PILOT STUDY FOR THE DESIGN OF A MOOC TO TRAIN BIOMEDICAL EQUIPMENT TECHNICIANS

IN LOW-/MIDDLE-INCOME COUNTRIES

A COMPARATIVE EVALUATION OF THE COURSE PERFORMANCE IN TERMS OF THE DELIVERY METHOD

DANIEL
GARCÍA DE LAS HERAS

TU Delft

PILOT STUDY FOR THE DESIGN OF A MOOC TO TRAIN BIOMEDICAL EQUIPMENT TECHNICIAN IN LOW-/MIDDLE-INCOME COUNTRIES

A COMPARATIVE EVALUATION OF THE COURSE PERFORMANCE IN TERMS OF THE DELIVERY METHOD

BY

DANIEL GARCÍA DE LAS HERAS

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF:

MASTER OF SCIENCE

IN **BIOMEDICAL ENGINEERING**

AT THE **DELFT UNIVERSITY OF TECHNOLOGY**

TO BE DEFENDED ONLINE ON WEDNESDAY, NOVEMBER 25, 2020

AT 10:00 AM.

SUPERVISORS	**PROF.DR. JENNY DANKELMAN** **DR. IR. ARJAN KNULST**
THESIS COMMITTEE	**PROF.DR.IR. JAAP HARLAAR** **DRS. LINETTE BOSSEN** **IR.ASHISH CHAUHAN**

TUDelft

i
Preface

With this report, I would like to present my master thesis, in partial fulfilment of the requirements for the degree of Master of Science in Biomedical Engineering, at the Delft University of Technology. As a Biomedical Engineer passionate about the design of medical devices and the improvement of the patient's health, this project not only reflected my vision, since it enclosed the design of a pilot study to train the Biomedical Equipment Technicians, and subsequently aid in reducing the large amounts of out-of-service medical equipment in LMIC; but it also presented itself as the optimal way to culminate my studies.

All in all, the completion of this project required approximately one year of work and dedication. It was a very nurturing experience involving theoretical research, the creation and running of a course, while working together with a variety of people from TU Delft, the Nick Simons Institute and experts in other LMIC. Hence, I would like to thank everyone who contributed to the realisation of this project; for the support, trust and help I have received through this process.

I would like to start by expressing my gratitude to the Delft University of Technology, for accepting my application on the M.Sc. in Biomedical Engineering, and to all the teachers, professors and lecturers who have participated in my education during the past two years. Specially, I would like to thank Prof. Dr. Jenny Dankelman, for entrusting me with this project, guiding me through it, and allowing me to work on it from my hometown Madrid, despite not being able to travel to the Netherlands due to COVID-19. Additionally, I cannot forget to mention Dr. Ir. Arjan Knulst, for all his dedication, willingness and the time he spent guiding me through the project, and helping me solve all the obstacles I found with along the way.

On another note, I would also like to acknowledge Roosmarijn Rutten, an essential contributor on the project, and with whom I had to the opportunity to collaborate in the design, setup and running of the pilot course. In addition, I also appreciate all the support and help provided by the TUDelft Online Learning team, in particular, to Naomi Wahls and Neil Wylie, for providing essential details and feedback during the creation of the course in edX.

It goes without saying that the pilot course would not have been possible without the involvement of our international collaborators, that validated the content and logistics of the pilot, prior to its release; as well as, the 119 participants who expressed their interested in participating on this study. More specifically, I am very grateful to Ir.Ashish Chauhan, from the Nick Simons Institute; and June Madete, from the Kenyatta University; for their implication in finding potential participants and distributing the surveys.

To conclude, I would like to praise my friends, who have been present during all or most of the realisation and development of this thesis, and from whom I have learnt patience, devotion and commitment. Finally, I must express my very profound gratitude to my parents, my brother and my grandparents, for providing me with unconditional support and unfailing encouragement throughout the project and the duration of my master studies.

D. G. DE LAS HERAS
MADRID, NOVEMBER 2020

ii

Abstract

OBJECTIVES In order to contribute to the research concerning the large quantities of out-of-service medical equipment in LMIC, this master thesis will focus on evaluating which combination of factors related to a MOOC's design, structure, logistics, content and delivery method; result in a better course performance, engagement and experience for the user; and consequently, how to translate these findings to the design of the future BMET MOOC to maximise its impact. Additionally, it will also evaluate whether the delivery of materials through interactive content could exhibit potential benefits for the students, directly reflected on the performance, by encouraging their involvement in the course and promoting active engagement.

METHODS A single blinded pilot study was created on edX Edge, in collaboration with local experts (NSI). It covered topics related to the Patient Monitor in four modules. To validate the hypothesis, the participants were allocated in two groups, related to the delivery method they were exposed to, after a stratified randomisation, balanced by two covariates. Following a Pre-test/Post test design, the performance was measured as the mean of difference between the grades on each test, across all candidates. The corresponding statistical analyses on the independent variables and covariates were performed. The content was validated by experts on the field; and the methodology behind the pilot was approved by the HREC of the Delft University of Technology.

RESULTS The differences in the delivery method, lead to a significant improvement in the performance of 11.9%, compared to regular content. The female students were more prone to this enhancement, as well as the African participants. Besides, these findings suggest that this new delivery method not only boosted the involvement in the course, and was able to take up part of the responsibility placed on the students in online education courses; but it also prevented the reduction in engagement.

The structure, and materials provided were sufficient and successful to teach the key concepts of this module. Moreover, there was no evidence found that suggested the need to segregate the future MOOC in difficulty levels based on the participants previous experience or location. However, since the main challenge faced by the students to finalise a MOOC, is to allocate sufficient time to work on it; it was recommended if the amount of work load per week could be reduced to 6 hours maximum.

CONCLUSION The overall analysis presented in this project concluded with a series of key factors, issues, and barriers related to the course's design, structure, logistics, content and delivery method. The study was not only fairly successful in reaching its targeted audience, but it also built a network of BMETs from diverse backgrounds, locations, and experience, interested in the pilot, and willing to collaborate in the versions to come.

On that account, the BMET MOOC presents itself as a great alternative to prevent the great amount of out-of-service medical equipment in LMICs, and these outcomes can be of great value in eventually transferring and implementing the complete curriculum to an online platform to train these professionals on how to properly use, maintain, and repair medical devices; and therefore, have a direct impact on the maintenance of medical equipment in these countries, to ensure a proper quality of the health care delivery.

KEYWORDS Biomedical Equipment Technician (BMET), MOOC, edX, Interactive Content, LMIC

iii
List of Abbreviations

A&P	Anatomy and Physiology
BME	Biomedical Engineer/Engineering
BMET	Biomedical Equipment Technician
ECG	Electrocardiogram
EM	Eastern Mediterranean
EU	Europe
FA	Final Assessment
HIC	High-Income Country
HREC	Human Research Ethics Committee
HTM	Health Technology Management
IKQ	Initial Knowledge Quiz
LATAM	Latin America
LMIC	Low/Middle-Income Countries
LMS	Learning Management System
MOOC	Massive Open Online Learning
NGO	Non-Governmental Organisation
NSI	Nick Simons Institute
PM	Patient Monitor
SEA	South-East Asia
TUDelft	Delft University of Technology
WHO	World Health Organisation

iv
Table of Contents

CHAPTER

1
Introduction

1.1. Problem Definition

Taking into consideration the recent advances in the field of healthcare technologies, the provision of effective and safe use of medical devices is considered a crucial aspect of any healthcare system in the world. However, reaching these standards is exceptionally hampered in low-/middle-income countries (LMIC), as they lack the proper resources, facilities and knowledge to operate such intricate devices. In certain areas of the South-East Asian region, it is estimated that almost 30% of medical equipment is out of service [1]. Meanwhile, according to the World Health Organisation, only in sub-Saharan Africa, 70% of the medical equipment stands idle [2].

Such variation reflects its dependency on the specific setting or location around the globe, making it unfeasible to accurately determine its health impact [3]. Furthermore, J. R. Roberts expressed his concerns with the large number of medical equipment donations arriving to LMIC with insufficient liaison, technical support and spare parts [4]. It is believed that these contributions intensify the problem, rather than solving it; since the lack of experience and training in these settings, makes the installation, operation and repair work more difficult. As a result, numerous medical devices are not even installed or maintained, and remain flawed for a long time.

On another note, Biomedical Equipment Technicians or BMETs, are the professionals responsible for the maintenance, repair, and troubleshooting of medical devices; to ensure its safety and adequate use for the diagnosis and treatment of patients [5-7]. However, the role of biomedical equipment technician is relatively new in LMICs; and in some cases, they are not properly trained. This produces a scarcity of technicians in this field, which is considered the primary cause of inoperable equipment, as it also means that fewer technicians are unavailable to train the medical staff on the proper use of the technology [5].

In response to this issue, various government agencies, NGOs, and private sector companies are trying to close this gap by developing training programs and workshops to provide technicians in LMIC with a basic understanding and skills for handling and repairing medical equipment in health care facilities in countries like India [1], Zambia [8], Rwanda [9], Nepal [10], and Uganda [11]. These trainings, with curated curriculums [12], provide a variety of educational opportunities for the learners, and include a certificate or diploma, to validate their qualifications upon its completion [13]. So much so that in recent years prestigious institutions like the Developing World Healthcare Technology Laboratory (DHTLab) at Duke University [9]; or the Engineering World Health (EWH), an American-based non-profit organisation, have joined this endeavour.

Even though the number of available academically oriented BMET programs is increasing in LMIC, the educational process via face-to-face learning is slow, and the volume of graduating trainees is not sufficient to overcome this issue. Besides, these training programs often face other obstacles, like the availability of an adequate number of qualified instructors to teach the courses, or the existence of proper infrastructure and materials to provide the students with the hands-on experience with medical devices.

Therefore, in order to further grow the number of quality trained BMETs in these settings, distance learning methods should be considered [4], like e-learning. The most common form of e-learning are "Massive Open Online Courses", also known as MOOCs [14-17]. These online courses aim at a large audience in an open manner, and are accessible at a reduced cost to anyone in the world with internet connection and a laptop or smartphone. On these platforms, the traditional learning methods, such as readings, videos and assessments are combined with engaging components and discussion forums to build a sense of community between the students and instructors. When approaching the Nick Simons Institute, a Nepal-based organisation that has offered a face-to-face course to train over 250 Biomedical Equipment Technicians since 2006; about their views on e-learning and the possibility to train BMETs in a more up-scale way, their response was optimistic and they really believed their training would benefit from such online course.

1.2. Research Contribution

1.2.1. Research Goal

In light of these events, a literature review was conducted in early 2020, under the title of "e-Learning potential for Biomedical Equipment Technician Training in Low-/Middle-Income Countries" [18]. The goal was to understand the advantages and capabilities of e-learning, its current adoption in LMIC, while determining the main aspects that could be learned from existing BMET courses and MOOCs in medical education; in order to elaborate a list of key considerations for the design of a BMET MOOC.

The findings indicated that, while there has been much research on the traditional education of BMETs, specially in LMIC [1, 5, 8-12], as well as, in the potential of e-learning and the creation of MOOCS [14-17, 19, 20]; few studies have taken into consideration the feasibility of transferring to a fully online platform this training discipline, which has always been taught in situ, as it requires skills and hands-on experience. Furthermore, some scepticism was found on the benefits of e-learning, as the bulk of the burden of learning is directly passed onto the student, since they are the ones accountable for deciding whether to gain exposure to the learning material and process it meticulously before completing the corresponding assignments/assessments, or if they opt for skipping them [17, 21, 22].

Therefore, in order to contribute to the research concerning the large quantities of out-of-service medical equipment in LMIC, this master thesis will focus on understanding which combination of factors related to a MOOC's design, structure, logistics, content and delivery method; result in a better course performance, engagement and experience for the user; and consequently, how to translate these findings to the design of the future BMET MOOC to maximise impact. Additionally, a portion of the project will evaluate whether the delivery of materials through interactive content could exhibit potential benefits for the students, by encouraging their involvement in the course and promoting active engagement; which could be directly reflected on the performance of the BMET online course.

For this purpose, a pilot study will be created in collaboration with experts in local settings, like the Nick Simons Institute, to fully understand the needs and requirements of these areas. The outcome from this project can be of great value in eventually transferring and implementing the complete curriculum to an online platform to train BMETs in low-/middle-income countries on how to properly use, maintain, and repair medical devices; and therefore, have a direct impact on the maintenance of medical equipment in these countries, to ensure a proper quality of the health care delivery [12].

1.2.2. Research Questions

Based on the research goal and the motivation behind the project, the subquestions supporting the main objective are presented bellow, divided in four main categories:

RQ ① PLATFORM

- What is the optimal platform to run the BMET MOOC?
  - What are the essential features that this platform should have, and be based on?

RQ ② COURSE CURRICULUM, STRUCTURE & LOGISTICS	• What topics should be included in the future curriculum? • Which device is preferred by the participants to access the course? • What is the optimal structure for each module? - How long should each module be in terms of workload? - Which is the most suitable duration for the forthcoming MOOC? • What is the desired guidance and flexibility that the future MOOC should offer?
RQ ③ COURSE CONTENT	• How does presenting the learning material through interactive activities and exercises, that increase the engagement with the online course content, compared to standard delivery methods (plain readings and figures); affect the performance in a BMET MOOC? - How is the performance related to the participants previous experience and demographic factors? - Will it be necessary to adapt the upcoming MOOC based on the results of the pilot? - Does the addition of activities imply a workload burden to the participants?
RQ ④ FEEDBACK FROM THE PARTICIPANTS	• What is the profile of the targeted audience? • What are the main challenges faced by the learners to finalised the course? • What other aspects can be learned from the students participation in the pilot? - What was the most valuable resource from the pilot? - What was the preferred problem type? - How was the design of the pilot (including user experience and user interface)?

1.3. Thesis Outline

To find the answer to these subquestions, and therefore, accomplish the aforementioned research goal; the content of the present master thesis is structured and divided into seven phases. Each one contains different chapters that individually contribute to the main objective of the project. The first five parts, comprise the main 10 chapters of the study; while the bibliography supporting the scholarly work can be found in the sixth part, before the appendices. Additionally, **Appendix A** includes a scientific paper written for this project. The article is a concept paper based on the main results regarding the interactive content. Therefore, it should be seen as a supplementary material, as it does not replace the overall thesis.

I ARCHITECTURAL & CONCEPTUAL CHOICES	**Chapter 2** serves as the theoretical framework of the thesis, and covers the main findings on the research questions of the Literature Study. The content is presented in a summarised manner, and only the topics that were considered relevant for the present project are enclosed. **Chapter 3** explains the process followed to select the optimal platform to design and run the BMET Pilot MOOC in. This section will further describe the app prototype that was designed as a first concept for the platform, and how, after its evaluation, it was decided to select edX as the most appropriate platform for the BMET MOOC. **Chapter 4** presents the Participation Survey that was distributed in June of 2020 to various professionals in the BMET field, to learn from their needs and perspectives, and apply such knowledge into the design of the MOOC. It also includes a detailed description of the goal, questions, platform and distribution channels that were used; as well as an evaluation of the results and responses.
II METHODS	**Chapter 5** focuses on the methods behind the pilot study. It covers the experimental setup and protocol that were followed, as well as the hypothesis, structure of the pilot course, group allocation, and data sources. There is also a section reporting the method of analysis, that describes the variables that will be later taken into account for the statistical analysis. Finally, the chapter concludes with the Ethics Approval Statement.

III BUILDING AND RUNNING THE BMET PILOT COURSE ON EDX EDGE

Chapter 6 sheds light on the main aspects behind the creation of the content for the pilot, as well as the validation process it underwent, prior to its release. It will cover the main differences between edX and Edge, the use of the edX studio, course logistics and grading system. Finally, the last two sections of the chapter will focus on the course material that was presented to the students, the interactive content, and the validation process it underwent, prior to its release

Chapter 7 describes the procedure that was followed to deliver the course to the participants, arguing the tools and channels that were used to do so. Additionally, it will also cover the steps of the enrolment on Edge, and the series of emails and reminders that were sent to the learners.

IV RESULTS

Chapter 8 includes a detailed overview of the outcomes from the BMET pilot MOOC. Not only does it evaluate the engagement and academic results from all the learners, but it also encloses the statistical analysis to determine which factors had an effect in the performance. Likewise, it will also cover the feedback given by the students in the Entrance and End-of-Course Surveys, as well as in the Non-Participation Survey, distributed to those who did not complete the pilot.

V EVALUATION

Chapter 9 will reflect upon the results obtained after the first run of the BMET Pilot MOOC, to determine its research contribution, and to introduce an overall discussion on the topics that consolidate this thesis project; as well as the recommendations for future research. Furthermore, the most significant research limitations and contributions will also be discussed.

Chapter 10 includes the main conclusions on the study, reflecting upon the research questions and the goal of the project.

PART I

ARCHITECTURAL AND CONCEPTUAL CHOICES

CHAPTER

2 Literature Review

In the beginning of 2020, a Literature Review was conducted with the goal of understanding the feasibility and capabilities of e-learning and the progress of its adoption in LMIC. This information was relevant for the future development and implementation of an e-learning platform to train Biomedical Equipment Technicians in low-/middle-income countries on how to properly use, maintain, and repair medical devices.

It was important for the project to collect as much detailed information on such broad research question, as no prior background research or similar project had been conducted at the Deft University of Technology, in the Netherlands. As a result, to understand the significance and rationale behind these project and to answer such a wide research question, it was essential to briefly study and understand the context behind it, by subdividing the topics in four blocks, as shown in **FIGURE 2.1**.

This chapter serves as the theoretical framework of the thesis, and covers the main findings on the aforementioned research questions of the Literature Study. The content is presented in a summarised manner. Only the topics that were considered relevant for the present project are enclosed. Nonetheless, for a detailed description, the literature study may be consulted at: D. García de las Heras "e-Learning potential for Biomedical Equipment Technician Training in Low-/Middle-Income Countries" [18].

BLOCK 1

LMIC AND HTM
- What is considered a LMIC?
- What is the importance of a solid Health Technology Management System?
- How can BMETs fit within a HTM?
- What are the main challenges when establishing HTM in LMIC?

BLOCK 2

BASICS OF E-LEARNING
- What is E-Learning?
- What are the differences between e-learning, distant learning and online learning?
- Which are the advantages and possible limitations faced by the proposed solution?

BLOCK 3

E-LEARNING IN LMIC
- What can be learned from existing MOOCs in the health sector in LMIC?
- Are there already existing online courses for BMET?
- What are the most common platforms? What are the main inconveniences reported by these studies?

