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Are Animations Effective Tools for Teaching Computer Science Courses in Developing Countries?

The case of University of Dar es Salaam

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Abstract— **Teaching computer science courses is a big challenge to majority of teachers in developing countries institutions. Most of these courses consist of abstract concepts where traditional pedagogical methods such as lectures and textbooks cannot be suited to enable students understand them. It becomes even more challenge due to the fact that majority of these institutions are faced with large class sizes while teaching facilities are few. Although several solutions have been proposed to alleviate these problems such as increasing student-computer ratio, improving teaching pedagogy and increasing number of teaching staff, the problem still exists. In this paper, we propose the use of computer animations as instructional tools so as to enable students learn difficult concepts in developing countries institutions. We conducted a pilot study at University of Dar es Salaam (UDSM) to determine if the use of animations can enable students to learn difficult concepts easier and master course contents. The study revealed that 67% of respondents (of 108 students) indicated that animated courses enabled them to grasp difficult concepts more easily. The study also found that the process of developing animations improves the quality of course design. However, it is essential to incorporate pedagogical and instructional design principles in the whole process of development and integration of animations into courses.**

***Index Terms*—Animations, Simulations, Computer Science, eLearning, animated courses**

I. INTRODUCTION

Teaching computer science courses which require conceptual understanding is a challenge to majority of teachers who used to teach through lecturers and textbooks specifically in developing countries institutions. This is because most of the institutions in these countries are faced with increased students enrolments (i.e. large classes), limited teaching facilities, and massive shortage of science teachers. While teaching computer sciences concepts requires teachers to use various instructional methods such as demonstrations, practical exercises and assignments, several institutions do not have enough facilities for that.

Despite the demand for well-trained computer scientists and software developers in the world, developing countries have been underrepresented, and worse enough they depend on imported software for majority of their organizations. Studies suggest that the nature of traditional pedagogical techniques may contribute to these challenges.

As a result of these challenges, the number of students who are dropping these courses has been increasing every year.

Several solutions have been proposed to alleviate these challenges, such as reducing student-computer ratios, improving teaching pedagogy, and increasing the number of teaching staff. Although much of the literature indicates that effective application of Information and Communication technologies (ICT) has the potential to alleviate some of these challenges, the benefits of using such technology remain an issue for further research.

Moreover, despite the improvement of ICT infrastructure, reduced costs of internet and emergence of low cost smart phone in developing countries, many lecturers within African universities have not fully utilized its potential to enhance their teaching methodology towards science courses.

In response to these challenges, the University of Dar Es salaam (UDSM), through the Centre for Virtual Learning (CVL), decided to implement a pilot project focused on developing and integrating computer animations into computer science courses. The project was funded by the Partnership for Higher Education in Africa (PHEA) and implemented in partnership with the South African Institute for Distance Education (Saide). This paper presents the findings obtained from 108 computer science students in order to know if the use of animated course materials can improve course design and enhance students' mastery of difficult computer science course concepts. It is expected that findings of this study will stimulate further research on the use of animated course materials as instructional tools to improve teaching computer science courses especially in developing countries institutions.

II. BACKGROUND

UDSM has made tremendous investment in ICT infrastructure to enhance the quality of teaching and learning. Some notable achievements include the increased bandwidth to 1/155MBS, deployment of a Wireless LAN (Hotspot) at the main campus and establishment of public access rooms (PARs). Other

achievements include the deployment of various Information systems such as the Human Resource Information System (HURIS), Financial Information System (FIS), Academic Register Information System (ARIS), Library Information System (LIBIS), and various eLearning Systems. In terms of educational technologies, UDSM started eLearning implementation in 1998. Initiatives include the introduction of Blackboard LMS (1998-2008), WebCT LMS (2003-2006) and the Advanced Level End User Competence Upgrading Project (2004-2007) [2].

Most of the above investments and initiatives focused on installation of network infrastructure and capacity building for both technical and academic staff on using the above systems. Through these initiatives, more than 2,000 staff members were trained on how to use the Blackboard LMS and 415 courses were created and uploaded [3]. These initiatives did not result into improved students learning due to the fact that effective integration of ICT in teaching and learning lies beyond mere access and ICT literacy as pointed out by Peeraer and Petegem [4]. According to Mtebe, Dachi & Raphael [2], little was done beyond improving the technological environment of the institution and equipping a few academic staff with educational technology skills. This is evident from the fact that most of 415 courses which were uploaded in the Blackboard LMS consisted of skeletal course guides or course hand-outs with minimum content, summarized in the form of Microsoft PowerPoint or Microsoft Word documents [3]. Lecturers uploaded courses into LMS in form of handouts and notes which they were using in face-to-face teaching and expected students to learn independently. In addition to that, these courses lacked interactivity and were designed without considering eLearning pedagogical approaches. The problems highlighted above regarding poor quality of course design have directly impacted on the mastery of course concepts for students and ultimately affect the quality of graduates.

