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Case-based implementation of healthcare technology management module

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ABSTRACT: Healthcare Technology Management is a required module for 5th-year Bachelor students in biomedical engineering at the Malawi University of Business and Applied Sciences. A relatively new module to the curriculum, it was initially taught using an entirely traditional lecture format in 2020. In 2021, the researchers modified the module using empirically based methods to involve a high degree of active learning; namely, case-based learning, which employs open-ended questions and small-group discussions. Student participation in the modified module was substantial with higher observed engagement and peer-to-peer sharing and learning. The average final grade in the module rose from 66 (AY 2020) to 73 (AY 2021) and can be attributed to the active learning and case-based approach. The chi-square test returned a p-value of 0.11, which is trending towards significance. The findings of this novel study can be applied to engineering courses in low-income educational settings to improve students' learning and interest.

Keywords: Active learning, case-based learning, healthcare technology management, higher education

INTRODUCTION

Educating to Meet the Needs of Healthcare Technology Management

Hospitals in developing countries, such as Malawi, are integrating technology within their health systems. Technology and computerisation enable a higher quality of healthcare, fewer errors and costs, and greater efficiency within the healthcare system [1]. Low-income countries, including many in sub-Saharan Africa, need clinical engineering professionals to establish and maintain such safe healthcare systems [2-5]. The overall goal of healthcare technology management is to ensure that the appropriate technologies are deployed to solve healthcare problems using suitable, cost-effective, safe, functional equipment at minimal risk to users, patients and the environment [2]. In Malawi, biomedical engineers and technicians are often part of the clinical engineering team. Clinical engineering professionals are responsible for the selection, maintenance, repair and deployment of medical equipment in hospitals and clinics [6].

In Malawi and other low-income countries, much of the education for clinical engineering professionals occurs after graduation in the clinical setting [2]. Recognising this gap, the Malawi University of Business and Applied Sciences (MUBAS) created a module for its biomedical engineering Bachelor students to be better prepared to work with the hardware and software systems adopted by local clinical environments. In preparing for this module, there was consensus from faculty and staff from local hospitals about what key topics to cover. However, there was very little published about best practices in teaching these topics in an undergraduate programme. This provided an opportunity for faculty at MUBAS to redevelop this module to improve student learning.

A literature search was conducted to discover key content and technical topics in the clinical engineering course. However, limited literature discussing best pedagogical practices for how clinical engineering is taught was found, thereby shedding light on a huge gap in the field. Particularly research on pedagogy in clinical engineering courses in low-income countries was limited to: a) e-courses [7][8]; b) the need to include information technology knowledge in clinical engineers' studies [9]; and c) dated studies. With this as a backdrop, further research into effective pedagogical approaches in this technical area is important and significant in clinical engineering and pre-hospital education.

Case-based Learning (CBL)

Andrew Ndalama, the instructor for the Healthcare Technology Management module elected an innovative case-based teaching method. As per Thistlewaite et al, *The goal of CBL is to prepare students for clinical practice, through the use* *of authentic clinical cases. It links theory to practice, through the application of knowledge to the cases, using inquiry-based learning methods* [10]. An article from Ethiopia on a laboratory medicine course defines CBL as a means …*so that trainees explore clinically relevant topics using open-ended questions with well-defined goals* [11]. In a meta-analysis of case-based learning from across the world, McLean found that there were three main components that constitute this type of learning: a) *a case as a stimulant for learning*; b) *advance preparation of the learner*; and c) *a set of learning objectives that must be adhered to* [12].

Case-based learning is an active learning technique. Active learning is a student-centred teaching strategy that engages students in the classroom [13]. Active learning has been found to improve student learning across science, technology, engineering and mathematics (STEM) fields [13]. Case-based learning is intended to immerse students in situations that they could expect to encounter while working in the field of study following graduation [14]. Thus, case-based learning has been employed more frequently in graduate school, especially in business and law [15].

Although more limited, case-based approaches have been taken throughout STEM education [16]. Case-based learning is particularly successful as a teaching method to bring real-world situations into the classroom and also foster a collaborative learning environment [16]. Implicit in case-based learning is the application of knowledge in context; this application supports students as they reach the middle levels of Bloom's taxonomy [17].