BLOCK 4

NEPAL: HEALTH AND E-LEARNING
- What are the HTM and Health Policies in Nepal?
- What are the cultural factors behind the Nepalese education system?
- How is their position towards the adoption of e-learning? Are there sufficient infrastructures?

FIGURE 2.1. SUBDIVISION OF THE MAIN RESEARCH QUESTION OF THE LITERATURE STUDY

2.1. Main findings from the Literature Review

The literature study was designed based on the principles of semi-systematic or narrative review, with a detailed search query and inclusion/exclusion criteria, to understand all the possibilities of online learning tools in the LMIC, while focusing in a deeper manner in analysing the background of Nepal. The breakdown of the selected literature and sources that contributed to the final report, is depicted in FIGURE 2.2. Since the chosen methodology was not the one of a systematic review, the flowchart is not a PRISMA [23] diagram. Instead, FIGURE 2.2 follows the RAMESES [24] guidelines for semi-systematic review.

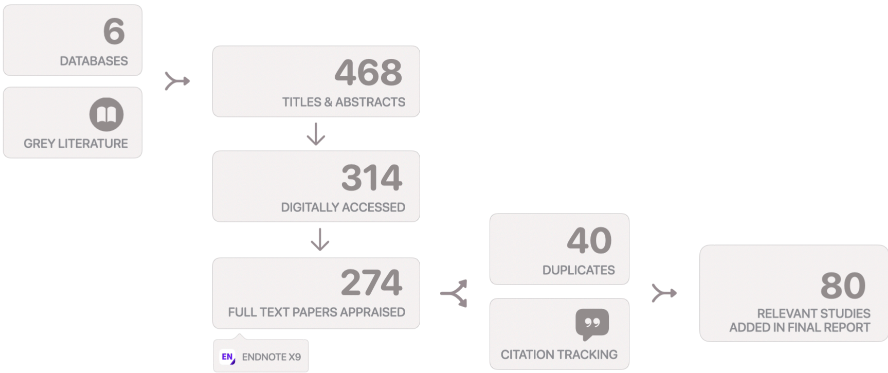

FIGURE 2.2. LITERATURE SELECTION PROCEDURE FOLLOWING THE RAMESES GUIDELINES

Before diving into the main findings, it was necessary to define one the main terms of the study: what are "Low-/Middle-Income Countries"? Annually, the United Nations publishes a report analysing the global economies called "The World Economic Situation and Prospects" (WESP) [25]. This report also reveals that the level of development of a country can be measured by other factors beside the standard categories—developed economies, economies in transition and developing economies—but rather the per capita gross national income (GNI).

In other words, countries can be classified as: high-income, upper-/middle-income, lower-/middle-income and low-income. On top of that, in order to keep a unified classification system, and to maintain certain compatibility within relatable groupings, the World Data Bank [26] created threshold standards of the GNI per country for each category. As a result, for the purpose of the present study, from now onwards, the term "Low-/Middle-Income Countries" will refer to those countries with per Capita gross national income of less than $3,995. This classification will include nations whose presence will be recurrent in the study like Nepal, Kenya and other countries in the African and South-East Asian region.

HTM AND CHALLENGES IN LMIC

Effective and efficient technical management of medical devices remains a concern in most LMIC, despite the existence of dedicated responsible units at the national level [2]. As a consequence, one of the major causes of insufficient levels of medical devices in LMIC is the lack of a proper Health Technology Management System (HTM) in their hospitals. Such need that was recognised by the World Health Organisation (WHO) in their 2017 publication: "Global Atlas of Medical Devices".

Furthermore, in the same report, HTM was defined as "*an area of biomedical engineering, comprises the domains of planning, needs assessment, selection, procurement, donations, inventory, installation and maintenance of medical equipment, training for safe use and finally decommissioning*" [2]. Thus, the next generations of trained professionals should be experts on this discipline, and that is why the curriculum of BMET training should include the main topics in HTM [27, 28].

On the other hand, there has been several challenges reported in the literature when trying to implement a HTM systems in LMIC. The most prominent, is the absence of existing standards and policies within the healthcare sector. Experts advice it is imperative to create a HTM team with biomedical engineers and technicians, experts on the matter, to guarantee a successful adoption [29].

Another drawback regarding the medical devices, is the lack of oversight and proper infrastructure framework, like internet access, that makes almost impossible to keep an up-to-date record on the status of the medical equipment. Besides, in some cases, even the engagement of international donors can pose some challenges, as the healthcare systems in LMIC are efficient in the resources and knowledge on how to operate such high-advanced instruments.

In 2014, the World Health Organisation stated: "*trained and qualified biomedical engineering professionals are required to design, evaluate, regulate, maintain and manage medical devices, and train on their safe use in health systems around the world*" [28]. However, the field of Biomedical equipment technology is relatively new in most of the LMICs. Even in developed countries, these experts on the medical field, have had to fight their way through the hospital, posing as a severe obstacle to the adoption of HTM practice .

Lastly, the existence of centralised systems is the crucial barrier to allow the implementation of HTM systems that allow changes from the lowest level. As it was described by E. Worm et al. [29], the education of the technicians is considered a bottom up approach. Therefore, the key for a successful implementation of HTM activities would be to follow a top down enforcement. For example, advertising organised HTM workshops by the competent authorities in the country to spread awareness on the correct practices.

E-LEARNING AND ONLINE COURSES IN MEDICAL EDUCATION

With the current challenges of implementing HTM systems in LMIC in mind, it is relevant to mention the most prominent handicap to conduct proper face-to-face BMET training in these settings, and that is the lack of proper infrastructures, including deficient number of lecture halls, facilities, classrooms and even instructors. To revert this situation will require a substantial investment, which in many LMIC, is not possible. Fortunately, e-learning holds the key to rapidly scale up the training and educating processes, without the need for simultaneous resource-intensive infrastructure upscaling. e-Learning can be defined as any teaching method that is based and distributed through the internet, or any other online platform [30].

From the point of view of lecturers, online courses pose several advantages over face-to-face learning, the main one being the reduction in the cost related to the academic infrastructures. This is followed by the easiness to create content and update the material. Additionally, the use of MOOCs breaks down the existing geographical and temporal barriers that limit the access to education; while providing improved access to relevant experts and novel curricula for the students [19, 20]. Unfortunately, these improvements come with a technological and pedagogical affordance for the instructors. Likewise, providing formative, timely, and individualised feedback to each participant has also been identified as a time-consuming challenge.

In a similar way, students also benefit from online courses, as this technology allows for personalised learning, based on the progress of each student. It also provides a ubiquitous learning through mobile learning and cloud learning environments, which can be combined with immersive learning experiences, through augmented reality and 3D learning platforms. However, it can sometimes be more time-consuming, and with the lack of student-teacher interaction, tutor support is more difficult and the students can develop feelings of isolation [19, 20].

On another note, when taking a closer look at several e-learning courses designed for medical education in LMIC [31-45], there were several common factors that could be highlighted. To start with, is the device used to access the MOOCs. Although some courses provided the students with the device, the most common option was to use their own; which they mainly were either laptops or smartphones. As for the platform used to host the course, there was not a general agreement on the matter; some studies used well-known MOOC platforms—like Moodle, YouTube or edX—, while others opted to design their own app or website for the course.

Regarding the lecture materials, they were presented in different formats, the most common one being PPT, videos and reading units. Besides, in 2012 the Duke University created an open-source biomedical equipment library to keep a record of the new instruments being introduced, and to provide reference texts and manuals to biomedical technicians in LMICs [46]. This repository, introduced an important feature for MOOCs in LMICS: the option to download the materials and make them available offline. As these countries suffer for low-stability internet connection, this feature assurers that every participant is able to follow the course, even if the device cannot connect or find a local network.

As it can be seen from these studies, their intention was towards the education of healthcare workers. Even though their results can be extrapolated as useful design criteria for the development of a BMET MOOC, it can be concluded that the Literature Study did not yield many results on e-learning courses designed specifically for the training of Biomedical Equipment Technicians. In particular, only three MOOCs were found that served this purpose. The first one was designed for Medical Aid International, a healthcare solution provider for low resource settings, with the aim of providing the right equipment for LMICs. However, since the course was launched in February 2020, there was not literature available on its performance [47].

The second one, called "E-learning education in Management of Biomedical Technology", was an asynchronous course developed in Greece [48]. It used Moodle as the delivery platform, although it was not fully online, but based on blended learning. Notwithstanding, not further literature was found on the adoption, results or evaluation on the course. Lastly, the International Federation for Medical and Biological Engineering (IFMBE) developed in 2015 a project proposal named "Electronic courses for developing countries" [49], whose goal was to train Clinical Engineers and Biomedical Equipment Technicians working in on three African countries (Gambia, Zambia and Mozambique) on the activities concerning medical equipment maintenance and management, with the help a virtual resources for the lectures. The delivery method was reserved for web-based content filled with text, figures and charts, explained through video or audio files. The overall course, currently being distributed at low price, aims to extend and implement the training courses to other LMICs, with the help of distant and local stakeholders.

NEPAL: BMET TRAINING & E-LEARNING

Nepal is a small land locked Himalayan kingdom, with a total surface area of 147,181 km^2, located in the South-East Asia region. This country was selected as the reference LMIC since the Nick Simmons Institute (NSI) is a partner in this project. This Nepal-based organisation has offered a face-to-face course to train over 250 Biomedical Equipment Technicians since 2006 [50], and the testimony and experience of their instructors was of great value for developing this project. When asked about their views on e-learning and the possibility to train BMETs in a more up-scale way, their response was positive and they really believe their training would benefit from a MOOC.

Although the country has been working on a solid HTM system [51], and despited the efforts of the NSI, one of its main weaknesses is the shortage of professionals in the BMET field. When analysing the latest report from the World Health Organisation, regarding the global workforce of biomedical engineers and technicians, there are no clear statistics of the current number of biomedical equipment technicians or biomedical engineers present in the country [6]. This shows there is an important insufficiency within this field while the efforts should focus on training new professionals to cover the vacancies.

Under those circumstances, it was essential to understand the educational culture in Nepal and their position towards the adoption of e-learning. Nepal has had its educational fundaments in face-to-face tutoring. This ancient practice has a long history that traces the contemporary education back to the Gurukul culture [52]. Notwithstanding, the high altitude terrain and irregular topography poses as the main difficulty for accessing face-to-face education. On top of that, students living in a rural areas cannot afford to education in a city areas.

Owing to this reasons, e-Learning seems to be the optimal tailored solution to the Nepalese lack of teaching facilities and educators. Furthermore, the population took a special interest in Massive Open Online Courses, since those students with an internet connection could easily access and tap into numerous global educational opportunities offered by various universities, using MOOC as the delivery platform. So much so, that two of the main universities in the country—the Kathmandu University and Tribhuvan University of Nepal—begun to offer MOOC courses for their students [53].

2.2. Conclusions

This literature study can conclude that there is a shortage of properly trained and qualified biomedical equipment technicians in the developing world, as reported by the WHO [6]. However, such dearth of BMETs is accentuated in LMIC, where the access to proper face-to-face education is limited. On the other hand, e-learning has proven to have several advantages over traditional education methods, as low-cost or better reachability, which can aid the education of BMETs in developing settings.

The results of this review showed the potential benefits of e-learning, despite its need for an existing internet infrastructure in LMICs. In addition, while there were many studies found on exiting online courses for educating healthcare workers, not many focused on the training of BMETs. This review also further critically analyses current e-learning courses in medical education to understand the platforms used, devices, and what were outcomes of these MOOCs.

As it was expressed by S. Frehywot [54]: "e-*learning in medical education is a means to an end, rather than the end in itself. Utilising e-learning can result in greater educational opportunities for students while simultaneously enhancing faculty effectiveness and efficiency. However, this potential of e-learning assumes a certain level of institutional readiness in human and infrastructural resources that is not always present in LMIC*". This can be translated to the need of fully understanding the current situation of Nepal and all the possible challenges that could be faced when adopting e-learning.

That is why a deeper analysis of the situation of the country was performed in the review. It included a study of the status regarding Health and HTM in the country, the institutions and policies that govern healthcare, as well as what are the needs and resources available in the region.Likewise, other authors have claimed that e-learning is the most efficient and effective way to bring international knowledge, research and expertises to LMICs [55]. Therefore, understanding what constitutes successful e-learning is an important first step for determining its effectiveness.

As a result, a series of key recommendations were elaborated based on these findings, which should be considered when designing the full version of the BMET MOOC. They are explained below.

① **OFFLINE MODE** — Even though the main idea of a MOOC is that the course is held on an online platform, it is important to keep in mind the geographical, economical or natural factors that might affect the access to the e-online platform, like the lack of electricity supply, the cost of the Internet connectivity, or the 16-18 hour blackout occurring during in dry seasons in countries in the South-East Asian region [45]. That is why the option to download the material or make it available without an internet connection should be present.

② **MOBILE FRIENDLY** — Research showed that in medical education, the most common device to access online courses was a computer, either laptop or desktop [52]. However, as the participants of the BMET MOOC would be from LMIC, there is a chance that not everyone interested in the course might have one of these devices, but only a smartphone. Thus, the selected platform should allow the participants to follow the course and interact with the material/exercises on the screen of smaller devices like mobile phones.

③ **VALID CERTIFICATION** — Participants will only follow the course if they are rewarded with a valid certification from a valid and trusted source once they have completed and passed the full version of the MOOC; which will allow them to have a career in this field.

④ **INTERACTIVE CONTENT** — As the training of Biomedical Equipment Technicians require the acquisition of practical skills and capabilities with medical devices, it is important that the selected platform and course allows for the creation of interactive content and the optional integration with a Simulation Tool.

⑤ **SELF-PACE COURSE OPTION** — The NSI reported that most of the students enrolled in their face-to-face BMET Training are working or studying while attending the course. In other words, their availability is limited. The BMET MOOC should have into account the needs of the participants, and offer the option to complete the course with a self-pace option, rather than having tight schedules and deadlines.

⑥ **NO DATE RESTRICTIONS** — Once the participants have completed and finalised the course, it will be of great value to them if they keep having access to the content and materials for future reference during their career as a BMET.

⑦ **NOTIFY THE LATEST UPDATES** — Going back to the drawbacks reported by the NSI, the course should have enough flexibility to adapt the content based on the current trends and medical devices being introduced to the market.

⑧ **FORUM** — Aside from studying only what is presented in the course content, it is important that the course offers the participants a space to introduce themselves and interact with other students around the globe. This is not only recommended for creating a feeling of community within the course, but also so that perhaps they can learn and help each other throughout the MOOC.

All in all, it can be concluded that the transition from traditional teaching methods, towards the adoption and implementation of e-learning as a viable teaching and learning strategy technologies, has begun in Nepal and other LMICs. Regardless, there are still some existing challenges that have to be faced.

CHAPTER

3
BMET MOOC Platform Selection

This chapter covers the process followed to select the optimal platform to design and run the BMET Pilot MOOC in. The conclusions from the Literature Study proposed in the previous chapter, served as the basis for this section, and they will be used as the design criteria to evaluate each of the different solutions. This section describes the app prototype that was designed as a first concept for the platform, and how, after its evaluation, it was decided to select edX as the most appropriate platform for the BMET MOOC.

3.1. Mobile App Prototype

Initially, as a first concept, it was decided to design and create a tailored platform from scratch, based on needs of the BMET MOOC and the design considerations included in the previous chapter; instead of trying to find an existing platform that matched all of the requirements. At this point, there were two main questions: "which type of device would be the best to design the platform for? Laptop or smartphone?"; and "what type of platform? Application or website?".

To make the most appropriate choice, it was substantial to analyse the current market situation and prospects. The year 2010 is considered the moment when the revolution of touchscreen smartphones occurred. Since then, the sales of these devices have increased from 139 million units in 2008, to 1.56 billion units, only in 2018 [56]. Nowadays, the total number of smartphone users exceeds three billion, surpassing the number of laptop owners [57]. Besides, it is predicted that this number will to grow exponentially in the proximate years. The companies leading the marker of smartphone sales are Samsung, Apple, and Huawei.

Taking all of this into account, the optimal supporting platform device for the MOOC would be a smartphone, rather than a laptop, so that a lager audience could be reached, specially in LMIC. Regarding the question about the proper type of platform, it was decided to design a mobile app, rather than a website. The reason behind this choice is that the latest, would not support the features presented in the previous chapter regarding the offline option to access the material; while the app would allow the downloading of course content to make it abatable when there is no internet connection and keep it organised.

APP PROTOTYPING SOFTWARE

Something that had to be taken into account, is that different smartphone companies work on different operating systems. Android, from Google, is estimated to have around 74.6% marketshare of the smartphones worldwide, while Apple and its software, iOS, accounts for 24.8% [57] . This leads to different requirements that the app developers have to follow in order to include their apps in the corresponding stores: Google Play and App Store.

Taking all of the above into consideration, for the purpose of this study, it was decided that at the current stage, it would be more revealing to quickly prototype and asses the functionality/limitations of the app, rather than diving into the coding and User Interface (UI) requirements. As a result, the software **Framer X** for MacOS was used [58]. It allowed the creation of a rapid prototype of the full app, so that the main ideas behind the MOOC could be tested. Without the need of coding skills, but rather the easily creation of components that could be linked to each other, the software produced a blueprint of a real app, which could later be tested on a smartphone.

DESIGN OF THE APP PROTOTYPE

The considerations proposed in the Literature Study served as the design criteria and main requirement that were followed when designing the app in FramerX. The navigation of the MOOC within the app was divided in four different sections—as shown in **Figure 3.1**— for a simple and easy-to-use User Interface (UI); and optimal User Experience (UX).

