, for example, apply their knowledge by working in a computer clinic or by designing networks of various kinds. There will also be a strong motivation for students to link their activities to those of local businesses during the projects so that they will be engaged in solving the kind of IT problems that emerge during the day-to-day activities of local business and society. In order to promote their problem-solving activities, students will also be encouraged to attend courses relevant to their project topics. A student who is studying website development for a project might, for example, be invited to study web programming and e-commerce as an ancillary part of his or her curriculum. In similar vein, a student who is engaged in building networks might be encouraged to take a course on networking. All these supportive measures help students to apply in practical projects the knowledge and skills they acquire from the course. The Tumaini University Science Park could play an important role in supporting such an application-oriented approach.

Table 1: Structure of the B.Sc. in IT programme.

Components	**Learning method**	**Learning Resources**
1. Use and administration of hardware and software	Hands-on activities and problem-solving related to the subjects	– Electrical engineering – Basic IT skills – System support and administration – Security (viruses, back-ups etc.)
2. Basic concepts of Computer Science (CS) and Engineering	Problem-based learning will be used for learning the basic concepts so that students can learn the necessary theory in the course of solving the problem.	– System design (participatory design) – Programming and Software Engineering – Artificial Intelligence – Databases – Operating systems – Networking
3. Applications (Projects linked e.g. to the local Science Park and businesses	In the beginning brainstorming to identify the problems that have to be solved, which lead to students' long-term projects. The projects include scenario development, activity and user analysis, implementation, tests with users, and evaluation. Stakeholders (business owners), supervisors/tutors (teachers), and problem-solvers (students) are included in the projects. This component can meet even emerge needs from various other projects.	– Educational use of computers – E-commerce – Cyber law – Agricultural project (e.g. irrigation system) – Multimedia production – IT teaching methods and educational technology
4. Bachelor Project	Each student follows an individual learning path throughout the programme. The student's learning path is based on his or her interests, priorities and learning goals (supported by components 1-3).	– Runs throughout the whole programme (3 years)

The bachelor's degree project and thesis (component. 4) is a continuous process in which students will engage throughout the duration of the whole study programme. Students therefore commence their bachelor project from the time of their enrolment in their first year and continue with their project until they qualify to be awarded a degree by the university. This arrangement makes allowances for the pursuit of various learning paths and specializations and should, in addition, strongly motivate student learning because students will be in a position to apply their knowledge to a project in each phase of their learning.

Figure 2 demonstrates how the various components of the course change over time. In the first year, components 1, 2 and 3 dominate over the bachelor project (4). The importance of the bachelor project (4) increases over the duration of study while other components support it. The components of the programme are inextricably and logically connected to one another. Thus, for example, programming will still be studied in component (2) because it is needed to complete the bachelor project (4). The bachelor project, on the other hand, might require a module in artificial intelligence (2) and an application expertise in e-commerce (3). The programme content is summarized in Table 1.

4. Implementation Plan

In the opening phases of the implementation plan, teachers from partner institutions will play an active role in supporting the teaching and teaching at the local university, which will therefore be a joint activity. Local staff will also be trained and educated in the institution and overseas. In the second year, students who have been trained in the first phase will work as assistant teachers to first year students and continue to develop their skills and expertise.

While the initiative will support local communities by engaging B.Sc. graduates for academic and business needs, IT graduates might also be engaged to support and train local teachers in primary and secondary schools in the region.

Continuous research will be carried out for the purpose of improving the quality of the degree programme. This means that M.Sc. and Ph.D. students from Tumaini University and the partner institutions will be taking part in the implementation process, evaluation and further development.

The IT infrastructure of Tumaini University and the Science Park will provide a solid basis for the degree programme. The additional infrastructure that will be needed for these purposes will also support the whole university and its development in a sustainable way.

The programme is scheduled to begin in September 2007, before which a maximum of 30 students will be selected. The number of students will increase after the first year. Students will be selected on the basis of the commitment evaluation and their results in A level Science. Diploma and vocational training will be taken into account if it was obtained in a related field. While mathematics is important, it is not a pre-requisite for the course. This will enable students from arts and humanities to also enter the programme.

5. IT Degree Programme from the CATI Perspective

In this section we will use the CATI model presented in section 2 to analyze the implementation plan of the IT bachelor programme.

Because the degree programme applies a problem-oriented approach, the design of the programme is based on the needs of the context. In terms of the CATI model, this is an ideal starting point. It is locally based and its structure is designed for that. The local institution, together with its partners, is committed to being an active developer of the programme.