In light of the above problems, CVL decided to implement a pilot project focused on developing animated courses and investigate if these courses can enable students understand difficult concepts easier and improve course design.

To achieve this, the project supported lecturers to redesign their course blue prints by identifying areas where animations can simplify understanding of difficult concepts. Moreover, animations learning objects were developed and integrated into course blue prints. The animated courses were converted into eLearning format and made available via the Moodle Learning Management System (LMS) and Compact Disc (CDs) for students' access.

To assess the effectiveness of the intervention, we conducted a study to provide a critical analysis of how the use of animations in computer science courses has enhanced subject matter concept mastery and improved course design at UDSM.

III. THEORETICAL FRAMEWORK

The implementation of this project was motivated by the assumption that appropriately uses of computer animations can provide additional instructional support to convey complex and dynamic topics and therefore make abstract concepts easier to understand. Literature seems to confirm this view. The use of computer animations in teaching science courses are said to offer several benefits in improving students' learning. They enable students visualize and construct mental models (a mentally-runnable simulation) [6] of various computer science concepts. These mental models are the most developed sense in humans and are important way by which students learn[7]. Moreover, these models help students to make connections between fragments of concepts, and therefore enable to learn problem solving and interact with course content as opposed to memorizing computer concepts rules or fragments of information [8]. By doing so, students develop understanding of abstract concepts which are otherwise considered to be 'invisible' [9]. Moreover, computer animations are thought to support students with different learning styles by presenting content in a variety of formats (video, audio and sound). In this case, students are given different ways of learning concepts and therefore more novices can be attracted to study computer science [10].

These potential benefits sparked the interest of several researchers to conduct studies and pilots to determine suitable roles for animations in teaching various science courses. Notable studies include the development and use of animations for teaching courses such as cell biology [11], operating systems [12], discrete structures [13], histology [14], molecular chemistry [8] and mathematical concepts [15]. The majority of these studies appear to indicate that animated learning materials are more useful in presenting difficult concepts than equivalent static learning materials. While most of these studies have focused on a single subject or discipline, our study has focused on more than one course in the specific domain of computer science.

The well-developed animations can be used to liven up lecture notes when teachers use computer animations to better demonstrate and explain difficult concepts in face-to-face classroom [16]. They can also be used to improve online versions of lectures notes where interactive animations presented in a lecture can also be offered on the Web version of course materials. In either case, they must integrated into the instructional design and making them part of overall course pedagogical framework in order to meet intended didactic objectives

IV. RESEARCH DESIGN IMPLEMENTATION

Methodology

This case study employed both qualitative and quantitative research methods to collect data. Questionnaires were prepared and distributed to students and lecturers. Qualitative data collection methods included one-to-one interviews with lecturers who were involved in the process of developing course blue-prints. Moreover, documentary evidence in the form of developed animations and integrated courses was used to assess the quality of developed courses based on proposed course design quality rubrics indicated in table 1 in the Appendices. Questionnaires were analyzed using Google doc tools. Further details on specific research methods are presented below.

Results

The results of this study are divided into two categories, namely:

- Animations in enhancing concept mastery of subject contents
- improvement in quality of course design based on the process of course development

Finding 1: Animations in enhancing concept mastery of subject contents

To determine if the use of animations enabled students to understand difficult concepts, we developed questionnaires and distributed to students at the end of Semester II, May 2012.

Through these questionnaires, we were interested in finding out about (a) students' perceptions of the usefulness of animations and simulations in making difficult concepts easier to understand; (b) some examples of concepts that were made easier as a result of animations; and (c) students' overall opinions on the usefulness (in terms of course mastery) of animations in learning science courses.

The questionnaires were completed by 108 students, of whom 86 were male (80%) and 22 were female (20%). Of these respondents, 27 were in their first year of study, 46 were second year, and 35 were third year.

When asked about their perception on the usefulness of animations in making difficult concepts easier to understand on a 5 tier scale, the results showed that 67% of respondents agree that animations made difficult concepts easier. The summary of results is shown in Figure 1.