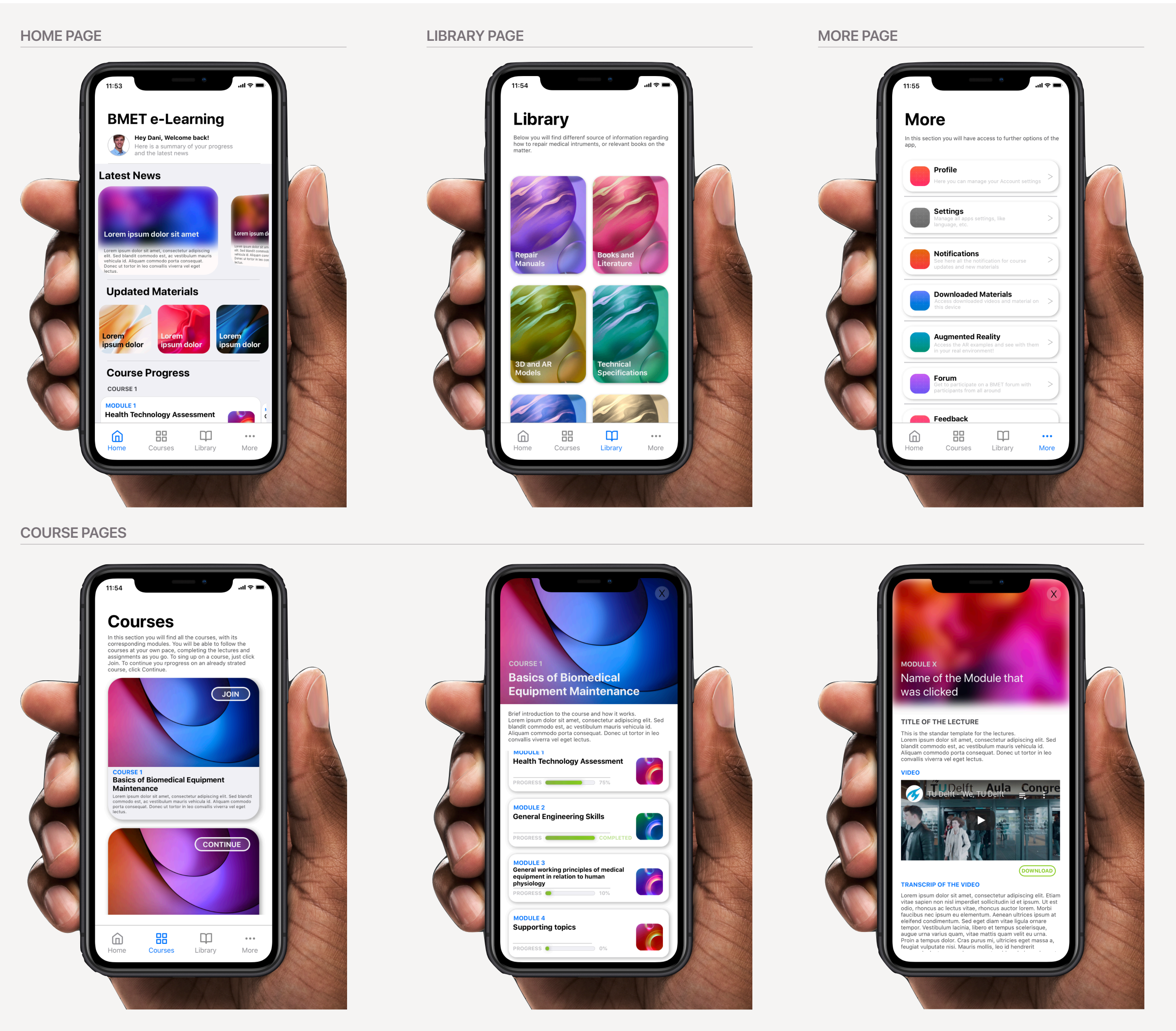

FIGURE 3.1. DIFFERENT SCREENS FOR THE APP PROTOTYPE DESIGNED WITH FRAMER X

① HOME PAGE	It features an overview page of the overall BMET MOOC, including a summary of progress in the different courses, while presenting the user with the latest news in the field, as well as the newest content or materials that have been updated.
② COURSES PAGE	The courses tab introduces the learner to the different modules in the curriculum of the MOOC. It was designed in a visual manner, so that the progress from each unit or module was easily seen at a glance. Furthermore, the lectures were structured with reading materials, videos and activities, to make the experience more interactive and engaging for the participants. Having the MOOC built on an app, would allow the participants to access the relevant content or lectures they had previously bookmarked on their smartphones anywhere they are.
③ LIBRARY PAGE	For a continuous learning and future reference, the library page was created. It would be a place that collected different repair manuals, books and literature on the BMET field, technical specifications for easy access when required, during the training or professional career. Taking advantages of the on-device technology, like Augmented Reality (AR) software present in smartphones; the library would also include various 3D models of medical devices that the participants could interact with and explore through their phone, as a simulation and skill testing tool.
④ MORE PAGE	Lastly, several other elements of the app were collected in a page called "More". Some of these features include: a Notification Center, to tailor the communication of the latest news to each of the participant's preferences; a section were all the downloaded materials from the lectures would be collected in a organised manner for easier access; and a Discussion Forum to create a community with the participants, so that they could learn from each other, and avoid the potential feeling of isolation when completing the MOOC

EVALUATION OF THE APP PROTOTYPE

Overall, the prototype of the app created with the software **FRAMER X** for MacOS [58] provided a very good understanding of all the possibilities that were open if the MOOC was to be finalised and fully created on a mobile app. Although the full design would be time-consuming, and require a software developer team to code all the content; the final result would be a self-paced BMET MOOC hosted on a mobile friendly platform. It would adapt to the needs of LMIC and those places with shortage of internet connection, as it offers the option to download the course materials. Additionally it benefits from the hardware and software of smartphones to support on-device simulation tools—like AR—and encourages the learner to interact with the materials, as well as with other participants, through the discussion forum.

On the other hand, despite these benefits, it is also critical to consider and analyse its potential weaknesses. Based on the considerations of the literature study, what can be concluded about the certification of BMETs that complete the MOOC on the mobile app? J. Wea et al. [13] reported the importance of a consolidated form of certification for biomedical equipment technicians and clinical engineers as these professionals find themselves working in both developed and developing countries. Such certificate is the proof that its holder has completed a training and possesses minimum level of qualifications to operate on the field. Thus, the issuing organisation should be a trusted source, so that the title can be accepted globally.

As a result, since it would be more difficult to provide the self-created app with sufficient credentials to be valid/accepted in most LMIC, it was decided to continue scouting for other potential, already-consolidated, trust-worthy platforms, which could host, in some sort of way, all the features presented in the app, which are required for an optimal online BMET training experience.

3.2. edX Online Platform

Throughout the search of an alternate delivery platform to the mobile app, it was decided to take a closer look at the Delft University of Technology (TUDelft) and is commitment to OpenCourseWare. The goal behind OpenCourseWare is to offer free access to online course content globally, by benefiting from the potential of the internet to surpass geographical and economical barriers [59]. In 2012, TUDelft joined the program and, a year later, launched its first two MOOCs [60, 61].

To deliver the MOOCs, TUDelft decided to partner with a well-known academic MOOC platform: edX. This trusted, non-profit platform for education and learning was founded by the Massachusetts Institute of Technology (MIT) and Harvard University in 2012. Its mission of expanding the access to high-quality education for everyone, everywhere, while enhancing the teaching and learning experiences through research [62]; matched with the principles of TUDelft and its work with OpenCourseWare.

As a result, from all of these initiatives, TUDelft decided to create a new division within its faculties to support the endeavour of expanding to online learning and education. The TUDelft Extension School was born with the objective of supporting the academic teaching staff in the creation and design of MOOCs in edX. The Extension School team was formed from different professionals, including e-learning developers, video production support, copyright support, and even marketeers [61].

Since then, it is estimated that the numbers of online learners who have benefited from TUDelft online learning has surpassed 2.5 million participants worldwide. This was achieved by creating an eye-catching varied proposal of over 100 MOOCs, in collaboration with all the different faculties in the university. The topics of the courses range from engineering, to science and even design [61]. An overview of the university's catalog can be seen in FIGURE 3.2.

Furthermore, apart from offering MOOCs, the university's online learning catalog also includes a total of 25 academic courses, which could be translated to online versions of campus master lectures, with the equivalent academic rigour, study load, and assessment. On top of that, TUDelft has recently begun to offer a collection of courses specifically designed for working professionals. The central point of these courses lies in the practical knowledge and skills that should be required by professionals in their day to day work. It is relevant to mention that, upon its completion, the participants receive an official certificate that specifies the study load and converts it to Continuing Education Credits (CEU's).

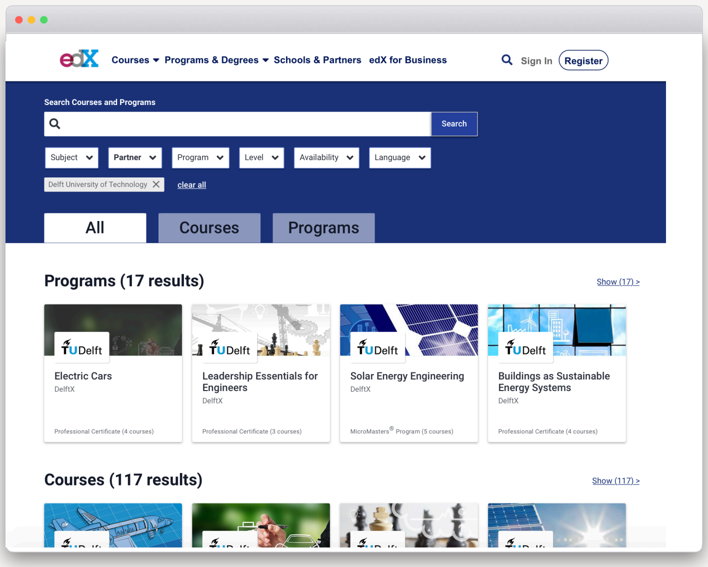

FIGURE 3.2. OVERVIEW PAGE OF THE TUDELFT CATALOG IN EDX

In summary, as a full overview of the online learning catalog, at the time of writing TU Delft has created a total of 25 online academic courses and 44 professional education courses; taught by 260 dedicated instructors. For the creation of these courses, the Extension School has been following a bottom-up approach because to publish a course on edX, one must have an agreement with the platform and specific approval from the corresponding institution. In other words, any TUDelft faculty lecturer can submit to the Extension School an application to be awarded with a financial grant and support form the team. For this reason, in February of 2020, professor Jenny Dankelman applied for the aforementioned grant, which was conceded in April 2020.

BUILDING THE COURSE IN EDX

In light of these events, a closer look was taken at edX, to analyse its possibilities and weaknesses as a potential platform to develop the full BMET MOOC in. The goal of edX is to connect, engage and inspire learners around the world, with a collection of over 2500 Online Courses from 140 global Institutions. Thus, to further dive in into its infrastructure, it was substantial to experience edX through the point of view of a learner, so as to gather the main impressions and understand its limitations.

That is why two basic courses were completed: "*edX101: Overview of Creating an edX Course*" [63] and "*StudioX: Creating a Course with edX Studio*" [64]. They helped get a big picture on how the platform works, what does it offer to the learners and how to create a course on it. One of the main ideas that has to be remarked is the subdivision of the platform into two ecosystems: **EDX** and **EDGE**. Although both sites are visually and functionally equivalent, their content and purposes are contrasting.

On the one hand, **EDX** hosts most of the public MOOCs from edX institutional partners. Therefore any course published there, would be publicly listed to the general public and anyone can enrol and complete it. While **EDGE** is considered a more private site, that offers the possibility to create courses in a low-visible environment, as they will not be published on edx.org. The main difference is that Edge does not have a public catalog, and the MOOCs cannot be found through search engines such as Google. In order to access and participate in such courses, the learner must receive a specific invitation from the course management team with the URL to enrol [65].

Despite these differences, the design process to built courses for either site, remains the same. The course has to be first built in the Studio, a parallel software that manages the creation of content and the set up and functionality of the activities, assessment and grading. Once the material is ready, it can be published and the different units become visible to all or part of the participant (depending on the set preferences). This feature allows for modifications to the content while the course is running.

When it comes to the main features of either platform, the basis of the learning process is sustained in the way the material is presented to the learners. The navigation between the various units is illustrated at the top of the screen in what is called: "the Learning Sequence". It is said that learning sequences replace in-classroom lectures in edX courses, as such interactive experience would allow the learner to receive immediate feedback on their progress [63].

The platform also supports the reproduction of videos within the units, with the option to include a transcript along side the video player. Besides, edX offers the lecturers a wide range of problem types to choose, from simpler to increasing complexity to the learner. Its use along the course is recommended to check understanding, to introduce new concepts, or to provide applications of what the learner just viewed. Finally, it is even possible to insert multiple discussion topics throughout the course, so that learners can discuss the material with others.

When it comes to the rest of the important features that were introduced in Chapter 2, they can also be somewhat adapted to edX, as it also offers the participants the possibility to access the courses on their mobile phone, through an app designed for both, Android and iOS. Besides, the platform gives the lectures the flexibility to tailor the rhythm of the course to their need, as well as the open and closing dates of the MOOC.

All in all, this chapter can conclude that, even though the mobile app offered a great deal of freedom and facilities for the design of the MOOC; it also revealed some weaknesses when it came to assessing the certification of the MOOC. That is why other alternatives with more credibility and authenticity were studied. edX, with the integration of the TUDelft Extension School, not only accepted the proposal to create a MOOC for BMETs in LMIC collaboratively, but also offered round-the-clock support during the design process. For these reasons, and after having received the confirmation of the financial grant from their side; edX was finally selected as the desired platform to continue with the project.

CHAPTER

4
Participation Survey

After having selected edX as the optimal platform to continue with the project, the next step was to conduct a deeper analysis of the current situation of Biomedical Equipment Technicians in various LMIC. This chapter presents a short Participation survey that was distributed in June of 2020 to various professionals in the BMET field, to learn from their needs and perspectives, and apply such knowledge into the design of the MOOC. It also includes a detailed description of the goal, questions, platform and distribution channels that were used; as well as an evaluation of the results and responses.

4.1. Goal of the Participation Survey

At this point, it had become clear that before creating and running the full BMET MOOC on edX, it would be of great value to run a short pilot first. It would allow to test and evaluate a simulated portion of the overall course, to learn which parts of the curriculum, structure and platform worked best for the students, and which sections need further refinements and improvements, before distributing the MOOC publicly to BMETs around the globe.

In order to do so, it was necessary to have a clear picture of the situation of potential participants, so that the content and format of the MOOC could be adapted accordingly. Even though the Literature Study, introduced in Chapter 2, already presented some requirements, with Nepal as the main LMIC; now that edX was selected as the distribution platform, it was essential to gather information from other BMETs, as the MOOC would be offer globally. Literature showed that there had been other studies that conducted surveys on the same field [66]. Still, for the purpose of the present study, it was decided to conduct our own, as it had to fulfil the following goals:

① DEFINE MOOC REQUIREMENTS	As previously mentioned, the main goal would be to reach not only experienced BMETs, but also students interested in the field, to learn from their perspective, insights and needs to design a Pilot Course that best fits to them. The objective would be to collect enough inputs from different countries to obtain a detailed picture from most LMIC.
② RECRUIT PARTICIPANTS	The second purpose of the participation survey would be to take advantage of its reach and already build a network of BMET professionals who would be interested in participating in the Pilot MOOC and give their feedback from the point of view of their experience once they had complete it, by collecting their email/contact at the end of the survey.

4.2. Materials and Methods

PLATFORM FOR THE PARTICIPATION SURVEY

As the Participation Survey was distributed before the Extension School granted the access to edX, other platforms hard to be assessed to create the survey in. There were a series of features that the potential surveying platform had to fulfil. Firstly, it was required that the platform had to be online for easier distribution, and the answers from different participants had to be properly collected and differentiated from the rest of questions. Additionally, it was important that the responses could be exported to a cvs file (or any other spreadsheet format) for the later analysis; as well as having the option to collect email addresses for those participants interested in completing the pilot. Lastly, most preferably, it should be free of cost.

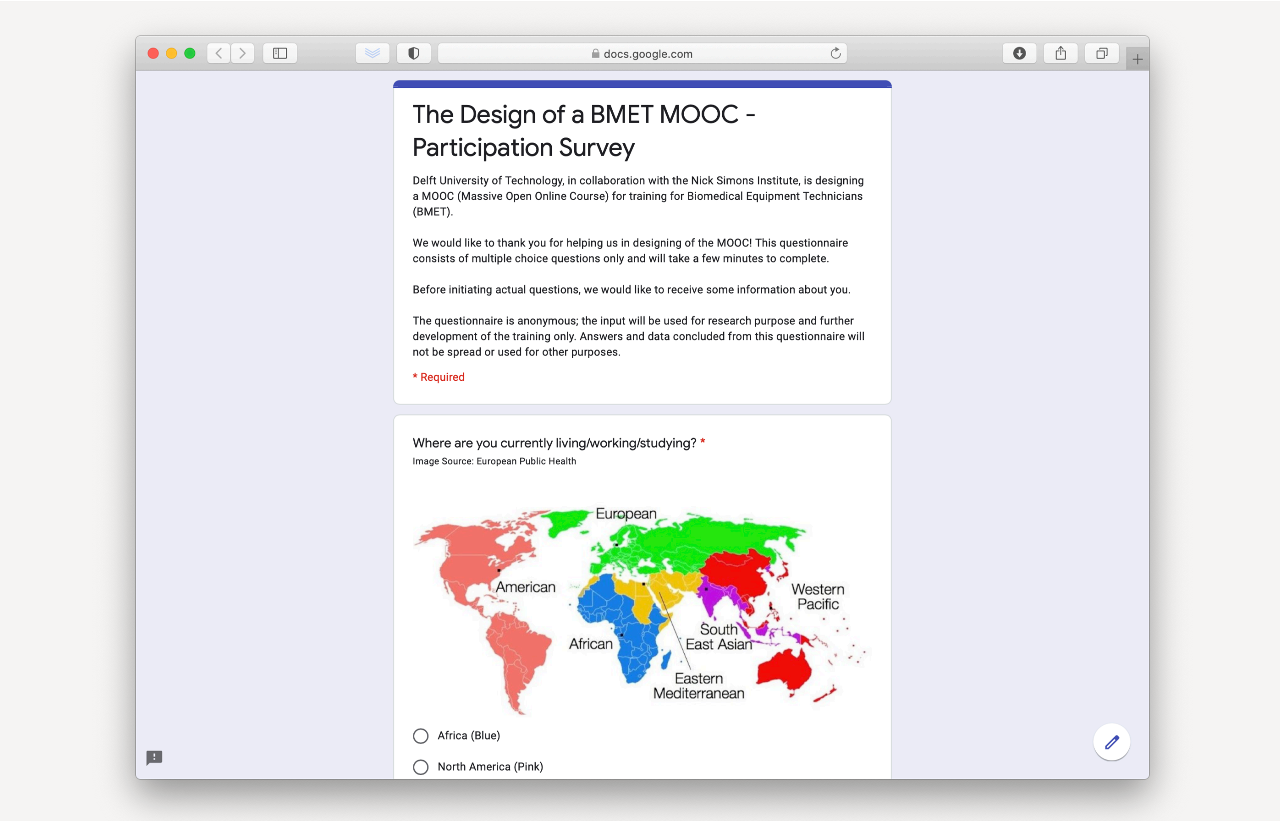

FIGURE 4.1. MAIN SCREEN OF THE PARTICIPATION SURVEY HOSTED IN GOOGLE FORMS

Eventually, Google Forms, the free online surveys platform from Google [67], was selected to host the Participation Survey, as it fulfilled all the specifications mentioned above. For visualisation, a screenshot of the main page of the Participation Survey is included in FIGURE 4.1. Nonetheless, the full survey can be accessed through the link: https://forms.gle/RXKnuJJRfz1CBPVU6

QUESTIONS

It is important to remark that the survey included a privacy notice at the beginning, stating that the completion was voluntary and no identifying information would be collected. Overall, the Participation Survey included a total of 10 questions, which were grouped in 3 categories, as described in TABLE 4.1.