Case-based approaches facilitate the discussion of topics among a diverse group of students where different perspectives and opinions can inform the outcome. The richness of the conversation informs student learning and supports the development of a framework for decision-making. For example, a teaching team in the United States implemented a case-based approach to teach ethics in a graduate-level course [18]. Student teams were introduced to a case involving an implantable medical device and a related quality problem. After assigning students different roles, the team discussed and researched the problem, and then presented a recommendation. Their teaching team found that the case-based group exercise was the most effective at helping students understand real-world ethical decision-making. Other teaching teams have used case-based approaches with ethics [16][19].

Team-based Learning (TBL)

As per Michaelsen and Sweet, the four elements of TBL are strategically formed teams, readiness assurance, activities that promote critical thinking and team development, and some form of peer assessment [20]. Students are more engaged in TBL courses than in traditional lectures [21] as TBL involves real-time student communication, group work and decision-making, whereas lectures frequently involve the passive absorption of content. Empirical studies of TBL have found increased test performance [22], engagement and positive attitudes towards group work [23] and long-term retention [24]. Yet, most of the studies about TBL are descriptive, rather than experimental, thereby driving this research to have a comparison group in the study.

METHODS

Healthcare Technology Management Module Details

Healthcare Technology Management (ELE-HTM-511) is taught in the first semester of the last year of a five-year programme for biomedical engineering students at MUBAS. This module provides students with basic knowledge on how to identify, acquire, use, manage and dispose of healthcare technologies. It is taught in the final year to equip students with healthcare technology management skills as they are going into clinical settings. In Malawi, hospitals are the biggest employer of biomedical engineering graduates. The knowledge from this module is very important as it introduces the students to issues concerning healthcare technologies found in Malawian hospitals.

The grades of ELE-HTM-511 are assessed by 30% coursework and 70% final examination. The coursework is made up of a mid-semester examination and various assignments throughout the semester. The examinations require students to describe strategies and explain the rationale for selection, management and inventory of medical equipment. The final examinations for both years were reviewed by an external evaluator and deemed to be rigorous. The module is taught twice per week with 1 hour and 40 minutes per class for 13 weeks (Table 1).

Table 1: The Healthcare Technology Management module.

The learning outcomes of the module are as follows:	The indicative content includes:
1. Identify steps involved in technology acquisition 2. Take an inventory of existing equipment 3. Analyse policies in health care technology 4. Assess the cost implications of decisions in health care	• Health technology assessment • Health technology acquisition • Good management practice and medical equipment • Assessment management • Risk management • Development of clinical engineering department • Clinical engineering support

Materials include two textbooks as references [25][26]. In 2020, the instructor at the time employed a lecture-based instruction method. Each lecture was delivered using a set of PowerPoint slides, adapted from the existing textbook references.

Module Intervention: Applying Active Learning to Healthcare Technology Management

The stimulus for the instructor's adoption of case-based learning was the fruitful partnership between MUBAS and Rice 360 Institute for Global Health Technologies (see Invention Education Toolkit) [27]. This collaboration included a series of workshops and supportive professional development for MUBAS faculty as they adopted research-based teaching practices. The overall goal of this collaboration was to increase MUBAS student achievement of stated learning outcomes and increase participation in invention education activities.

When a new instructor (A. Ndalama) took over teaching ELE-HTM-511 in 2021, he used various active learning principles, such as think-pair-share, case-based learning, group discussions and presentations. Think-pair-share involves giving students time to think about their responses to questions before they discuss with peers and share with the classroom [28]. Each day in class, A. Ndalama started by asking a question and the students discussed their views in small groups. From those responses, he introduced the topic of the class, followed by the indicative content (the technical content that should be covered in the module). The second half of class featured a case study, in which students worked together to discuss a healthcare technology management situation and answer a set of questions. Groups shared their analysis of the case study and any recommendations to the entire class through an informal presentation. Class presentations enabled students to hear other perspectives and receive feedback from the instructor. Specific aspects of the class are explained in more detail below.