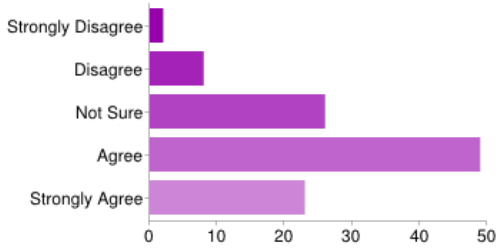

Fig. 1. Perception of students on animations and simulations in making difficulty concepts easier

When asked to mention specific examples of animations which made some of course concepts easier, respondents mentioned the following animated concepts:-

- The concept of deadlock in operating systems.
- In networking, animations help to understand how traffic travels from one device to another.
- In networking, understanding the flow of data from sender to the receiver by the OSI seven layers was made easier to understand through that simulation because it shows how data changes from top layer to the bottom layer.

Other concepts mentioned include:

- E-R Diagram;
- Boyles law;
- B-+trees(insertion and deletion) as shown in figure 2 and figure 3;
- Data encryption and decryption using DES algorithm;
- Data Structure (Recursion, concept of Towers of Hanoi);
- Applications of gates in digital circuits.

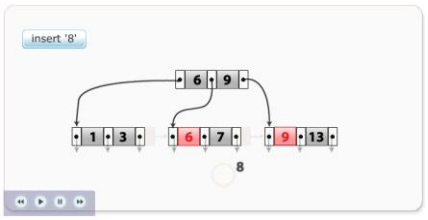

Fig. 2. Snapshots on B+ tree Insertion Animation in Database implementation course, one of animation mentioned by students.

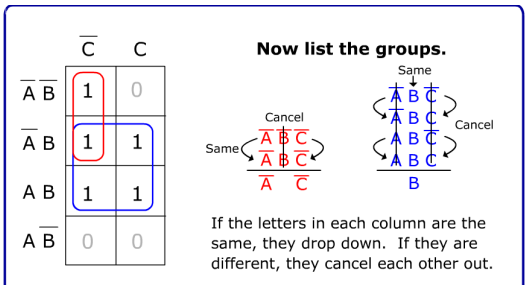

Fig. 3. Snapshots on Simplification by K-MAP in Digital Circuits course mentioned by students as one of the concept made easier by animations.

Finally, we requested their opinion on the overall usefulness (in terms of course mastery) of animations and simulations materials in learning science courses on a 5-tier scale. The results showed that: 84% of respondents indicated that animations and simulations are useful in science courses; (12) 11% said they are somewhat useful; (5) 5% indicated they are a little useful; and no respondent said they are not useful at all. The results are shown in Figure 4.

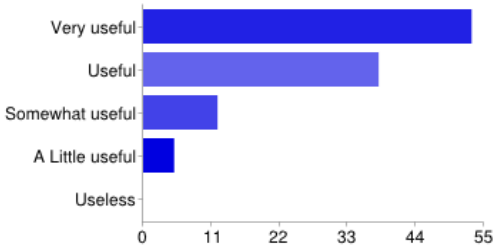

Fig. 4. Usefulness of animationated materials in learning science courses

Finding 2: Improvement in Quality of Course Design

In order to determine if the process of developing animations had an impact on improving the quality of the course design, we conducted two tasks to collect information. First, we developed Course design Quality Metrics (see TABLE I in the Appendices), which provided guidelines on how the quality of a course's design should be judged. These metrics were adapted from the course development template (given to lecturer during course development) and Quality Matters Rubric Standards 2011-2013 (extracted from www.QMprogram.org). Second, we distributed questionnaires to lecturers to obtain their opinion on the usefulness of the use of animations in improving the quality of course design and enhancing concept mastery.

TASK 1 RESULTS

From the table metrics developed (*TABLE I in the* Appendices), it can be seen that in most of the courses, the overall course information was made transparent to students at the beginning of the course. This information include titles of modules, course objectives or outcomes, pre-requisites, list of assignments, lecturer contact information, student evaluation, and grading criteria. Using the course development template, lecturers were able to provide all required and relevant course information.

Moreover, a course calendar was developed and provided in almost all courses. The course calendar is very important because it helps students to learn at their own pace and plan their learning time accordingly. Students learn better when they control the pace of their learning [21]. With the presence of the calendar, students can plan when to submit assignments and when to undertake tests or examinations.

The challenging part was the development and integration of LO into various modules at the same time ensuring that they enable learners to achieve stated learning objectives. CVL staff had to ensure that animations reach specific outcomes related to skills or acquired knowledge for intended students as insisted by Taylor, Pountneya and Malabara [15]. From the developed Quality Metrics, it can be seen that integrated animations complemented text materials by presenting difficult concepts using multimedia elements. Also, most lecturers were able to develop learning activities/practical exercises that encouraged reflection.