TABLE 4.1. CLASSIFICATION OF THE QUESTIONS IN THE PARTICIPATION SURVEY

PARTICIPANT INFORMATION	MOOC INFORMATION	PILOT INFORMATION
3 QUEST.	4 QUEST.	2+1 QUEST.
To collect information about their location, experience in BMET Field and previous Training	Focusing on the Device that they would use, available time, desired duration and internet reliability	Specified on the desired duration of the pilot, interest in participation and emails for those interested

DISTRIBUTION CHANNELS

As of June 24TH 2020, the process of creating the Participation Survey in Google Forms was finalised, and it was ready to be distributed, with the objective of reaching as many participants as possible. Initially, since the Nick Simons Institute was a partner on the project, it was decided to approach them, and benefit from their already-established network of experienced BMETs and students, and use it as the distribution channel.

However, it was later realised that having the NSI as the only distribution channel would prevent reaching a wider and global audience. In the end, it was decided to scout other channels, to increase the chances of obtaining responses from a varied group of people. On the whole, the three distribution channels that were used for the participation survey are presented below:

① SOUTH-EAST ASIA

Ashish Chauhan, a BMET Instructor at the Nick Simons Institute, in Nepal, offered his help to circulate the online survey within his contacts. He did not only reached his current students, but he was also able to approach his former trainees and other personalities in the BMET field. The distribution from his side begun the 26TH of June 2020.

② AFRICA

Prof. Jenny Dankelman invited June Madete to be a collaborator in the MOOC. She is a Biomedical Engineering Lecturer in the Kenyatta University, in Kenya. Even though she was contacted a bit later than Ashish, June served as an essential channel that spread the survey to her students and other contacts in hospitals. The distribution from her side, begun on July 22ND 2020.

③ INFRATECH COMMUNITY

Following the directions of previous surveys conducted on the field, it was decided to use the Infratech Forum as the last channel to reach additional BMETs in other parts of the world. The registration on the platform was completed the 1ST of July 2020, and two days later, a confirmation email was received that the link to the Google survey had been sent to all the Infratech subscribers (approximately 430).

Finally, the 27TH of July 2020, the Participation Survey was closed, and Google Forms no longer accepted new responses. The questions in the survey were substituted with a message for the respondents, to thank them for their interest and to inform them that the project had proceeded to the next phase, and therefore the survey was closed. At this point, the responses to each question were compiled in a **GOOGLE SHEET**, downloaded, and exported as a spreadsheet to conduct the data analysis in **NUMBERS** for MacOS.

4.3. Results from the Participation Survey

The Participation Survey was opened for a total of thirty-three days, between the period of June 24TH, 2020 and July 27TH, 2020. During this time, a total of 155 responses were registered in Google Forms, and once the survey was closed, the researcher begun to analyse each question and response set. It was at this point, when several duplicate answers from the same individual were found in the data set. Thus, a detailed scanning was conducted to detect and remove all the coupled submissions. After the data collection and filtration processes to remove the duplicates, the Participation Survey yielded a total of 142 valid responses. Detailed 2D bar plots of the categories presented below, are shown in FIGURE 4.2.

Ⓐ LOCATION

Geographically, the locations of the participants were segregated based on the health regions set by the World Health Organisation. The greatest number of participants were in South-East Asia, accounting for 42.2%; closely followed by Africa, with 41.5% of participants. The rest of the regions (Europe, Eastern Mediterranean, North America, Latin America and Western Pacific) made up 16.2% of participants.

Ⓑ MOOC DURATION

When asked about the preferred duration of the final BMET MOOC, most of the respondents (39.4%) agreed that they would rather follow a detailed course, even if it lasts more than 10 weeks. The remaining options ("Around 6 weeks" and "Between 7-10 weeks") reached a consensus at 30.3%.

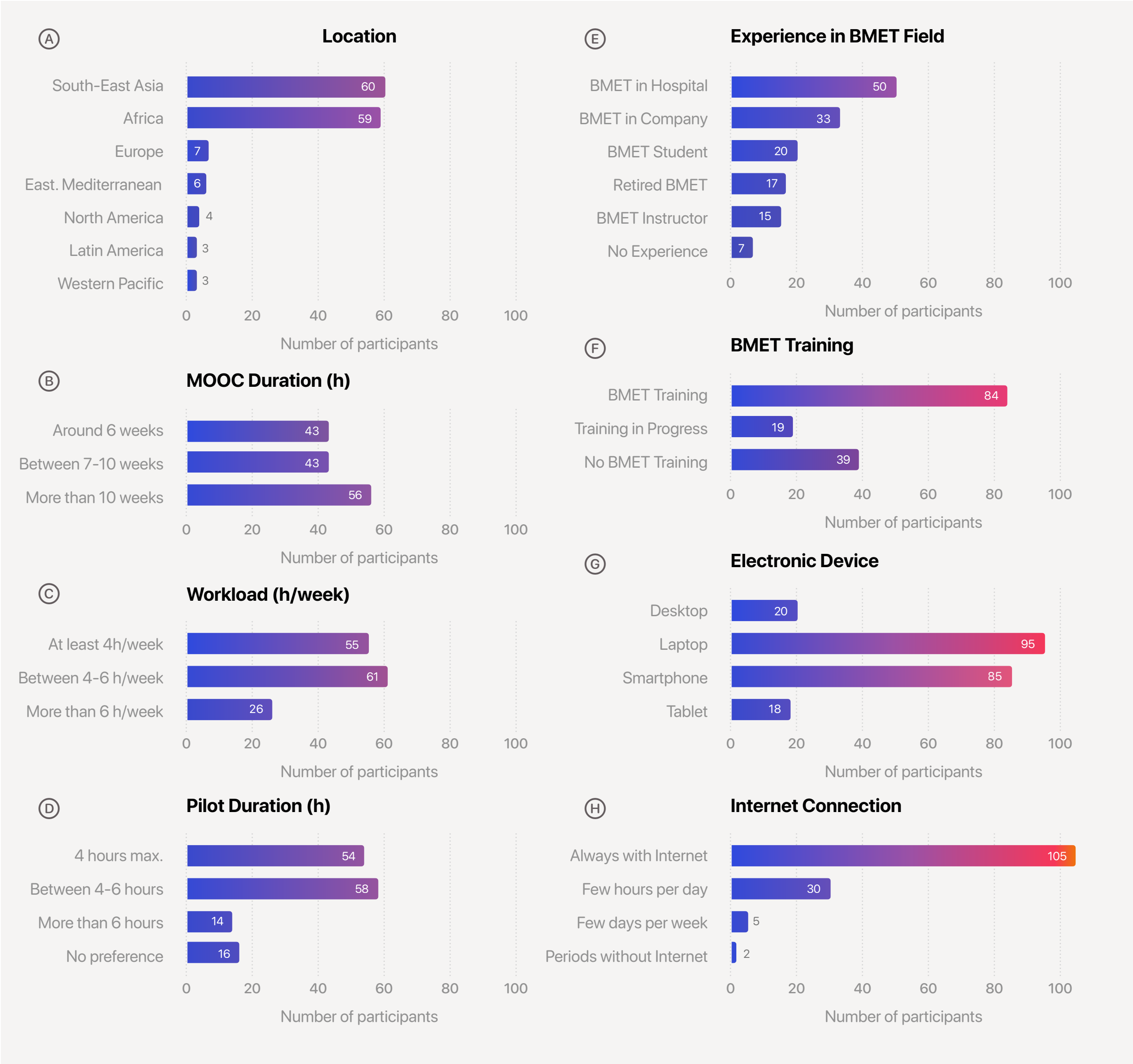

FIGURE 4.2. ANALYSIS OF THE RESPONSES IN THE DIFFERENT QUESTIONS OF THE PARTICIPATION SURVEY

Ⓒ **MOOC WORKLOAD**

Regarding the amount of hours per week each participant would be able to dedicate to the MOOC, the majority (42.9%) preferred to spent between 4 to 6 hours, rather than "At least 4 h/week" (38.7%), or "More than 6 h/week" (18.3%).

Ⓓ **PILOT DURATION**

The workload answers were reflected when asked about the desired duration of the Pilot, if they were to participate in it, as similar responses were obtained. "Between 4-6 h" was the general reply (40.8%), followed by "4 hours max." (38%) and "More than 6 hours" (9.8%). Additionally, 11.3% of the interviewees reported no preference in the duration of the pilot.

Ⓔ **EXPERIENCE IN BMET FIELD**

A total of 35.2% of the participants gave their current occupation as a BMET working on a hospital, while 23.2% were also BMETs, but in an organisation/company. Other professions included BMET student (14%), retired BMETs (12%), BMET Instructor (10.6%), and no experience on the field (4.9%)

Ⓕ BMET TRAINING	Furthermore, it was not important to identify the level of experience and occupation of the participants, but also to monitor wether or not they had received previous training in the BMET field. In total, 59.1% of the respondents confirmed that they had received at least one training, while 13.4% were in the middle of completing their first training course, when they received the survey. Only a 27.5% had received no previous training. Additionally, it was discovered that some participants (21.8%) reported to be working in hospitals, or companies as a BMET have started working in the position without having relied proper training. They were all from South-East Asia and Africa
Ⓖ ELECTRONIC DEVICE	When asked about the type of device that they have and they would use to complete an online course, the most common answer was "Laptop" (43.6%), followed by "Smartphone" (%). The remaining two, "Desktop" and "Tablet" obtained 9.17% and 8.25%, respectively. More over, the mode was to only report one device (60%), as those that marked two or more, barely made up 40% of the total.
Ⓗ INTERNET ACCESS	Lastly, the participants were asked if had access to an internet connection either at home, university, workplace or café; and how expense was that access. Even though 73.9% reported to always have a connection, there were still some participants with difficulties to access it, as it might only be available few hours per day (21.1%), few days per week (3.5%), or even, long periods without it (0.1%).

PARTICIPATION IN PILOT

As it was introduced in SECTION 4.1, the second goal go the Participation survey was to create a networks of potential testers of the pilot course. That is why, before submitting the survey, the participants were asked if they would be willing to take part in such pilot study. The responses are explained in TABLE 4.2.

TABLE 4.2. PARTICIPATION IN THE PILOT STUDY

YES ✓	MAYBE ?	NO ⊗
117	20	5
Participants or 82.39%	Participants or 14.08%	Participants or 3.52%

Unfortunately, out of those potential 137 pilot testers, only 118 submitted their email address. In other words, as the survey was made anonymous, there were 18 respondents interests in the pilot but forgot to leave their contact, and thus, impossible to reach them back.

4.3. Conclusions from the Participation Survey

Overall, the results of the Participation survey demonstrate that the study was not only fairly successful in reaching its target audience, but also in building a network of BMETs from diverse backgrounds, locations and experience, interested in participate in the Pilot study of the BMET MOOC. Besides, it is relevant to mention that at this point no statistical analysis was conducted with the presented data, as it will be later performed with the data obtained from the Pilot. To conclude, TABLE 4.3 presents a summary of the main findings from the survey, which will be taken into account during the design of the MOOC.

TABLE 4.3. MAIN FINDINGS FROM THE PARTICIPATION SURVEY

LOCATION	BMET TRAINING	DEVICE	INTERNET	MOOC DURATION	PILOT DURATION	PILOT TESTERS
84 %	59 %	(laptop)	74 %	10 WEEKS	6 HOURS	118
Were from LMICs in SEA and Africa	Had received prior BMET training	Laptop was reported as preferred device	Had a reliable access to the internet	Per course, With a workload of 4-6 h/week	As maximum	Contacts interested in the pilot

PART II

METHODS

CHAPTER

5 Methods and Protocol

After having selected edX as the potential platform to run the BMET MOOC, and closed the Participation Survey, it was time to design, build and test a small version of the full BMET MOOC, in the form of a pilot, to find the answer of the rest of the research questions. The present chapter focuses on the methods followed in this second phase of the study. It covers the experimental setup and protocol that were followed, as well as the hypothesis, structure of the pilot course, group allocation, and data sources. Theres is also a section focusing on the method of analysis, that describes the variables that will be later taken into account for the statistical analysis. Finally, the chapter concludes with the Ethics Approval Statement from the Human Research Ethics Committee of the Delft University of Technology.

5.1. Experimental Setup

Before diving into the details of the pilot study, it is important to explain in advance the concept of the final BMET MOOC. It is estimated that there global market of medical devices hosts a catalog of more than five hundred thousand instruments [68]. As a consequence, the professions connected to this field—such as Biomedical Engineers, Clinical Engineers and Biomedical Equipment Technicians— are expected to be the first ones in demand and properly trained to deal with the rapid evolution of the market. Such progression can be translated into a constant pressure for a never-ending update in the knowledge and skills for these professionals.

That is why their education and training should be based on a curriculum that is acquainted with these updates and meets R&D and market demands [68]. While the curricula for Biomedical Engineers is more focused on the more complex theoretical aspects of engineering and its application to biology and medicine; BMET's curricula should be centred on device-specific applications in the areas of design, support, troubleshooting, preventive maintenance, and installation.

MOOC BLUEPRINT

In light of these circumstances, the BMET MOOC had to be designed upon the basis of evidence-based data from studies, surveys, reviews from existing training and the feedback from instructors and students, so as to collect the knowledge and skills required by the ever-changing medical devices market [68]. Following the recommendations of the WHO, the base curriculum of the training for these professionals should include lectures on Anatomy and Physiology and Basics on Engineering [6].

Therefore, having as a reference some of the existing face-to-face BMET training courses in LMIC [1, 4, 5, 7-9, 11, 12], as well as the experience from the Nick Simons Institute's instructors, and the findings form the literature study presented in Chapter 2; Prof. J. Dankelman and A. Knulst blueprinted the first draft of the curriculum for the BMET MOOC. Later on, the Learning Objectives were further defined during the Onboarding Session with the TUDelft Extension School, on the June 4th 2020. Structure-wise, the complete MOOC, will be divided in two different courses, as shown in **FIGURE 5.1**.

COURSE 1
BASICS OF BIOMEDICAL EQUIPMENT MAINTENANCE

- **Module 1** Health Technology Management
- **Module 2** Preventive Maintenance of Medical Equipment in Low Resource Settings
- **Module 3** General Working Principles of Medical Equipment in Relation to Human Physiology
- **Module 4** Supporting Topics

COURSE 2
MAINTENANCE AND REPAIR OF BIOMEDICAL EQUIPMENT

- **Module 1** General Engineering Skills and Good Practices
- **Module 2** Diagnostic Medical Equipment
- **Module 3** Therapeutic Medical Equipment
- **Module 4** Analytical Medical Equipment
- **Module 5** Miscellaneous Equipment
- **Module 6** Supporting Topics

FIGURE 5.1. DIVISION OF THE BMET MOOC CURRICULUM INTO TWO DIFFERENT COURSES

The main learning objectives of Course 1, "Basics of Biomedical Equipment Maintenance", are that the learners will be able to understand the working principles of most medical equipment, comprehend and manage the health technology in the hospital, as well as give inputs to the hospital's procurement process, while being able to find information on medical devices using online resources.

On the other hand, Course 2, aims at providing sufficient knowledge so that the participants will be able to understand the working principles of most medical equipment and differentiate between equipment types, follow the set criteria based on standards; and to diagnose, repair and troubleshoot the common problems in medical devices. Nonetheless, it is still a provisional curriculum, accepting changes and proposals, as the devices included in modules 2-5 from course 2 are yet to be selected.

THE STUDY'S MAIN ATTRIBUTES

With all of the above in mind, what can be said about the purpose of conducting the Pilot Study? Firstly, it would not only allow for the evaluation of edX as the platform; but also it will help define the course logistics, as well as evaluating the efficiency of the interactive delivery method; and determining the optimal the course content and learning from the participants perspective, so that the final course is tailored to their needs and situations. However, before explaining the hypothesis and group division, it is substantial to define the study's main attributes [69]. The Pilot Study was characterised by the following features:

① SINGLE BLINDED STUDY	Even though the participants of the study were aware that their results and inputs in the pilot would be used for research, they were not informed that they were being exposed to contrasting factors to evaluate the differences. Only the researchers were able to identify these factors, and see which participant belonged to each of the 4 groups.
② BETWEEN-SUBJECTS EXPERIMENTS	Related to the property above, this feature means that each participant was assigned to a group, which were later treated in the exact same way; with the only difference being that each group underwent a different procedure or performs a different task.
③ RANDOMISED CONTROLLED TRIAL	The group allocation was randomised, within certain parameters, to avoid disparities between cohorts. Additionally, there was one group which was not exposed to any factor, to serve as a reference for the evaluation, known as the control group.

5.1.1. Hypothesis and Cohorts

The Pilot Study was designed and created collaboratively between R. Rutten and D. García de las Heras, as it served a double purpose. It was not only used to find the answer to the research questions presented in Chapter 1, but it was also part of the graduation project of R. Rutten, on the Master of Science in Biomechanical Design. The purpose of her work lied on evaluating the skill acquisition technique through the online platform, and if it was enough to meet the requirements demanded by the BMET profession. Additionally, there was set of subquestions introduced on her project that analysed the effects on motivation on the overall performance of the BMET MOOC [70]. As a result, there were two specific research questions that were tested in the study, which required the need of exposing the participants to various factors:

RQ **R. RUTTEN MOTIVATION**

What is the effect of emphasising motivational incentives on the results achieved in a BMET online course?

This RQ lead to two factors: "Exposed to Motivation" and "No Motivation". They will be represented by and , respectively.

HYPOTHESIS: Those participants exposed to motivational video will perform better on the MOOC.

RQ **D. GARCIA DE LAS HERAS INTERACTIVE CONTENT**

How does presenting the learning material through interactive activities and exercises, that increase the engagement with the online course content, compared to standard delivery methods (plain readings and figures); affect the performance in a BMET MOOC?

This RQ lead to two factors: "Exposed to Interactive Content" and "Not Interactive". They will be represented by the symbols and , respectively.

HYPOTHESIS: *Those participants exposed to interactive content will perform better on the MOOC, compared to those delivered with the standard units*.