The curriculum, the use and administration of hardware and software (component 1) and basic concepts of CS and Engineering (2) are related to the international concepts, standards and approaches [17], like in distance education presentation of programming. The application projects (3) that start from the very beginning of the degree programme are all required to be clearly linked to local context and needs. One such link is to the local Science Park in which a number of companies already represent their businesses. But links to other local businesses, municipal institutions, secondary schools and hospitals are also all necessary. These connections should provide students with hands-on experience of regional businesses and conditions. The first year's content and action refers mostly to CATI's transfer level. (see Figure 3).

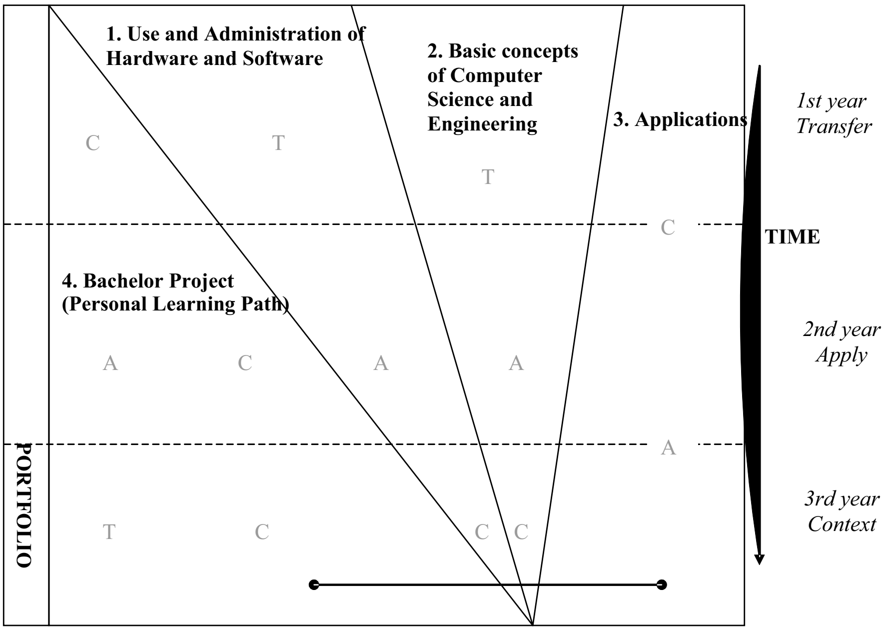

Figure 3: Degree programme in terms of the CATI model (C=Contextualize, A=Apply, T=Transfer)

In the second year, when the introductory courses have been completed, students will have opportunities to apply what they know about hardware and software (component 1) and even some basic concepts of CS and Engineering (2) to their local circumstances. During this time students will pursue their bachelor's projects (4) as well as other application projects (3). In the fourth semester students will begin their project in multimedia. An e-commerce project, commencing in the fifth semester, will give students opportunities to develop their own prototypes in multimedia and e-commerce for local use. Projects such as these could easily demonstrate the kind of application and contextualization outlined in the CATI model from the very beginning of the degree programme. One may in fact characterise the second year as the application year (Figure 3).

The final year of the degree will focus on contextual application projects (component 3) and completion of bachelor projects (4). These activities will demonstrate the degree of expertise that the students have achieved. By this time several implementation projects will have already been completed and students will be qualified to work in the field in various positions because of their theoretical knowledge and practical skills. Students will in fact be able to transfer a significant number of these skills to different contexts. The final year is designed to fulfil students' contextual understanding of IT (Figure 3).

6. Conclusions

This paper has presented the design of an IT degree programme in a way that takes local context and needs into consideration. It is based on several years of joint development and research. The process begins with the introductory courses which are global but linked to contextual issues. As the course proceeds, the amount of application and contextualization becomes proportionately larger. This in turn leads the student to the contextual phases of the thesis and field projects in some area such as business, administration or education.

We are confident that this curriculum equips students for significant careers in the field of IT. While this particular contextualized approach was implemented in Tanzania, the lessons learned from it are universally relevant *mutatis mutandis* in all other developing countries. In each specific case, however, local needs should be taken into account by means of a careful needs analysis and commitment to the indigenisation of course content.

The implementation of this degree programme is the product of a long-term research-based development process, and the practical implementation of the degree programme will be further analyzed as the results of new research become available. The next step might well be an international master's degree to serve the particular needs of this constituency.