Module Intervention: Launching Class with an Open-Ended Question

To motivate the class topic, the instructor started each class with an open-ended question. By sharing their views in small groups, the question facilitated discussion specifically designed to get the students thinking about the topic for the day. The length of this discussion was typically 5-15 minutes. Examples of these prompts include:

- Topic: Healthcare technology assessment. Prompt: Why do we need to assess healthcare technologies in Malawi?
- Topic: Healthcare technology acquisition. Prompt: What do you know about the process of medical device acquisition in Malawi hospitals?
- Topic: Incoming equipment inspection. Prompt: Why is it important to conduct an inspection on incoming equipment before installation and usage of said equipment?

Module Intervention: Delivery of Indicative Content

After students shared a few responses to this open-ended prompt, the instructor then introduced the topic of that class meeting, followed by the indicative content. The instructor typically used PowerPoint slides to deliver class content. The length of delivery of this content was around 30-45 minutes. Students frequently asked questions during the lecture. Additionally, the instructor asked open-ended questions throughout the class to assess if the students understood the class content. For example, *Most Malawian hospitals have medical devices, mostly donated, that are not being used, due to lack of consumables or user manuals. Sometimes the devices do not work at all. Explain, in your own words, how performing a thorough incoming inspection could have prevented this scenario*.

Module Intervention: Case-Based Learning to Enhance Application of Knowledge

The second half of each class featured a case study that involved the practice of healthcare technology management in a clinical setting. Following a prompt given by the instructor, groups of two to three students self-assembled to discuss the prompt. The case studies applied the indicative content that was shared during the lecture, encouraging students to think about how to operationalise the knowledge gained in the Malawian context. During the case studies, students explored different perspectives and related their knowledge to consider how to make decisions in healthcare technology management. Examples include:

- Topic: Medical equipment standards and regulations. Prompt: Assess the medical device regulatory framework in Malawi and with reference to either the USA or Europe. Discuss the areas that need improvement.
- Topic: Healthcare technology assessment. Prompt: Explore the ethical and social considerations that arose during the first pig-to-human heart transplant [29].
- Topic: Healthcare technology maintenance. Prompt: With reference to your industrial attachments done in the fourth year, discuss the type of maintenance that was practiced at the organisation where you were attached.

Students discussed each case for about 30 minutes. In a report-out to the class, groups summarised their responses to the challenge through a 2-3 minute presentation. Other class members and the instructor then gave feedback and/or asked questions. The participation in case study discussions was not graded.

Module Intervention: Team-based Projects to Encourage Knowledge Application

Two times during the semester, student teams were assigned projects that they worked on outside of class. These projects required students to research healthcare technology management and its implementation in the Malawian healthcare system.

The instructor formed teams of four to six students. Each team wrote a short report and presented their findings in class, followed by a class discussion. These 2-week assignments were graded as part of the 30% coursework grade. Example project topics include:

- Topic: Medical device regulation. Prompt: Choose any high-income country and explore its medical device regulatory system. Assess how Malawi may or may not be able to adopt such systems.
- Topic: Modern trends in the management of healthcare technologies. Prompt: Review a journal paper about healthcare technology management.

Module Intervention: Grade Collection

The final grades were collected from the Dean of Engineering at MUBAS, with appropriate permissions from MUBAS leadership. Additionally, Rice University's Institutional Review Board (IRB) considered this work exempt from their review. The 2020 module was the control, and the 2021 module was the treatment.

The final grades included the average and binned grade data for both the treatment and the control years. The percentage of students scoring 70+, 60+, 50+, 40+, 35+, and 0+ was included in the binned grade data. Note that the notation of 60+ means 60-69, and similarly for other scores. No student names were on any documents; additionally, no specific final grades were retrieved, as the only retrievable data was the number of students scoring in the given grade ranges.

A statistical treatment was applied to evaluate whether student performance was different during the control and treatment modules. The hypothesis was that the students would perform at a higher level when the module was taught in the modified version including a case-based approach and active learning. Specifically, the authors used a test of homogeneity to determine if the frequencies of different populations were distributed identically or not (alpha = 0.05). Because the final grades were ordinal (interval) data, they constructed a contingency table followed by a chi-squared test to compare the grade distributions from the treatment and control.

RESULTS

Student Performance

The average student grade in ELE-HTM-511 rose from 66 (AY 2020) to 73 (AY 2021), after the addition of the case-based approach (Table 2). The distribution of grades is also shown in Table 2. In 2020, females made up 33% of class members; in 2021, 46% were female.