The two-by-two combination of these factors, resulted in the creation of four cohorts, as shown in TABLE 5.1. The participants in Cohort Ⓐ had access to the motivation video and the units with the interactive content. Whereas those in Cohort Ⓑ or Cohort Ⓒ, would only be exposed to either the motivation video or the units with the interactive content, respectively. Finally, Cohort Ⓓ serves as the control, as it will have access to standard content units and no motivation video will be shown.

TABLE 5.1. DIVISION OF THE RESEARCH QUESTIONS INTO FOUR DIFFERENT COHORTS

	Interactive	Not Interactive
With Motivation	Cohort Ⓐ Access to motivation video and interactive content units	Cohort Ⓑ Access to motivation video and standard content units
No Motivation	Cohort Ⓒ Access interactive content units	Cohort Ⓓ Access to standard content units

Even though there were four different groups, the present thesis will only focus on the interactive content and its effect on the BMET MOOC. Therefore, from now onwards, the cohorts Ⓐ+Ⓒ will be combined in a group called "INTERACTIVE"; while cohorts Ⓑ+Ⓓ will form the "NOT INTERACTIVE" group. For more details on the effects of the motivation video and conclusions on the BMET skill acquisition through the MOOC, please refer to R. Rutten thesis at "Educate biomedical equipment technicians via an online platform in low-/middle-income countries whilst stimulating intrinsic motivation"[70].

INTERACTIVE CONTENT

Before concluding this section, it is significantly important to define what is considered as interactive content, and the rationale and importance behind this factor. As John Dewey, American educational reformer wrote: "*give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results*" [71]. However, despite all the benefits of e-learning in the course delivery process, several authors have expressed their concerns with online education, as the bulk of the burden of learning is directly passed onto the student.

In order words, in most online courses, the learners have to make use of the content on their own. They are presented with readings and videos, and it is up to them to go over the materials and complete them. As a result, a great deal of responsibility is transferred to the learners [17, 21, 22]. They are the ones accountable for deciding whether to gain exposure to the learning material and process it meticulously before completing the corresponding assignments/ assessments, or if they opt for skipping them.

Therefore, this thesis intends to answer if the mergence of theoretical aspects of the course with interactive content—such as multiple choice questions, videos, drag and drop exercises and short answer activities—can take up part of this responsibility from the students, while guiding them through the content, guaranteeing that the material has been revised and completed, before reaching the assessment. That is to say, if including interactive content through the theoretical modules can exhibit potential benefits for the students, which are directly reflected on the online course performance. The components with interactive content will not be graded questions, but rather they will provide feedback to the learner and boost their involvement in the course by promoting active engagement.

5.1.2. Pilot Course Structure

As the Pilot Study was intended to be a small replica of the Full BMET MOOC, so that it could be tested and evaluated prior to its public release; it only made sense that its structure was based on the MOOC blueprint and curriculum that were explained previously in this chapter. Since Course 1 presented in FIGURE 5.1 was more theory based than Course 2, it was decided to take a closer look at the Modules from this second course, and take it as the template for the Pilot. The reason behind this choice, is that the curriculum from the course "Maintenance and Repair of Biomedical Equipment" is more versatile when it comes to the content to be evaluated, and its more centred on the topics that R. Rutten's thesis and the present one are studying.

In the end, it was decided to select a medical device and complete the lectures that would be applicable or related to such device, in a way that they could be completed in 6 hours maximum, as recommended in TABLE 4.3. The World Health Organisation has published a report containing a list of instruments that are considered the core medical equipment that the healthcare centres in LMIC should have [72, 73]. After revising this list, it was brought to a conclusion that the optimal device to build the pilot upon, would be the Patient Monitor.

PILOT COURSE BLUEPRINT: PATIENT MONITOR

The patient monitor is a Class I Diagnostic Medical Device, whose role is to continuously measure and monitor the patient's vital signs of the patient while he/she is in the Operating Room (OR), Intensive Care, etc., and inform the medical staff of any abnormalities or drastic changes by sound alarms. The physiological data is displayed continuously on the screen as time signals. Characteristically, this instrument is a complex piece of equipment. In order to properly master its maintenance and repair, the training demands various lectures that throughly cover its functioning and the principles behind it. Besides, the feature of monitoring the vital signs requires the understanding of different anatomical and physiological aspects.

In other words, the Patient Monitor served as the perfect example to use in the Pilot, as part of the Diagnostic Medical Equipment Module. Following the nomenclature introduced in FIGURE 5.1, the patient monitor did not only cover the corresponding lectures from Module 2, but also it was decided to include the lectures on Module 1 - Anatomy and Physiology, that were pertinent to the device.

The storyboard of the pilot course begun on June 11th 2020, with the help of the Delft Extension School. However, the outline underwent several iterations and modifications until reaching the final arrangement, that was presented to the participants on July 31st 2020. The final structure of the Pilot is presented in TABLE 5.2, as well as the number of units included in each lecture and the author of those units. Nonetheless, a more detailed description of the storyboard, with an explanation on the units within each lecture, can be found in Appendix C.

As it can be seen, the pilot course was divided in four parts. The first one included the introduction lectures to the course, as well as the Entrance Survey and Initial Knowledge Quiz (IKQ). This portion of the pilot also comprised the Motivational video for R.Rutten's research question. Analogously, the last part, included a similar End-of-Course Survey and a Final Assessment (FA) to compare the performance of the participants.

TABLE 5.2. BLUEPRINT OF THE CURRICULUM FROM THE PILOT MOOC

PART	LECTURES		AUTHOR	UNITS/LECTURE
①	Introduction to Pilot Course			
	Welcome!		R. Rutten & D. García	1
	Why become a BMET?	video	R. Rutten	2
	Outline of the course		R. Rutten & D. García	3
	Introduce Yourself!		R. Rutten & D. García	1
	Entrance Survey - Google Forms		R. Rutten & D. García	1
	Introduce Yourself! - Discussion Forum		R. Rutten & D. García	1
	Initial Knowledge Quiz		R. Rutten & D. García	1
②	Module 1: General Biomedical Engineering Skills			
	Anatomy and Physiology	interactive	D. García	5
③	Module 2: Diagnostic Medical Equipment			
	Patient Monitor.I - Device and Components	interactive	D. García	6
	Patient Monitor.II - Preventive Maintenance		R. Rutten	3
	Patient Monitor.III - Troubleshooting		R. Rutten	2
	Patient Monitor.IV - Repair		R. Rutten	1
	Patient Monitor.V - Testing		R. Rutten	1
④	End of Pilot Course			
	Final Assessment		R. Rutten & D. García	1
	End-of-Course Survey - Google Forms		R. Rutten & D. García	1

The two remaining parts, focused on the content related to the Patient Monitor. Module 1 contained five units describing the Anatomy and Physiology associated to the monitoring features of the device, such as ECG, Pulse Oximetry, and others. While Module 2 included a subdivision of the lectures explaining the technical aspects and components of the Patient Monitor.

The lecture "Patient Monitor.I - Device and Components" was a block of units specific to the device, which covered the Health Problem addressed, the environment of use, the system block diagram, the measurement principle applicable to the different parts, as well as a detailed description of the components and the operating steps. The remaining four lectures of the Patient Monitor series focused on the training needed to perform preventive maintenance, troubleshoot of the most common errors, repair and testing of the device.

The authorship of these units was assigned to each researcher based on their previous experience, education, and following the line of research of their thesis. Therefore, only the units included within the "Anatomy and Physiology" and "Patient Monitor.I" lectures were designed with Interactive content. Even though it would have been optimal to include it also in the rest of the modules, this distinction was necessary to prevent that the effect of this factor to further spread to the modules created by R.Rutten and thus, affect her research. This will be explained more in detailed in section 5.2.

5.1.3. Data Sources

In order to analyse the outcomes of the BMET Pilot course, there were two main sources to collect the data:

① GOOGLE FORMS

The responses in the Google Form surveys, served as the primary source of data for the study. As shown in TABLE 5.2, the Pilot contained an Entrance and End-of-Course surveys, which procured information about the participants, as well as their feedback on the experience in the course. The data from these surveys was linked to the responses in the already-closed Participation Survey, through the participants' email address. Lastly, a Non-Participation Survey was distributed to those respondents who expressed their desire to participate in the pilot but did not actually finish it.

② EDX PLATFORM

edX allows the course instructors to download a series of reports that include information about the students' profile, grades and answers to specific problems. For this study there were two reports that were of great importance: "Grade Report", which contained the details of the participants' cohort and enrolment, and "Problem Grade Report", that described the scores obtained in every question in the Pilot. Being able to download the grade reports was substantial in order to compare the responses from the Initial Knowledge Quiz and Final Assessment.

Additionally, the platform provided a subsection, called edX Insights, which revealed real-time statistics and figures about the learners, the enrolment and engagement with the course content. However this data was not available for download, and therefore it served as merely illustrative purposes.

Unfortunately, there were some other details that edX did not provided, such as the total time spent in the course, individualised reports on the number of times the participants posted in the discussion forums or which participant engaged with which type of content.

DATA RESEARCHER ROLE

In order to be able to download the grade and performance reports, an application had to be submitted to the edX Support Team to be given the role of "Data Researcher". The main condition to be granted with this permission was that the data for the participants had to be made anonymous before its publication. The application was mailed on 3rd August 2020, and two days after, it was accepted and R.Rutten and myself were given the role of data researcher, so that we were able to download the data we required for our thesis.

5.1.4. Participants Allocation to Cohorts

In order to reduce potential imbalances in the cohorts, and thus, in the outcome of the study; it was decided to follow a minimisation procedure [69]. This way, the Participation Survey's respondents who expressed their disposition to test the pilot (118 in total), were allocated to each of the four cohorts, depending on the current group composition, in order to minimise the differences between the cohorts in terms of covariates.

Covariates are those variables that, next to the independent variables (Interactive content and Motivation), can be a predictor of the outcome of the dependent one (Course Performance). In the case of the present study, Stratified Randomisation [74] was the procedure selected to produce equal-sized study groups that are balanced by covariates. This method only works when the participants have been identified before the cohort assignment. Fortunately, the Participation Survey already provided three useful covariates: Location (6 levels), BMET Training (3 levels), and BMET Work Experience (6 levels).

In the end, only BMET Training and Location were selected as the main covariates for the stratified randomisation (3 x 6 = 18 blocks), as the method of stratified randomisation would fail if we were to add the remaining covariate [75], because the number of blocks would approach half the sample size ($^{118}/_{2}$ = 59). Therefore, the list of participants (118) was first categorised based on their **BMET Training** (Yes/No/In progress), and then subdivided according to their **Location**. Then, the participants were allocated into the cohorts following the chain block arrangement "**ABCD**". In the end, the final arrangement prevented the chances of obtaining a cohort filled with similar covariates.

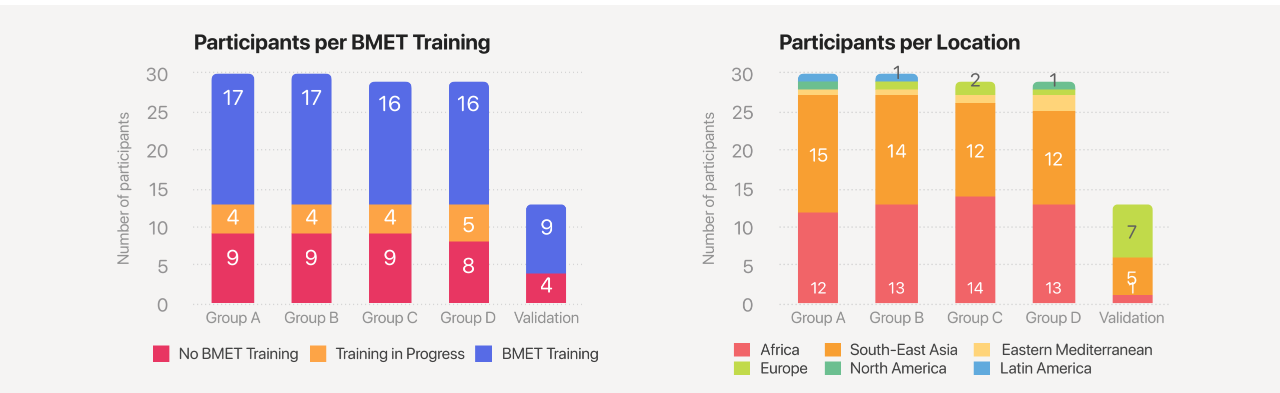

FIGURE 5.2. COHORT DISTRIBUTION: BMET EXPERIENCE LEVEL AND LOCATION

The results from the allocation in terms of the BMET Training and Location are shown in FIGURE 5.2. In the end, there were a total of 30 participants assigned to cohort Ⓐ and Ⓑ; while cohorts Ⓒ and Ⓓ contained 29. Nonetheless, when the pilot started, an additional participant emailed us, expressing their interest to participate. He was randomly assigned to group Ⓑ, making a total of 31 in this group. Additionally, in FIGURE 5.2 there can be seen an additional cohort, the Validation Group, with 13 participants. The relevance of this group will be later explained in Chapter 6.

Furthermore, in order to assure that the stratified randomisation did produced balanced groups, an analysis was conducted to asses the equilibrium between Location and BMET Training on every cohort. The results are depicted in FIGURE 5.3, which indeed proves that all the cohorts are well-balanced, specially the participants from South-East Asia and Africa.

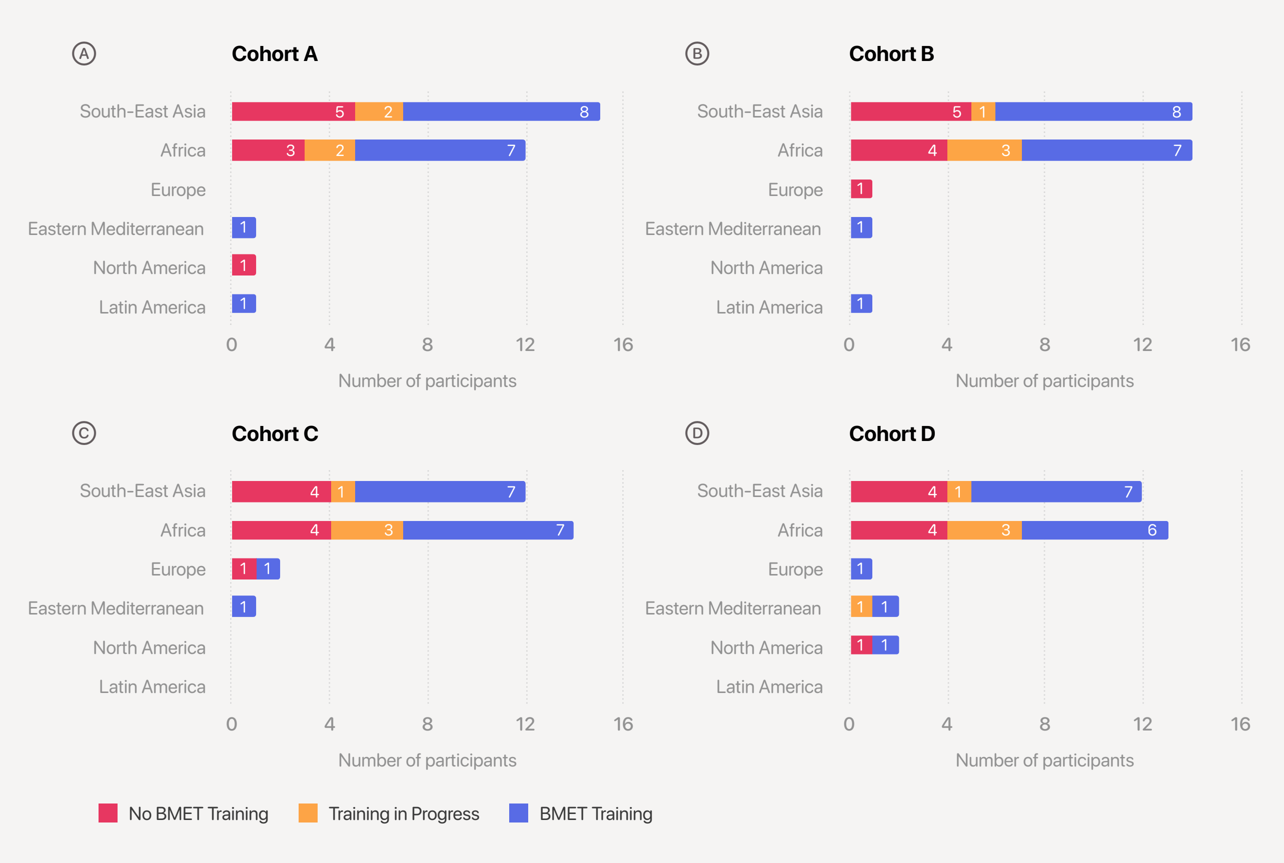

FIGURE 5.3. COHORT DISTRIBUTION ANALYSIS: BMET EXPERIENCE LEVEL VS. LOCATION

5.2. Measures and Method of Analysis

TYPES OF VARIABLES AND TREATMENTS

After having introduced the experimental set up of the pilot study, this section aims to present a more in depth overview of all the variables and measures that played a role in the beta course. As previously shown in TABLE 5.1, there are two main independent factors that lead to four cohorts. The first one being the presence of interactive content in a selected portion of the units within the course (refer to TABLE 5.2) and the second one, the screening of a motivational video, on a unit only visible to half of the participants. A thorougher explanation on the course logistics, and how different units were shown to specific learners, will be explained in Chapter 6.

Apart from these independent factors, there were a series of additional covariates that might have played a role in the outcome of the course. These included: the location of learners, if they had received previous BMET training, their work experience in the BMET field, knowledge in the subject of anatomy, the device used to access the pilot course, their education level, gender and age. Some of these factors were obtained from their answers in the Participation Survey (Chapter 4), while others were asked through the different surveys embedded in the pilot. TABLE 5.3 includes a clear description and categorisation of al the variables present in the study, including their type, measurement level and their values.

The association of all the responses between the various surveys, to each participant was made possible thanks to **Google Forms**, and its feature to request the email of the respondents before they submitted the questionnaires. This allowed the downloading of all the responses in CSV formant, and later link them in a spreadsheet in **Numbers** for MacOS [76].

Once the Pilot course closed, a process to collect the responses from the different surveys and including them in the spreadsheet begun. Additionally, the data had to be cleaned and filtered, since some surveys included duplicate responses from the same participants. Please notice that, since the pilot and its content was created collaboratively between R. Rutten and myself, there are some responses to particular questions in the surveys that will not be covered in this thesis, as their relevance lies within R. Rutten's research question, and vice versa.