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Appendix A:

Research permission by Costech

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY
(COSTECH)

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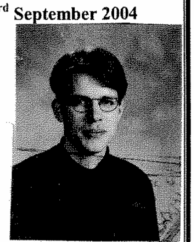
Telephones: (255 - 51) 75155 - 6, 700745-6
Director General: (255 - 51) 700750 & 75315
Fax: (255 - 22) 75313
Telex: 41177 UTAFITI
E-M: Rclearance@costech.or.tz

Ali Hassan Mwinyi Road
P.O. Box 4302
Dar es Salaam
Tanzania

RESEARCH PERMIT

No. 2004 – 217 - NA– 2004/46 Date: **3rd September 2004**



1. Name : **Mikko Olavi Vesisenaho**
2 Nationality : **Finnish**
3 Title : **The Development of Culturally Contextual ICT Education. The Influence of Concretizing in Teaching Programming**
4. Research shall be confined to the following region(s): **Dar es Salaam, Iringa and Kilimanjaro.**
5. Permit validity: **3rd September 2004 to 2nd September 2005**
6. Local Contact/collaborator: **Prof. D.P. Katule, Tumaini University P.O Box 200, Iringa Tanzania**
7. Researcher is required to submit progress report on quarterly basis and submit all Publications made after research.

A.E Mosha
for: DIRECTOR GENERAL

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY
(COSTECH)

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Ali Hassan Mwinyi Road
P.O. Box 4302
Dar es Salaam
Tanzania

In reply please quote: **CST/RCA 2004/46/1985/2004**

3rd September 2004

Director of Immigration Services
Ministry of Home Affairs
P.O. Box 512
DAR ES SALAAM

Dear Sir/Madam,

RESEARCH PERMIT

We wish to introduce to you **Mikko Olavi Vesisenaho** from **Finland** who has been granted a research permit **No. 2004 – 217- NA– 2004-46** dated **3rd September, 2004**

The permit allows him/her to do research in the country entitled **"The Development of Culturally ICT Education, The influence of Concretizing in Teaching Programming"**

We would like to support the application of the researcher(s) for the appropriate immigration status to enable the scholar(s) begin research as soon as possible.

By copy of this letter, we are requesting regional authorities and other relevant institutions to accord the researcher(s) all the necessary assistance. Similarly the designated local contact is requested to assist the researcher(s).

Yours faithfully,

A.E. Mosha
for: DIRECTOR GENERAL

CC: 1. Regional Administrative Secretary: **Kilimanjaro**
2. Local contact**: Prof. D.P. Katule, Tumaini University, P.O. Box 200, Iringa.**
3. Co-researcher: **None.**

Appendix B:

Research permission from students

Introduction to Programming.
Applying ICT within context.

Starting questionnaire.

This is the beginning questionnaire for the Introduction to Programming course. The course will be held in cooperation between Tumaini University, Iringa University College and University of Joensuu, Finland together with the University of Southern Denmark. The results of this questionnaire and other course outcomes will be used for research purposes for the development of information and communication technology (ICT) education. The material will be analyzed and published anonymously.

The course and the questionnaire are part of the project called Information and Communication Technology Education for development: a Tanzanian perspective. The project is funded by the Academy of Finland under grant No. 201682, and has the permission (2004-217-NA-2004/46) from the Tanzanian Commission of Science and Technology (COSTECH). We appreciate your support in this joined development process.

_ I accept that the material mentioned above will be used for the development of education anonymously

_ I do not accept that the material mentioned above will be used for the development of education anonymously

Contact information:
Researcher, Project Manager Mikko Vesisenaho
Department of Computer Science, University of Joensuu
P.O. Box 111
FI-80101 JOENSUU
FINLAND

Email: mvaho@cs.joensuu.fi

Appendix C:

Extract of the questionnaire I (questions)

A. Personal Information

Please answer the following questions by using your personal views and opinions. If there is not enough space please use the backside of the paper. You may also use figures in answers.

1. Name
2. Age:
3. Gender: male / female
4. Do you have sisters or brothers?
   If yes, the ages of sisters are ____________________
   If yes, the ages of brothers are ____________________
5. What is the profession of your
   a) father? ____________________
   b) mother? ____________________

6. Where do you come from and what is your tribe?

7. What is your educational background (for instance primary, secondary, teacher seminar):

B. Prior experiences in information and communication technologies (ICT)

8. For how many years have you been using computers? ________________

9. Describe the experience you have had in the following ICT application areas:

Application	*Yes/no*	*Software used*	*For which tasks*	*For how long (months/years)*
word processing				
email				
Presentation tool (e.g. power point)				
Publishing tool (e.g. Publisher, Page maker)				
Spreadsheets (e.g. excel)				
Internet tools for			Web browsing	
			Searching information on Internet	
			Designing web pages	
			Filling web forms	
			Chatting	
Image processing (e.g. Photoshop)				