TASK 2 RESULTS

The second task involved eliciting lecturers' opinions on the use of animations to improve the quality of course design and enhanced concept mastery in their courses. 71% strongly agreed that animations are useful in enhancing students' mastery of difficult course concepts, while 29% agreed and indicated that the process was also useful. They also indicated that the use of animations in their courses helped to easily explain difficult course concepts.

V. DISCUSSION AND LESSON LEARNT

Animations and simulations improves the quality of course design

This study suggests that the process of developing computer animations improves the quality of course design. Lecturers strongly agreed that this process ensured that course goals, course content and methods of assessment were well planned and integrated in the courses, unlike before. However, the study revealed that it is essential for pedagogy and instructional design principles are incorporated in the whole process of development and integrating animations into courses so as such animations to have an educational value. Likewise, they must be attractive, engaging and intuitive while enabling learners to navigate easily to learn course content. If developed animations are not user-friendly, learners spend more time learning how to use them rather than learning the course content [17]. Also such kind of animations are often cognitively demanding and therefore resulting in decreased learning outcomes [18].

To ensure this, CVL developed course template whereby all pedagogical considerations were incorporated. The template included important instructional principles such as Gagne's Nine Levels of Learning [22], Bloom's Taxonomy [23] of learning objectives and other related learning theories and principles.

Animations enable students to learn difficult course concepts easily

We also examined the effect of computer animations in enabling students to master course content and making difficult concepts easier. The study has revealed that "animations can serve as effective multimedia tools to engage students while facilitating and enhancing the student learning experience by explaining difficult concepts through visual means instead of the traditional way of heavy textual based presentation" [24]. This conclusion comes from the fact that 67% of respondents indicated that animations in courses enabled them to grasp difficult concepts more easily. This finding is in line with what other researchers also found such as [11],[15],[25],[14] and [12] regarding the benefits of animations help students grasp difficult concepts.

Animations and simulations can be used to complement face to face classroom

The study revealed that some lecturers were using animations to complement face-to-face teaching. This shows that animations are not only useful in online or independent learning, but can also be used to easily explain difficult concepts in face-to-face classrooms.

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VI. CONCLUSION

This study has shown that the use of computer animations assists students to better understand complex and difficult concepts in various computer courses. Although the project focused on computer science courses, the same benefits can be attained in any science course. In addition, this process enabled

quality course materials to be made available to students, improved course design and ensured the availability of teaching resources even when some experienced staff member retires or leaves the institution. The challenge remains on how to ensure that animated courses are reviewed and updated regularly.

Despite these benefits, many lecturers hesitate to incorporate animations into their courses[12]. They do not value the process of course development the same way as conducting research or teaching. Lecturers in universities need to realize that developing quality course notes for their students is as important as teaching and doing research. Therefore, there is a need for institutional management to sensitize lecturers on the value of animations in education. In addition to that institutions should create various motivations mechanisms such as promotions, provisions of facilities for lecturers who use educational technologies in teaching.

Finally due to advancement in technology and availability of modern equipment, the possibilities for educational animations are endless. We recommend that future research to consider how animations can assist students with disabilities.

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Appendices

TABLE I. PROPOSED COURSE DESIGN QUALITY METRICS

A:General Course Information	CH 240	IS 263	IS 273	IS 353	IS 364
Course Title	Yes	Yes	Yes	Yes	Yes
Course Code	Yes	Yes	Yes	Yes	Yes
Lecturer(s) Introduction	Yes	Yes	Yes	Yes	Yes
Course Overview	Yes	Yes	Yes	Yes	Yes
Course Outcomes/Objecti ves	Yes	Yes	Yes	Yes	Yes
Pre-requisites	Yes	Yes	Yes	Yes	Yes
Course assessment and Grading options	Yes	Yes	Yes	Yes	Yes
Course Calendar	Yes	Yes	Yes	Yes	Yes
B: Instructional Materials					
A:General Course Information	CH 240	IS 263	IS 273	IS 353	IS 364
Course Title	Yes	Yes	Yes	Yes	Yes
Module Xi:					
Clearly stated course outcomes	Yes	Yes	Yes	Yes	Yes
Objectives are stated clearly and written from the students' perspective.	Yes	No	Yes	Yes	Yes
The instructional materials contribute to the achievement of the stated module/unit learning objectives.	Yes	Yes	Yes	Yes	Yes
Content pitched at level matching course outcomes	No	No	Yes	Yes	Yes
Animations and simulations present a variety of perspectives on the course content.	Yes	Yes	Yes	Yes	Yes
There are learning activities/practical exercises that encourage reflection	Yes	Yes	Yes	No	No
The learning activities promote the achievement of the stated learning objectives.	Yes	No	Yes	Yes	Yes