After the data filtration process, Statistical analyses were performed using the software **IBM SPSS Statistics 25** [77], with the objective of finding which variables did actually produce statistically significant results and affected the outcome of the pilot [78]. However, as shown in **Table 5.3**, most of the values from these variables were strings, and therefore, they had to be converted into numeric ones so that the software was able to conduct the statistical computations.

TABLE 5.3. CLASSIFICATION OF THE VARIABLES PRESENT IN THE STUDY

VARIABLES OF THE STUDY	TYPE	MEASUREMENT LEVEL	VALUES	BEFORE/AFTER PILOT
① Independent Variable				
Delivery Method	Qualitative	Nominal	"Interactive" or "Not Interactive"	Before
Motivational Video	Qualitative	Nominal	"Motivation Video" or "No Motivation Video"	Before
② Dependent Variable				
Outcome of the Course/ Performance	Quantitative	Continuous	From -100% to 100%	After
③ Covariates				
Location	Qualitative	Nominal	"Africa", "EM", "Europe", "North America", "Latin America" or "South-East Asia"	Before
BMET Training	Qualitative	Ordinal	"No Training", "In Progress" or "Yes Training"	Before
Work Experience in BMET Field	Qualitative	Nominal	"Hospital", "Company", "Instructor", "Retired BMET", "Student" or "No	Before
Anatomy Knowledge	Qualitative	Nominal	"Yes" or "No"	After
Device	Qualitative	Nominal	"Desktop", "Laptop", "Smartphone-Android", "Smartphone-iOS" or "Tablet"	After
Education	Qualitative	Ordinal	"Elementary", "High School", "Bachelors", "Masters", "PhD's" or "Post-Graduate"	After
Gender	Qualitative	Nominal	"Male" or "Female"	After
Age	Qualitative	Ordinal	"21-25", "26-30", "31-35", "36-40" or ">40"	After

MEASUREMENT METHODOLOGY: OUTCOME OF THE COURSE/PERFORMANCE

When it comes to analysing the outcome of the pilot course, it is important to acknowledge the double-thesis purpose that the pilot was serving, as it has been explained previously in section 5.1.1. As a result, several measures had to be included on its design, in an attempt to minimise the cross contamination between both thesis and experimental designs. In other words, to avoid/reduce the effect of the interactive factor in R. Rutten's thesis, the units with interactive content were only present in 2 out of 5 theory modules: "Anatomy & Physiology" and "Patient Monitor.I Device and Components".

Likewise, to lessen the side effects of her motivation video in this thesis, the aforementioned distribution of interactive content in only those two modules presented an advantage. The reason behind this is that the motivation video was about how to become a successful BMET. Therefore, it could be expected that it would have hardly any effect on the outcome of the Anatomy and Physiology module, as the topics were fairly different. On that account, the overall grade obtained on the course would not be a direct indicator of the real effect of interactive content. Besides, this grade would be related to the "knowledge gain", which can be a very abstract concept to study, as it is conceptually wide and covers different abilities, like motor and intellectual skills, etc . Hence, other ways to measure the effect of the interactive factor had to be researched.

Literature has shown that the connection between learners' input of effort, and the gained learning output, can be considered a valid method to study the efficiency in the education process, specially in online courses. The concept of efficiency refers to the relationship between the inputs put into the system versus the outputs gained from it [17].

In the case of MOOCs, the efficiency can be increased through the process of carefully creating learning resources, like videos and readings, as well as interactive content, to boost the learner's involvement in the course by promoting active engagement [17, 79].

Hence, the efficiency of the performance presents itself as the most promising way to measure the effect and potential interactive content units. This is because the research questions of this thesis are not aiming at quantifying the amount of knowledge or skills gained by the learners; but rather which content delivery method (Interactive and Not Interactive) performed better among the students and was more efficient.

Following the advice from the Nick Simmons Institute on their face-to-face training methodology, the pilot course included an Initial Knowledge Quiz, as shown in TABLE 5.2. The combination of the grades from this exam with the Final Assessment, allowed the creation of a Pre-test/Post test design study, in which the performance would be measured as the mean of difference between their grade on each exam, across all candidates. To put it simply: $\text{Grade}_{\text{Final Assessment}} - \text{Grade}_{\text{Initial Quiz}}$

Notwithstanding, following the same principle as before, the Final Assessment and Initial Knowledge Quiz included questions on every topic presented on the course. Thereupon, to measure the effect of interactive content effectively, the performance analysis should only include the grades of the sections where the interactive content was present. Additionally, even though the PM.I Module included Interactive Components, the assessment of this section was more general knowledge based, as a simulation tool could not be built to asses this module properly. This means that, from this point onwards, the term "Performance" or the glyph "" would refer to:

$$\text{PERFORMANCE} = \text{GRADE}_{\text{A\&P FINAL GRADE \%}} - \text{GRADE}_{\text{A\&P INITIAL GRADE \%}}$$

On another note, to prevent the difficulty level of the assessments from biasing the results of the performance, the questions were designed in a specific manner. While they covered and focused mainly on the theoretical elements presented through interactive/not-interactive components; the questions on A&P in both tests, were formulated with the same level of difficulty. To verify this, R. Rutten included on her thesis a Subject Pair Analysis (SPA) to compare the difficulty level of both exams [70]. This method has been widely used by the examination boards in England, Wales and Northern Ireland [80].

A total of 15 candidates with no previous knowledge on the BMET field were selected to complete both exams. Later the grades from them were averaged and compared. The results concluded that the final assessment was 1.39 times more difficult than the knowledge quiz. However, based on the performance equation above, this thesis is only interested on the A&P questions, and wether they were of equal difficulty. Consequently, based on the results from R. Rutten's study, only the responses from the A&P questions were taken into account. The participants scored a total of 56% on the A&P-Initial Knowledge Quiz (IKQ) and 43% on the A&P-Final Assessment (FA). Furthermore, a Mann-Whitney U Test was performed, as the IKQ grades followed a normal distribution but the FA's scores did not. The statistical test produced a p-value of **0.133**, which is bigger than the α level of 0.05. This means that the difference between both assessments is not big enough to be statistically significant. On that account, it can be concluded that the A&P questions on both test were on the same difficulty level and it would not be a factor affecting the performance.

Furthermore, it is important to remark that a performance result of 0% or less, does not mean that the participant "learned less" or "lost knowledge" in the course, but rather that the delivery method (Interactive or Not Interactive) was not as efficient in boosting their involvement in the course and promoting active engagement. This is because knowledge gain stands apart from the delivery medium through which it is transferred. Additionally, this thesis will not include a learning curve, because such correlation between the learner's performance on a task and the number of attempts/time required to complete it [81] requires a series of variables that unfortunately edX did not provide to the course instructors, like the average time that each participant spent on the units.

VALID PARTICIPANT

Lastly, it was important to define the requirement that had to be met by a participant in order to consider their input valid for the study. This is because not a 100% participation is expected by the 118 pilot testers. Therefore, a valid participant would have had to: (1) completed the Participation Survey, (2) registered in edX and enrolled in the course, (3) completed the Entrance and End-of-course Surveys, (4) participated in the activities from the theoretical modules of the course, including the interactive content; and lastly, (5) submitted the IKQ and Final Assessment. If one of more of these five requirements were not to be met, for instance, completing the surveys without going over the materials of the course, the responses from those participants will not be taken into consideration when analysing the results.

5.3. Approval by the Human Research Ethics Committee

As it can be deduced by now, the present thesis involves the participation of human subjects. As a consequence, it was required to apply for the approval of an Ethics Board, so that the protocols of the study could be considered valid for publication [82]. The Delft University of Technology created their own Human Research Ethics Committee (HREC) to examine every research which involves human subjects.

An approval application was submitted to the HREC, which included two documents to review. The first one, was a detailed description of the DATA MANAGEMENT PLAN relating to the administration of the participant's details and methods of acquisition. The second file was the ETHICS REVIEW CHECKLIST FOR HUMAN RESEARCH. This checklist helps determining whether the proposed research poses more than a minimal risk to the subjects. "Minimal risk" is understood as the standard, every-day risks faced in our daily lives.

Additionally, prior to the students enrolment in the course, they were informed of the study beforehand: during the Participation Survey, and in the invitation email sent to them with the details on how to enrol. Furthermore, in the introduction module of the course, they received further information on the protocols and purposes behind the pilot; and in the Entrance and End-of-Course Surveys they had to agree on with the INFORM CONSENT FORM before completing them. All participants were assured that their personal information will not be shared with third parties. The authors and instructors of the pilot took care to ensure that students did not feel pressured to respond or participate.

What's more, since the authors agreed with the Data Researcher role and the commitment to edX that no identifiable information of the students would be published; all the results presented in Chapter 8 were anonymised. As a result, the approval of the Human Research Ethics Committee (HREC) from the Delft University of Technology was granted to conduct the research. The letter of approval issued from the committee, indicating that the study had been reviewed and approved; can be fount in Appendix D.

PART III

BUILDING AND RUNNING THE BEET PILOT COURSE ON EDX EDGE

CHAPTER

6 Building the BMET Pilot MOOC: Design and Validation

The main goal of the sixth chapter of the thesis is to shed light on the main aspects behind the creation of the content for the BMET Pilot MOOC, as well as the validation process it underwent, prior to its release. It will cover the main differences between edX and Edge, and why it was opted to run the pilot on the latest. Furthermore, the use of the edX studio, course logistics and grading system are also discussed below. Finally, the last two sections of the chapter will focus on the course material that was presented to the students, the interactive content, and the validation process performed with experts on the field, and students.

6.1. Building the Pilot Course on edX Edge

Before diving into the details of the platform and how the pilot was designed, it is important to reflect on the two domains of edX that are offered to the lecturers to build the MOOCs on. The first one, and the most well-known, is called **EDX.ORG**, which can be considered the home of MOOCs, and any learner in the world is able to enrol on the courses offered in its catalog. On the other hand, the antagonist domain is called **EDGE**, which is the edX platform offered to organisations and institutions for the development of courses in a low-visible environment.

Edge is characterised for providing the instructors with a space to test and experiment with online course development, prior to its release on edX. The main idea is that any course built within Edge, will not be publicly listed on edX's catalog; and the enrolment can only be processed with a with a specific URL provided to the learners through email by the course staff. In light of these events, Edge was considered, and also recommended by the TUDelft Online Learning team, as the optimal platform for testing out the features and choices of the present pilot study, in a controlled environment.

Furthermore, the platform technology and functionalities between edX and Edge are the same. Since the following process is identical for both domains, from this point onwards the report will only refer to Edge, as it is the space that was used for the pilot. When it comes to the design of the course, the Edge platform can be subdivided in two parts: the so-called "Learning Management System" or LMS, and the Studio [63-65].

The LMS is the website where the students are presented with the actual content of the course; where they can engage with it, complete the activities/assessments and watch the videos. This is also the space where the instructor can tack the recorded progress of the students, download the grade reports, manage the enrolments and cohort allocations. On the other hand, the components of the lectures and units are created and published to the live version of the LMS, through a distinct web-based course authoring tool, called Studio [63-65]. In other words, the instructor builds the course in the Studio, and the students engage with it via the LMS.

Since the access to both tools in Edge had to be granted by the institution partnering with edX, on June 17TH 2020, the edX Support Team was contacted, with the help of the TUDelft Online Learning team, to request the creation of the instance for the pilot on the platform. After the application was processed, it was accepted, and on June 22ND full access to edX Edge was received to start creating the BMET Pilot MOOC. The pilot was hosted at: https://edge.edx.org/courses/course-v1:TUDelft+BMET2+2020_Q3/

6.1.1. Course Logistics: Interactive Content and Grading Policy

HOW WAS THE INTERACTIVE CONTENT DESIGNED?

Following the methodology and group structure presented in the previous chapter, it was important to find a way on Edge to link certain components, to specific cohorts of learners, in order to answer the research questions related to the delivery method (Interactive vs. Not Interactive) and the motivational video of R. Rutten. Fortunately the LMS website offered the option to enrol the participants in different cohorts, and later, it was decided via the Studio which component of each unit was associated and visible to a particular cohort.

Based on the distinctions made for the four cohorts (A to D), in terms of delivery method and motivational video; the components of the different units were made visible to the corresponding groups of learners, according to the rules presented in TABLE 5.1. It is important to notice that in the units with the Interactive elements (A&P and PM.I Modules), the content had to be duplicated in the Studio. To put it simply, there was one component that contained the materials presented as regular/standard lecture readings and figures, visible to cohorts Ⓑ and Ⓓ exclusively; while the interactive component referred to the same materials, but with elements such as multiple choice questions, drag and drop exercises, that captured the learners' attention, guaranteed its completion; being only visible to the leaners in cohorts Ⓐ and Ⓒ. Therefore, the objective of the interactive elements was to prevent that the key concepts were skimmed over or skipped by chance. Additionally, it was mainly used for presenting new concepts, associating the correct definitions to key terms, identifying elements in figures, or responding questions from a video. Some examples of this can be seen in FIGURE 6.1.

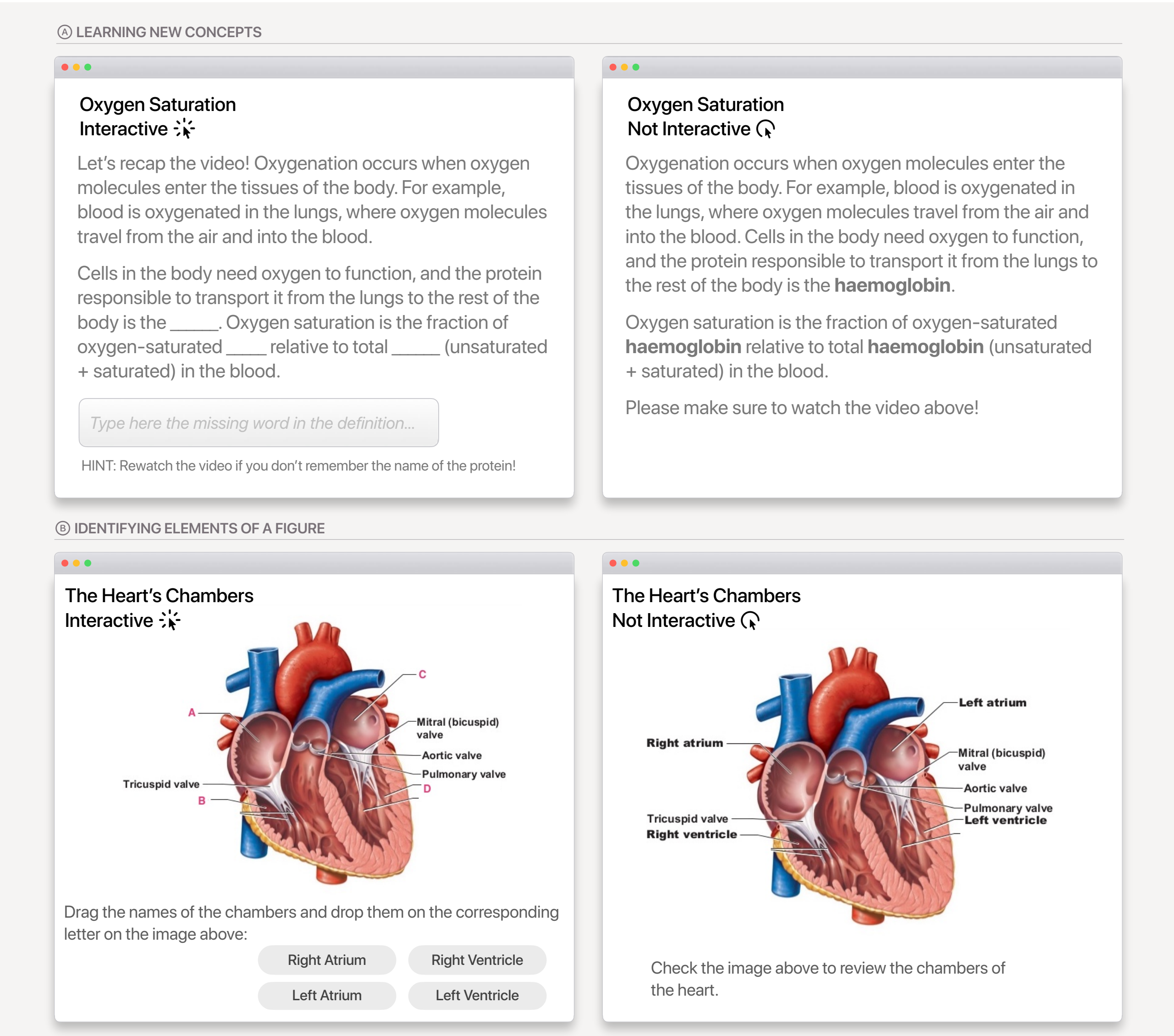

FIGURE 6.1. EXAMPLES OF TWO INTERACTIVE CONTENT COMPONENTS FROM THE A&P MODULE AND THEIR COMPARISON WITH THE STANDARD ONES

GRADING SYSTEM

In order to provide the participants of the Pilot MOOC with a reference to review their progress on the course, and check which elements they had left to complete, it was recommended by the TUDelft Online Learning team to create a grading policy that included all the components of interest to the research. By doing so, each learner could verify if they were missing any of the requirements to become a valid participant before the deadline. Thus, the overall grade of the students in the course was computed according to the grading policy presented in FIGURE 6.2. It is important to remark that this grading system was tailored to the needs of the present Pilot MOOC, and it will have to be readapted for the future BMET MOOC accordingly, as the proportions and amounts of content between both will not be comparable.

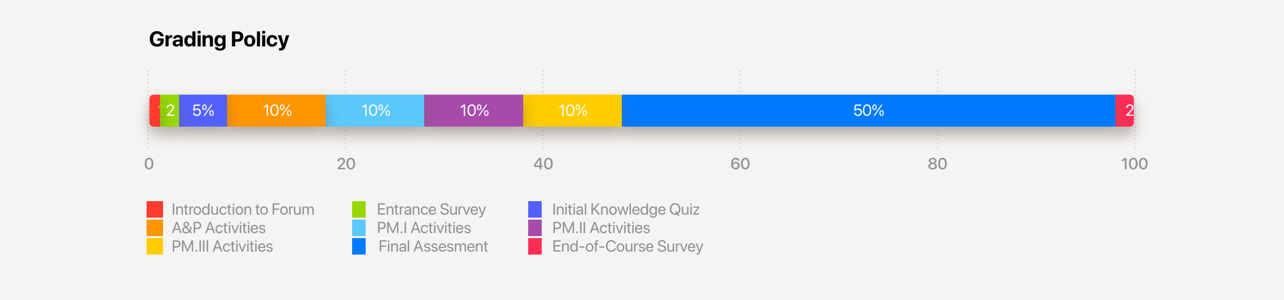

FIGURE 6.2. GRADING SYSTEM FOR THE BMET PILOT MOOC

It can be seen that some of the elements that required the learners' participation barely contributed to the grade (with a 1% and 2%), as it was the case of the introduction in the discussion forum and the completion of the Entrance and End-of-course Surveys. Moreover, the grade obtained in the 24 questions of the Initial Knowledge Quiz contributed 5%, as compared to the 46 questions of the Final Assessment, which weighted 50% of the final grade. The reason behind such difference, was the intention of not giving an unfair advantage to those students with prior knowledge on the topics, while keeping the IKQ relevant enough, so that it would motivate the vast majority of the students to complete it.