Table 2: Summary statistics of control and treatment in ELE-HTM-511.

	Number of students	Average grade	70+	60+	50+
Control (2020)	17	66	7	7	3
Treatment (2021)	26	73	19	5	2

The histogram of final student grades is shown for the percentage of students (Figure 1). There is a clear shift toward higher grades in the treatment group. The chi-square test returned a p-value of 0.11, which is trending towards significance.

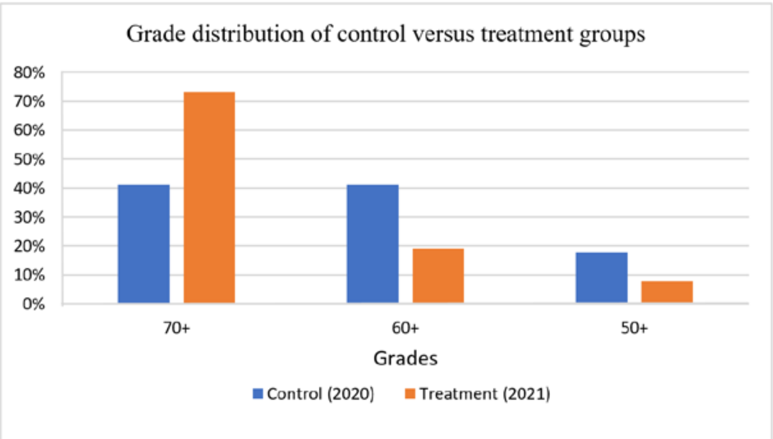

Figure 1: Percent of students scoring in a particular grade bin.

Encouraging Productive Team Interactions

Team composition was random and different each time students completed a group activity, and the size of the team varied each time depending on the scope of the task. When the students were discussing in their groups, the instructor circulated and talked with various teams, answering questions, and sometimes coming up with question prompts on the spot to facilitate and guide the direction of the discussions. Following the discussions, random students in each group were selected to present their findings. Over the entire term, this rotating team composition gave students exposure to different individuals and team sizes while being challenged to maintain productivity.

Student behaviour evolved through the use of these case studies. At first, during the first two case studies, students mostly asked the instructor questions, especially in cases where the team failed to reach consensus on the question prompts. With later case studies, students learned quickly to discuss among themselves and draw conclusions on the topic at hand on their own. The instructor merely ensured the discussions were in line with the topic for that day.

Fostering Increased Student Participation

Student participation was a class behaviour that required practice and effort from the instructor to coax student behaviour. During the first classes at the beginning of the semester, some students were reluctant to participate in the class discussions, and also they did not respond warmly to the questions that were posed at the start of lessons. As students got used to this style of teaching, they started to participate fully in the discussions and provide their views on the diverse topics included in the syllabus.

Before any group discussions, the instructor would introduce the topic and give the students all the necessary information about that topic in the form of a lecture. The motivation for this action was to ensure that the students have the necessary background information before they began the discussion. Not all students would participate equally in all case discussions. Participation was dependent on the familiarity of the topic being discussed. Easy and/or familiar topics resulted in lively class-wide discussions while the participation dropped for the more challenging topics.

Class Behaviour during Discussion: Diversity of Thought and Consensus

The nature of the topics influenced the range of answers received from the students. For challenging topics, the answers were diverse, and the instructor had to steer the discussions close to reasonable answers by providing more information and more prompt questions. With more familiar topics, the groups often reached a consensus quickly.

After each group presented their findings, the instructor would evaluate each group's answers. The instructor gave necessary prompts so that the students from different groups recognised links and similarities among their recommendations, as well as differences and contradictions. The instructor tried to guide the class toward consensus, but sometimes a consensus was not reached. In these cases, the instructor would offer additional reading resources.

Familiar topics that involved Malawian challenges worked best as far as participation and reaching a consensus as a class was concerned. Students would participate more if the topic was familiar to them and also if the case topic was in the Malawian context. Topics that dealt with global healthcare technology issues were not very familiar to the students, as a result the participation was not as great.