Continue

		Programming environment and language	*For which task and where?*	*For how long time (months / years)*
Programming				

10. Give a list of computer classes that you have participated in addition to the obligatory ones in university.

11. For what kinds of purposes do you use computers? (mention the 3 most important ones)

12. What is the role of ICT in your life and what it has been?

C. Introduction to Programming course

13. What are your personal goals for this course?

14. What are you practically expecting from this course? (e.g. arrangements)

D. Every day concepts of ICT

15. Where is information and communication technology or robotics around you in your every day life? (give 5 examples)

16. What do you think, what are
a) the opportunities for ICT in your life?

b) the opportunities for ICT in Tanzania?

17. Where could you apply programming or robotics skills in your society?

E. Computational concepts

18. You are calling your friend in Dar es Salaam by a cell (mobile) phone. Describe what kinds of actions / operations (e.g. technical) take place during the the call.

19. Give instructions to a person called John about how to arrange bus travel from Iringa to Arusha where his girlfriend is waiting for him. Please notice that some buses might be full, the money taken aside for tickets might not be enough, and weather conditions might change. However, you should make it sure that John succeeds in getting to Arusha by following your instructions despite the problems encountered during the trip.

20. Explain what the following computer program does and how it works. What happens within the computer? You can use figures in addition to text when explaining.

we have variables *a*, *b*, *c, final*

```
if a is less than b
then    if a is less than c
        then final <- a

        else final <- c

else
        if c is less than b
        then final <- c
        else final <- b

print final.
```

21. Use the program presented in exercise 20, so that *a equals 2, b equals 1 and c equals 3*

What is the value of the final in the end of program?

- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 6
- ❑ 9
- ❑ 12
- ❑ OTHER ____________________

22. Answer the following questions:

a) What data type would you choose to store the value **7**?

- ☐ char
- ☐ double
- ☐ int
- ☐ boolean

b) What data type would you choose to store the value **true**?

- ☐ char
- ☐ double
- ☐ int
- ☐ boolean

c) What data type would you choose to store the value **3.14158**?

- ☐ char
- ☐ double
- ☐ int
- ☐ boolean

d) What data type would you choose to store the character **'p'**?

- ☐ char
- ☐ double
- ☐ int
- ☐ boolean

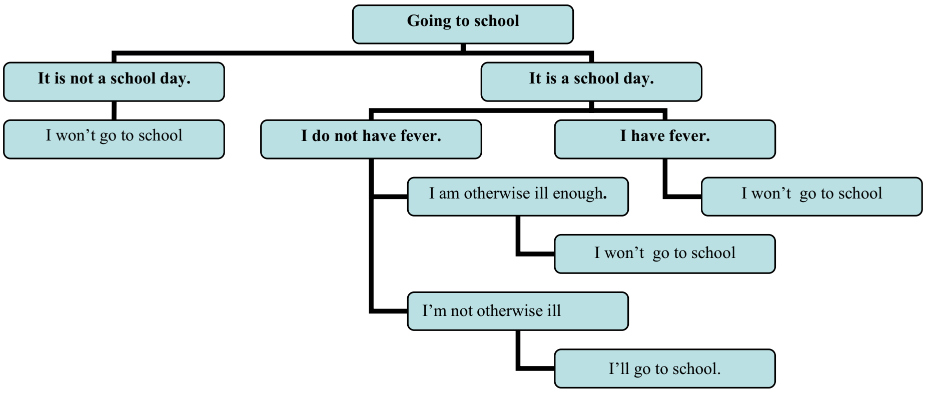
e) You have declared the array: a[0] = 1, a[1] = 2, a[2] = 3

What is **a[a[0]]** ?______________________________

What is **a[a[0] + a[0]] + a[0]**?______________________________

23. Decision tree. Under this text you can find an example of a decision tree. Your task is to draw your own decision tree among the description under the example.

You are about to buy ugali for your lunch. But the person from whom you have normally bought ugali doesn't have it. Draw a decision tree which helps you to find the reasons for this *shida*.



F. Programming and robotics *(removed, not used in this research)*

G. Robotics *(removed, not used in this research)*

H. Other questions

40. What would you like to learn next?

41. Could you teach programming at the moment at a secondary school?

42. Is there something else you want to tell us?

Many thanks for your answers!

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