Lastly, the course activities included in the four remaining sections of the *Anatomy and Physiology* and *Patient Monito*r Modules, accounted for 40% of the final grade, 10% each. However, it has to be highlighted that edX does not allow for the creation of two different grading systems for exclusive student cohorts. This meant that, aside from the activities included in these units, which were common for both groups; there was an imbalance in the number of exercises between the interactive and not interactive groups. For example, the score for the A&P Activities included the results of 3 exercises for the standard delivery method, while there were 6 additional problems for the interactive group, which unavoidably contributed to the grade due to edX settings. In a similar way, the grade for the *PM.I-Device and Components* section also had an unevenness, as one group had 2 activities, while the other had 9.

Thus, it can be concluded that the set up of the pilot course led to evident differences in the overall grades of the interactive and not interactive groups. For all these reasons, the overall grade, which will be later presented in Chapter 8, should not be considered as an index of the success of the Pilot course, but rather an indicator of the engagement with the various elements, and course progress.

6.1.2. Course Materials

The course materials were created collaboratively between both researchers, following the Pilot structure presented in the previous chapter. This subsection will focus on the units individually created by D. García de las Heras, as well the course elements created with R.Rutten. Apart from the introduction to the discussion forum, the *Introduction to the Pilot Course Module* also included a video presenting the members of the course team that contributed to the creation and distribution of the course. Since each lecturer was residing in a different country, the clips were recorded individually and joined together using KEYNOTE and IMOVIE for MacOS. The resultant video can be watched through the following link: https://www.youtube.com/watch?v=ezz4up8HZfk

Also included in this module, was the Entrance Survey, whereas the End-of-Course Survey was contained in the *End of Pilot Course* module. Following the success of the Participation Survey, these two were also created using Google Forms [67], and the link was pasted in the corresponding units, as recommended by the TUDelft team. Both surveys can be access in full through these links, respectively: https://forms.gle/RxnDqPnTYMukhEoGA and https://forms.gle/p61T2cLxSy1w9pU67.

The content for the *Anatomy and Physiology* module was summarised to include only the topics related to the functioning and vital signs recorded by the patient monitor. The majority of the concepts and images in this section were obtained from: *E. Marieb & L. Smith. 2014, "Human Anatomy & Physiology Laboratory Manual, 10th Edition"*. Besides, to make the units more lively, these materials were accompanied and complemented with existing videos, mainly from the YouTube channel of TED-Ed. Nonetheless, the source of every part included in these sections was properly reference on the Pilot. Likewise, for the *PM.I-Device and Components* module the content was sourced from the Engineering World Health BMET Library, and the lectures from current face-to-face training conducted by the NSI. This section also included some original figures created from pictures of existing PM. Moreover, some of the videos for this section were recorded in Nepal, with the actual device; while others were obtained from YouTube.

Throughout these two modules, the lecture readings, figures and videos were intercalated with activities (which were common for both groups), and the interactive content elements, as explained above. Multiple choice, checkbox, fill-in-the-blank, dropdown and drag-and-drop problems were the preferred exercise type used in the pilot, as they allowed the learners to quickly check their understanding [64]. The main objective when setting up the activities was to maintain a balanced ratio of theory and practical exercises, and to keep the problem type interspersed so that the participants would not perceive a heavy feeling or intense workload from the course. Lastly, since no simulation tool could be implemented within the extension of edX, to test the practical skills; it was decided to use the same problem types for the Initial Knowledge Quiz and Final Assessment.

6.3. Validation Phase

Once all the course materials were finished and the logistical arrangements were set, it was critical to verify and run the pilot with a small group of experts on the field, to assure that every element on the course was properly designed, and that the content was accurate and in accordance with he standards of BMET training. With the help of A. Knulst and J. Dankelman, a group of 13 "pre-pilot testers" were gathered, which will be referred to as the "validation group". The division of experts included: four BMET instructors from the NSI in Nepal; one BMET from the United Mission Hospital Tansen, two BMETs from the Utrecht Medical Center, one Clinical Scientist from the Bristol Urological Institute and one Biomedical Engineering lecturer at the Kenyatta University. Furthermore, a group of younger participants were also gathered to collect some insights from the perspective of a student. Although one of them had no relevant experience on the field, the remaining were: a BME from La Paz Hospital in Spain, one BME M.Sc. from the Technical University of Munich and one PhD from TUDelft.

On 20TH July 2020, the "pre-pilot" was distributed to the validation group, and they were given a total of 7 days to go through it and give their feedback on the corresponding surveys. The 13 members were enrolled as students in the cohort Ⓐ, which was the one that had full access to the motivational video, and the interactive content. That way, all the interactive activities could be tested and ensure its proper grading and functioning. Between the 27TH and 30TH of July, their inputs, responses from the surveys and points to improve were collected. At the end of this period, 46% of the members went over the whole pilot and engaged with it, while 54% browsed thought the units.

Overall, it can be concluded that their feedback was very useful to modify some minor mistakes, in the content, which were pointed out by the experts; and also in the structure and experience of the course, which were highlighted by the younger participants. The components and units were adjusted accordingly and re-scored, so that the final version of the pilot was ready for distribution. On average, they graded the course with a 7.7$_{/10}$; and left some very positive feedback on the surveys regarding the interactive content (*"I think it is very useful to have exercises as part of the theory, so you force yourself to pay attention and go back to it in case you had any doubt. Also, the short videos were very clear and helped understand the concepts*"); "*In general I think the course was very nice, interesting and well organised*".

CHAPTER

7

Running the BMET Pilot MOOC: Delivery and Enrolment

After having finished and validated the content of the BMET Pilot MOOC, it was time to distribute it among the 119 respondents of the Participation Survey, who expressed their desired to test the preliminary content. The aim of the present chapter is to describe the procedure that was followed to deliver the course to the participants, arguing the tools and channels that were used to do so. Furthermore, it will also cover the steps of the enrolment on Edge, and the series of emails and reminders that were sent to the learners.

As it was covered in the previous chapter, the BMET Pilot MOOC was hosted in the private domain of edX, Edge; and therefore the learners needed to receive the URL or link to the course in order to gain access to it. The enrolment process for Edge starts in the Learning Management System website. Any team member with the appropriate credentials will find an exclusive button for the Instructors, where the membership of the students can be modified, and new learners can be enrolled in the course. This is what edX calls "Batch Enrolment", and allows the registration of multiple students, who will receive the notification with the course's link by email.

To avoid any further possible uncertainties, it was decided to send a secondary email to these 119 participants with the instructions, with a specific email account, directly linked to the BMET MOOC. The email account was: bmetonlinecourse@gmail.com. It had to be created under Google's mailing server, Gmail, because the account served a double purpose. In order to be able to upload videos to the units of the pilot course, the media elements had to be previously posted on YouTube. Even though some of the used videos in the course were from external YouTube channels, there were some original videos created specifically for this pilot, which had to be uploaded first to the BMET Online Course Channel.

Once the Gmail account was created, the communication with the participants was redirected to that email address, so that it could be monitored by both researchers. The invitation email was drafted to include the purpose behind the research, the request for their participation, the instructions on how to enrol via the separate email sent by edX with the course's URL, and an incentive to encourage the completion of the pilot. A copy of the email sent to the participants with all the details can be seen in **FIGURE 7.1.**

Email - 31ST July 2020
Participation Pilot Course - BMET Training

Dear participant,

You are receiving this email because you indicated you are willing to participate in the pilot course, as part of the development of a MOOC (Massive Open Online Course) for Biomedical Equipment Technicians (BMETs). First of all we would like to thank you for your time and contribution to this research. Your input is extremely valuable and will help us reach the maximum result! Together with your help, we aim to set the first important step in the development of freely available training to reduce the amount of out-of-service medical equipment in developing countries.

RESEARCH EXPLANATION

As you probably already know, together with the Technical University of Delft, the Nick Simons Institute in Nepal and other partners across the world, we are developing a MOOC to train Biomedical Equipment Technicians in Low-/Middle-Income Countries. The first step in the development of the MOOC is the creation of a pilot course. Via this pilot course we are investigating most effective teaching methods and tackle technical limitations or hurdles. The pilot course is set up to be a small part of the actual MOOC, and will consist of two modules; (1) Anatomy & Physiology , (2) technical learning, both applied to the patient monitor.

WHAT WE REQUEST FROM YOUR PARTICIPATION

We would like you to complete the pilot course in time and give feedback. We request to critically look at all aspects of the course (content, setup, layout, duration, difficulty, level, completeness, etc). This feedback can be given in the surveys you will find within the course; (1) 'Pre-survey', in which we question expectations and (2) 'Feedback on the course' in which we request your feedback on the course. You might need to make notes of any issues that you experience, in order to give complete and substantial feedback.

INSTRUCTIONS

Later today, you will receive an email from edX (the course platform), with an invitation to register and create an account. Once you have completed this step, an activation link will be sent by email, after confirmation via that link, you will be able to access the course! The pilot course is designed to be completed in less than four hours, including all surveys. The pilot is now open to start and will be open for 15 days, until Friday 14TH of August 23:59 (UTC+1, Amsterdam). This should allow flexibility to start and complete the pilot course whenever fits you best and at your own pace.

REWARD FOR PARTICIPATION

Since your feedback and input is of high value to this research and the development of the full course, we would like to thank you for participating by a reward:

We will grant everyone who has completed the complete pilot course within the set time frame (so finalise before the 15TH of August), with free access to the final MOOC to become a Biomedical Equipment Technician. For this MOOC, you will receive an official certificate of Delft University of Technology, the Netherlands.

In order to receive free access to the certificate granted course, you must meet the following conditions:

- Complete the pilot course within the set time frame (so finalise before the 15TH of August)
- Complete all parts of the course attentively; course statistics will show what material is used and completed. So partial participation will not count unfortunately. Only additional material provided by the course is not mandatory to fulfil these conditions.
- Complete both surveys; (1) Pre-survey and (2) Feedback on the course, which can be found and completed in the pilot course

If you have any questions or feedback, please do not hesitate to contact us! You can reach out by contacting the following email address: bmetonlinecourse@gmail.com

For now we would like to thank you once again for your time and contribution. Enjoy the course!

Best regards,

Daniel Garcia de las Heras and Roosmarijn Rutten

FIGURE 7.1. COPY OF THE INVITATION EMAIL SENT TO 119 PARTICIPANTS WITH THE INSTRUCTIONS ON HOW TO ENROL IN THE BMET PILOT MOOC

On July 31ST 2020, the invitation emails were sent, and the same email addresses were entered in the Batch Enrolment. This procedure was done one cohort at a time, to avoid any possible errors when assigning the participants to their corresponding cohorts, in accordance with the results of the stratified randomisation. In addition, the number of participants registering on the course was monitored daily, for the entire duration of the pilot. During this time, the Gmail account served as the main platform to communicate with those students with questions or doubts on the registration process.

By the end of the first week, only 23 out of 119 participants had fully finished the pilot, so it was decided to send the remaining 96, two consecutive reminders, requesting their participations on August 10TH and 12TH. Even though they served their purpose, and more learners finalised the course; it was decided to extend the completion date from the 14TH to the 17TH, only to those registered students who had started the units but not yet finished the Final Assessment. The BMET Pilot Course officially closed August 17TH with 42 valid participants. Nonetheless, after revising the submissions, it was discovered that 6 students completed everything, except the Entrance and/or End-of course survey. Thus, they were emailed individually requesting its completion before August 20TH. The final outcomes of the pilot will be presented in the next chapter.

PART IV

RESULTS

CHAPTER

8 Outcomes of the BMET Pilot MOOC

The one-time run of the BMET Pilot MOOC took place in the summer of 2020. After having the course content validated by 13 students and experts from the BME field, the invitations to the pilot were sent via email to 119 participants who expressed in the Participation Survey their willingness to test the preliminary content. On that account, the present chapter includes a detailed overview of the outcomes from the BMET pilot MOOC. Not only does it evaluate the engagement and academic results from all the learners, but it also encloses the statistical analysis to disclose which factors had an effect in the performance. These tests were performed under the standard Significance Level $\alpha = 0.05$ [78, 83-85]. Likewise, the eighth chapter of the thesis also covers the feedback given by the students in the Entrance and End-of-Course Surveys, as well as in the Non-Participation Survey, distributed to those who did not complete the pilot.

8.1. Pilot Course Engagement

The invitations for the BMET Pilot MOOC were sent on July 31ST 2020. Although the initial idea was to have it open for two weeks only, it ended up being available for a total period of 21 days. During this time, the progress of each participant was tracked and recorded on a spreadsheet using the program NUMBERS for MacOS [76]. Such progress came as a combination of data from the Google surveys and the Grade Reports, downloaded from edX, in CSV format. This allowed the researchers to have a daily perception of the engagement and completion rate of the MOOC. The spreadsheet with all scores and responses from the learners is presented in APPENDIX B, and its main figures are summarised in TABLE 8.1. Nonetheless, it is necessary to highlight that all the data included in this report was anonymised, and no personal details from the participants were published.

TABLE 8.1. MAIN FIGURES FROM THE BMET PILOT MOOC

INVITATIONS	FAILED EMAILS	EDX LOGIN	SURVEYS	VALID PARTICIPANT	GROUPS
132	3	86	68 & 57	48	24 & 24
Were sent to the participants (119), including the Validation Group (13).	Addresses were rejected when sending the invitations.	Course enrolments were registered on edX during this period.	Responses were collected from the Entrance and End-of course surveys, respectively	Learners fulfilled the requirements to be a Valid Participant and include their results in the study	The number of participants that were part of the each group Interactive and Not Interactive

As it can be seen in the table above, 10% of the invitations (13 in total) were destined to the Validation Group. Out of which 4 participants only enrolled and barely engaged in the actual course content; while the remaining 9 did actually complete every component of the course. Moreover, regarding the genuine pilot testers, they composed 90% of the invitations. Regrettably, three addresses failed to reach their corresponding owners, as the mailing server rejected them. The rest did received the edX enrolment instructions properly, and by the end of the MOOC, the platform registered a total of 73 usernames (or learners) with access to the course.

However, one thing was the enrolment process, and another was to truly start the MOOC. To put it another way, the data shows that not everyone who got access to the course, did actually engage with it (9.2% of the testers) or was able to find enough time to finish it (11.8%). Fortunately, there were a total of 48 participants that managed to complete every element of the pilot and thus, they met the requirements defined in Chapter 5 to be considered a Valid Participant.

When it comes to comparing the engagement between the four cohorts, it can be seen in **FIGURE 8.1** that there were at least 10 valid participants on each one of them, represented by the colour green. This translates to a balanced distribution of the engagement among the cohorts. In addition, in terms of the delivery method, the **INTERACTIVE CONTENT GROUP** was formed by 24 Valid participants: 14 from Ⓐ and 10 from Ⓒ. Interestingly, the **NOT INTERACTIVE CONTENT GROUP** also contained the same amount: 13 from Ⓑ and 11 from Ⓓ. Therefore, the rest of the participants that were not in these two groups, were classified as "Not Valid ", and accounted for almost 60% of the pilot testers.

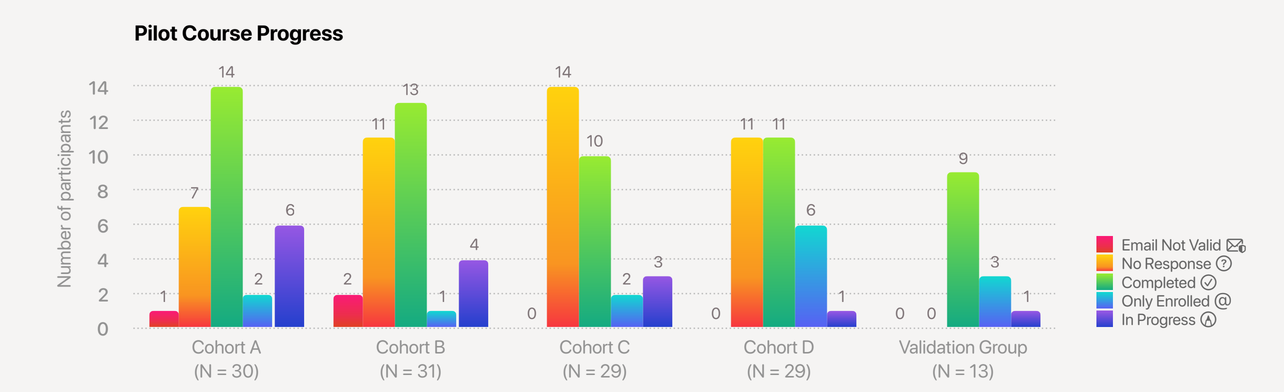

FIGURE 8.1. COMPARISON OF THE PILOT COURSE PROGRESS/ENGAGEMENT PER COHORT AND VALIDATION GROUP

At the same time, the Entrance and End-of-Course Surveys obtained a series of responses that had to be filtered to remove the duplicates. In general terms, both Surveys obtained 48 responses from Valid Participant and 8 from the Validation Group. However, the Entrance Survey included 12 sets of responses from learners that did not manage to finish the pilot on time, while the End-of-Course Survey included 1 response from a student that did not complete the Entrance one. Therefore, these 13 set of responses were discarded, as they were missing their equivalent on the other survey.

MOTIVATION TO FINISH THE COURSE

Did the presence of interactive content encourage the learners to complete the rest of the course? In order to answer this question, the relationship between the interactive factor and the motivation to finish the course had to be studied. The number of participants on each group that reached the Anatomy and Physiology Module were identified, and compared to the number of learners that finished all of the remaining units. The reason behind selecting this module was because it contained the first units of the course were the distinction of the delivery method (Interactive/Not Interactive) was made. These observed values are presented in the contingency table, with the marginal frequencies in **TABLE 8.2**.