DISCUSSION

The study's goal was to investigate the impact of applying research-based best practices of case-based instruction and active learning in a healthcare technology management module in Malawi. This interaction was motivated to attempt the changes based on a collaboration with Rice360 and workshops that have taught instructors to apply these research-based best practices. The instructor staged the modifications to the module with the hopes of increasing student learning outcomes and student engagement in the module.

The addition of the case-based approach to this module was highly beneficial. Student final grades went up by seven points on average in 2021 when case-based instruction and active learning were introduced. Other variables between the modules in 2020 and 2021, such as indicative content, final examination difficulty and student preparation, were held constant and thus the authors can attribute this change in grades to the case-based instruction and active learning methods. The distribution of grades was marginally statistically significantly different, implying that the students in the treatment year were trending toward higher final module grades.

The students responded very well to the introduction of the case-based approach to teaching. Students particularly appreciated the discussion of the application of healthcare technology management strategies to Malawi and comparing and contrasting that with strategies in other countries. From the participation in the group discussions, class attendance, and the examination and coursework grades, the students did not only enjoy the class, but they also grasped the concepts of healthcare technology management well. Overall, apart from the teaching style used, this response from the students is also due to the nature of the module. Students deemed the content of the module very important to their careers especially in the 5th year as they are about to graduate and go into the health industry.

From a teaching standpoint, instituting these changes presented some pedagogical challenges. The biggest challenge with this teaching style was inadequate class time available to do thorough discussions after the lecture section of class periods. Typically, a lecture would take around half of the class, with the remaining shared between the case discussions and other active learning activities. With future classes the instructor feels that this balance of time can be adjusted for maximum impact.

This study's strengths include the application of this method of active learning in the context of Malawi, a low income country. Available research has failed to report on the use of such techniques in this context. Moreover, the use of a comparable control group allows for this study to be a naturalistic experiment with causal results as opposed to the correlational nature of most studies in the field. Lastly, the intervention itself was designed to include cases relevant to the context where the students would be doing professional practice in Malawi, making these findings highly impactful.

There are some limitations to the study, which should be noted. First, there were different instructors for the two instances of the module. Changing instructors for modules are common at MUBAS, so it is difficult to have a more controlled comparison. However, both final examinations, which was worth 70% of the grade, were reviewed by both internal and external evaluators and deemed to be rigorous. The practice of standardising final examinations and reviewing grades by the entire faculty minimises grade inflation based solely on easier assignments or lighter grading.

Second, the authors make a methodological assumption that final grades are indicative of student mastery of the material. Yet, grades based on tasks throughout the module rather than a singular examination have been found as sufficient evidence of student mastery over time [30].

The last limitation is the small sample size for the treatment group as well as the control group. This limited the statistical power of the chi-square test as this test is sensitive to sample size. As with other modules, class size is not a variable that is under faculty control, and this was a new module at the University.

Limitations notwithstanding, this study's findings contribute to the field of clinical engineering education research and particularly demonstrate techniques that can be used to improve learning and engagement in such classrooms. This article paves the way for future research on low-income course structures and the process of reflection and improvement.

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BIOGRAPHIES

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Matthew Wettergreen is Director of the Global Medical Innovation Master of Bioengineering programme and teaches engineering design and prototyping as an Associate Teaching Professor at the Oshman Engineering Design Kitchen at Rice University, USA. He is the co-author of the textbook *Introduction to Engineering Design*. At Rice, Wettergreen's curriculum design efforts have been recognised with both of the University's curriculum innovation awards. His professional interests are in methods of prototyping, supporting curriculum that builds capacity for student use of makerspaces, and he has co-created materials and delivered workshops to establish international engineering design programmes.

Ann Saterbak is Professor of the Practice in Biomedical Engineering and Director of the First-Year Engineering Program at Duke University, USA. Prior to Duke, she taught at Rice University, where she was on the faculty since 1999. Saterbak is the lead author of the textbooks, *Bioengineering Fundamentals* and *Introduction to Engineering Design*. At Rice and Duke, Saterbak's outstanding teaching has been recognised through five school- and university-wide teaching awards. For her contribution to education within biomedical engineering, she was elected Fellow in the BMES and the American Society of Engineering Education. She is the founding Editor-in-Chief of *Biomedical Engineering Education*.