TABLE 8.2. CONTINGENCY TABLE TO ANALYSE THE MOTIVATION TO FINISH THE PILOT

	STARTED A&P MODULE AND FINISHED THE PILOT	STARTED A&P MODULE AND DID NOT FINISH THE PILOT	TOTAL
Interactive Group	24	6	30
Not Interactive Group	24	4	28
Total	48	10	58

This data shows that there were a total of 58 participants that reached the A&P module and engaged with the interactive components, out of which only 48 finished the pilot. To check the relationship mentioned above, a Chi-square test for independence was computed using the data from the Contingency Table with the marginal frequencies. The null hypothesis H_0 being that the two categorical variables are independent from each other.

The results of the statistical test ($\chi^2(1) = 0.331$, $p = 0.564$) yielded a p-value bigger than the significance level (α=0.05). Hence, the null hypothesis is accepted and it is concluded that there is not enough evidence to suggest an association between the delivery method (Interactive and Not Interactive) and the motivation to complete the course [86]. Unfortunately, the equivalent analysis with the factor of the video could not be computed, as edX does not provide the details of which participants did in fact watch the video.

8.2. Grade Report: Final Grade and Performance

The final grade of the Pilot course was calculated based on the Grading System introduced in Chapter 6. Overall, it can be concluded that all of the participants passed the pilot study and obtained a grade higher than 60%. In order to test the normality of the distribution of these grades, a Shapiro-Wilk test was computed to check if the normal distribution model fitted the observations [87]. The null-hypothesis of this test is that the population is normally distributed.

In the end, the Shapiro-Wilk test showed a significant departure from normality, $W(48) = 0.828$, $p = 0.00$. This is visually represented in FIGURE 8.2.A, where the histogram of the final grades appears with an asymmetrical distribution, negatively skewed and positive kurtosis. The reason behind this behaviour is that the vast majority of the grades lied between 80%-90% (15) and 90%-100% (29). Furthermore, the distribution was also studied in terms of the independent variable of interest in this study: Delivery Method. Even though the Shapiro-Wilk test concluded the non-normal distribution for the Non interactive group, $W_{Non\ Interactive}(24) = 0.679$, $p = 0.00$; the final grades of those students presented with interactive components did followed a normal distribution: $W_{Interactive}(24) = 0.921$, $p = 0.063$. The individual group distributions are represented also in the same figure. As commented previously in Chapter 6, this mark is a mere indicator of the course engagement and progress.

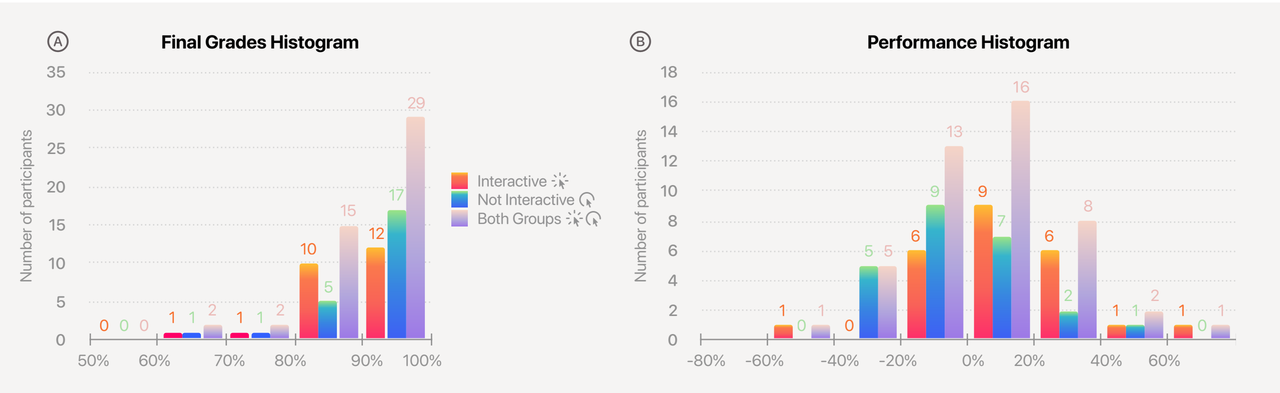

FIGURE 8.2. FINAL GRADES AND PERFORMANCE HISTOGRAMS COMPARING THE RESULTS FROM THE INTERACTIVE AND NOT INTERACTIVE GROUPS

The identical statistical analysis was also conducted for the performance, which was defined in Chapter 5 as the reference dependent variable to test the efficiency of the delivery method. Not only did the performance of the 48 valid participants follow a normal distribution, $W_{Performance}(48) = 0.980$, $p = 0.602$; but when it was segregated in groups based on the delivery method, both individually maintained the normality of their distributions: $W_{Interactive}(24) = 0.961$, $p = 0.463$ and $W_{Non\ Interactive}(24) = 0.959$, $p = 0.413$. The histogram of the performance can be seen in FIGURE 8.2.B. This analysis was required since normality is one of the main assumptions that the dependent variable has to meet in most of the statistical tests.

8.3. Effect of the Independent Variables and Covariates on Performance

The present section will assess which of the variables presented in TABLE 5.3 had a statistically significant effect on the Performance, and thus, need to be highlighted on the future BMET MOOC. The evaluation was performed in three clusters of variables: the first includes those related to the pilot course itself, the delivery method and the motivational video (from R.Rutten's thesis [70]); followed by those coming from the participants's experience on the BMET field, such as past training, current work and prior A&P Knowledge; and lastly, a demographic analysis to estimate wether the gender, age, education, location or device, could have also affected the results.

Before conducting the tests, it was important to study the descriptive statistics of the dependent variable, and see how it was distributed between the independent one and covariates; and among both groups of the delivery method. The **TABLE 8.3** presents the number of valid participants within each of the levels of the variables, as well as the performance mean from each group, extracted from SPSS.

TABLE 8.3. DISTRIBUTION OF PERFORMANCE AND VALID PARTICIPANTS THROUGH THE DIFFERENT INDEPENDENT VARIABLES AND COVARIATES

		TOTAL IN THE COURSE		INTERACTIVE		NOT INTERACTIVE	
		SIZE	PERFORMANCE	SIZE	PERFORMANCE	SIZE	PERFORMANCE
DELIVERY METHOD	Interactive	24	10.84%	24	10.84%	0	
	Not Interactive	24	-1.12%	0		24	-1.12%
MOTIVATION VIDEO	Motivation Video	27	1.54%	14	10.90%	13	-8.53%
	Not Motivation Video	21	9.12%	10	10.70%	11	7.64%
	Total	48	4.86%	24	10.84%	24	-1.12%
BMET TRAINING	At least one BMET Training	31	2.76%	14	7.51%	17	-1.14%
	Training in Progress	5	-2.02%	3	8.03%	2	-17.10%
	No Training	12	13.13%	7	18.70%	5	5.30%
	Total	48	4.86%	24	10.84	24	-1.12%
PROFESSIONAL EXPERIENCE	BMET in Company/Organisation	12	0.13%	5	-1.16%	7	1.06%
	BMET in Hospital	22	2.38%	13	7.25%	9	-4.64%
	BMET Instructor	5	9.84%	1	29.20%	4	5.00%
	BMET Student	4	7.50%	3	10.26%	1	-0.80%
	Retired BMET	3	-3.90%	0		3	-3.90%
	No Experience	2	55.85%	2	55.85%	0	
	Total	48	4.86%	24	10.84	24	-1.12%
A&P KNOWLEDGE	Had received an A&P course	38	18.98%	19	18.12%	19	19.41%
	No A&P Knowledge	10	27.36%	5	22.00%	5	27.78%
	Total	48	4.86%	24	10.84	24	-1.12%
LOCATION	Africa	22	2.38%	10	17.75%	12	-10.42%
	South-East-Asia	20	3.58%	10	3.60%	10	3.57%
	Europe	3	26.66%	2	15.00%	1	50.00%
	Eastern Mediterranean	1	25.00%	1	25.00%	0	
	Latin America	2	2.10%	1	-8.30%	1	12.50%
	Total	48	4.86%	24	10.84	24	-1.12%
GENDER	Female	5	23.00%	2	55.85%	3	1.10%
	Male	43	2.75%	22	6.75%	21	-1.43%
	Total	48	4.86%	24	10.84	24	-1.12%
AGE	21 - 25 years old	14	1.90%	6	10.00%	8	-4.17%
	26 - 30 years old	9	0.65%	6	0.7%	3	0.56%
	31 - 35 years old	10	10.99%	3	28.63%	7	3.42%
	36 - 40 years old	2	23.35%	2	23.35%	0	
	More than 40 years old	13	3.40%	7	9.05%	6	-3.20%
	Total	48	4.86%	24	10.84	24	-1.12%
EDUCATION	Elementary School	1	-34.20%	0		1	-34.20%
	High School	14	4.22%	6	9.86%	8	0.02%
	Bachelor's Degree	19	4.38%	10	8,84%	9	-0.55%
	Master's Degree	10	11.09%	6	10.71%	4	11.65%
	PhD's	1	-7.50%	0		1	-7.50%
	Postgraduate	3	7.20%	2	24.15%	1	-26.70%
	Total	48	4.86%	24	10.84	24	-1.12%
DEVICE	Desktop	6	19.03%	3	19.46%	3	18.60%
	Laptop	27	3.39%	11	12.28%	16	-2.71%
	Smartphone	14	-0.12%	9	4.16%	5	-7.84%
	Tablet	1	29.20%	1	29.20%	0	
	Total	48	4.86%	24	10.84	24	-1.12%

It can be seen that each cell combination of variables with the delivery method holds a similar number of participants, implying a balanced design. Moreover, the standard deviations σ (the square root of the variance) were not included in the table, since each ANOVA test will later check for equal population variances between groups through the Levene's Test.

This data was later used to compute the different two-way ANOVAs, with the purpose of understanding whether there are any interrelationships between the nine factors presented in TABLE 8.3, and the dependent variable, which in this case is the performance [88]. The two-way ANOVAs were computed in SPSS [89] to test three null hypothesis: the means of observations grouped by one factor are the same; the means of observations grouped by the second factor are the same; and that there is no interaction between the two factors. For significant main effects of those variables with more than two levels, a Post Hoc was included; while for significant interactions between covariates and delivery method, a simple main effects study was performed.

On another note, it is relevant to mention that it was feasible to compute the two-way ANOVAs because the main assumptions required by the test were met: (1) the performance was a continuous dependent variable, and normally distributed, as proven in section 8.2; (2) the data came from independent observations, as there were exclusive participants in each group; and (3) the homoscedasticity or homogeneity of variance, meaning that the standard deviation of the dependent variable was equal for each group combination of respondents. This last assumption was validated individually on each ANOVA, as SPSS conducted a simultaneously a Levene's test, with the null hypothesis that the population variances are equal, or homoscedastic.

8.3.1. Delivery Method and Motivation Video

Since the data obtained from the pilot came from a double-factor study, the first step was to determine wether there the Motivational Video from R. Rutten's thesis [70] influenced the performance results, or if there was a statistically significant interrelation between this factor and the delivery method. A two-way ANOVA was conducted that examined the effect of delivery method and motivational video on the performance of the pilot study. Levene's test (p = 0.959) indicated that the variances between the groups were statistically equal. Besides, a Post Hoc test was not needed, as there were only two levels per variable.

The ANOVA test could not demonstrate an interaction between the independent variables (delivery method and motivational video), $F_{\text{Delivery Method*Motivational Video}}(1, 44) = 1.721, p = 0.196$. On the other hand, the results of the F statistic proved that those participants presented with Interactive content in the units of the A&P Module performed better in the Final Assessment, compared to the Initial Knowledge Quiz; than those students with regular/non interactive content: $F_{\text{Delivery Method}}(1, 46) = 3.644, p = 0.031$ (see FIGURE 8.3.A). However, the motivational video did not present a sufficiently significant effect on the results of the performance: $F_{\text{Motivational Video}}(1, 46) = 1.374, p = 0.247$ (FIGURE 8.3.B).

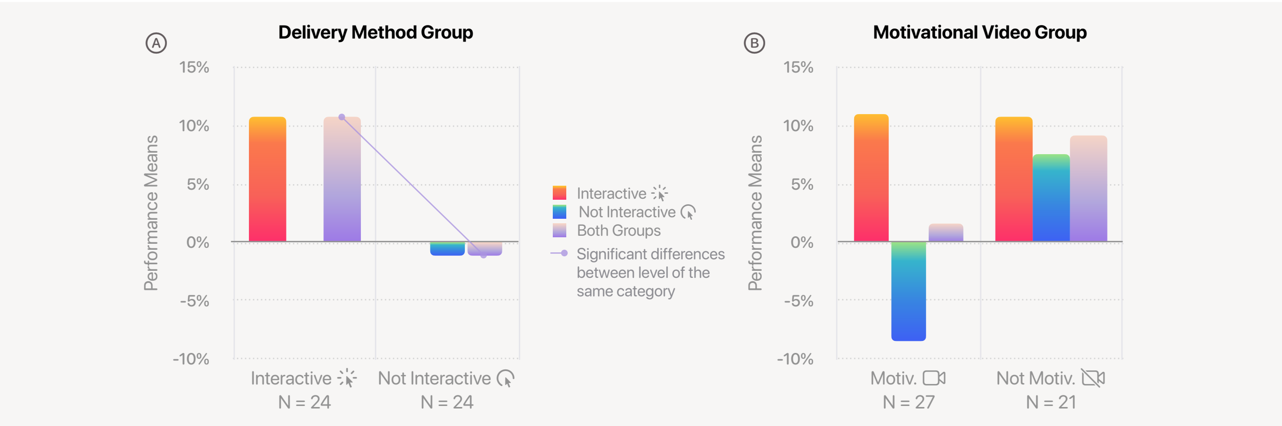

FIGURE 8.3. SIMPLE MAIN EFFECTS PLOT REPRESENTING THE INTERACTION BETWEEN THE COVARIATES LOCATION (A) AND GENDER (B) WITH THE INDEPENDENT VARIABLE (DELIVERY METHOD)

To further analyse these results, it was decided to conduct a Chi-square test for independence to test the dependency of the independent variables from the performance. The contingency table was built after identifying those participant who improved their performance (positive result) after the pilot, and those that worsen it. The results are presented in TABLE 8.3. In the end, an association between the delivery method and performance efficiency was observed χ^2 (1) = 4.148, p = 0.042, with a Cramer's V effect of $\phi_c = 0.294$, which indicates a moderate association of these two categorical variables [83]. On the other hand, there was not enough evidence to suggest a dependency between the motivational video and performance efficiency, χ^2 (1) = 1.646, p = 0.199 [86].

TABLE 8.4. CONTINGENCY TABLE TO ANALYSE THE ASSOCIATION BETWEEN THE PERFORMANCE AND DELIVERY METHOD OR MOTIVATION VIDEO

	INTERACTIVE	NOT INTERACTIVE	TOTAL	MOTIVATION	NO MOTIVATION	TOTAL
Improved Performance	17	10	27	13	14	27
Negative Performance	7	14	21	14	7	21
Total	24	24	**48**	27	21	**48**

From these results, it can be concluded that the delivery method, which was the factor of relevance for this thesis, did indeed have a significant effect on the outcomes of the pilot study. The main effect analysis shows that this factor improved the performance of those students who were presented with interactive components by a 10.84%, when compared to those students exposed to regular content. Therefore, since it was not affected by the other independent variable present in the study, the delivery method will be used as the main factor to asses the interaction effect of the remaining variables. Even though they were defined as covariates, their effect will be evaluated via a two-way ANOVA, and not the ANCOVA, because they are all categorical variables and not continuous ones

8.3.2. Participants Previous Experience

The present study followed a unique curriculum for the Pilot BMET MOOC, as presented in CHAPTER 5. All the participants were presented with course content based on a single difficulty level, without considering their previous experience on the BMET field. This subsection aims to study if such prior work experience, training, or A&P knowledge could have had an effect on the student performance on the course. The outcome of this analysis will be the crucial to decide wether the content of the future MOOC needs to be segregated in levels of difficulty based on the participants previous experience, or if a single level will be sufficient to report satisfactory outcomes from the students.

In the Participation Survey, presented in Chapter 4, the learners reported the BMET Training Experience they had before enrolling the pilot. A two-way ANOVA was conducted to examine the differences in performance by Delivery Method (interactive vs. non interactive) and BMET Training Experience (no Training vs. Training in Progress vs. Training). A non-significant Levene's test ($p = 0.137$) indicated that the population was homoscedastic. However, the results from the test could not demonstrate a significant interaction between these variables: $F_{\text{Delivery Method*Training}}(2, 42) = 0.305, p = 0.739$. Additionally, there was not a statistically significant difference between training groups: $F_{\text{Training}}(2, 42) = 1.139, p = 0.330$. The results of the Post Hoc test also demonstrated that the average performance was equal for the three training groups.

During the pilot, the beta testers were asked wether they had received a course on A&P before enrolling in edX. The answers were recorded: 79.16% learners did have previous knowledge on this subject, while 20.8% were new to it. The distribution per groups presented equal variances, as demonstrated by Levene's test ($p = 0.807$), so the two-way ANOVA was computed. An interaction between Interactive/Non Interactive components and Knowledge on A&P could not be demonstrated, $F_{\text{Delivery Method*A\&P Knowledge}}(1, 44) = 1.589, p = 0.214$. However, on its own, FIGURE 8.4.B shows that the participants with no A&P education performed better than those with prior knowledge on the subject: $F_{\text{A\&P Knowledge}}(1, 44) = 8.251, p = 0.006$. In other words, the pilot course improved, by a 27.36%, the participant's performance on the main A&P concepts required by the BMET profession.

Finally, the Entrance survey provided information regarding the testers' professional experience, and whether they were BMETs for a hospital or company, instructors, students, already retired, or had no experience at all. Since the Levene's test ($p = 0.062$) indicated that variances between the groups were statistically equal, a two-way ANOVA was conducted , which examined the effect of these levels of experience and delivery method on the performance. Although an interaction between both variables could not be demonstrated ($F_{\text{Delivery Method*Professional Experience}}(2, 42) = 0.471, p = 0.704$), there was a statistically significant difference in performance between the different experience levels: $F_{\text{Professional Experience}}(3, 38) = 2.451, p = 0.049$ (see FIGURE 8.4.A). Tukey's post hoc test revealed that the performance in the A&P Module was statistically significantly lower for the learners working on a Company ($\bar{x} = 0.13\%$, $p = 0.013$), on a Hospital ($\bar{x} = 2.38\%$, $p = 0.014$), and retired BMET ($\bar{x} = -3.90\%$, $p = 0.032$) compared to those with no experience on the field ($\bar{x} = 55.85\%$). There was no statistically significant difference between the BMET Instructors and students with the other groups.

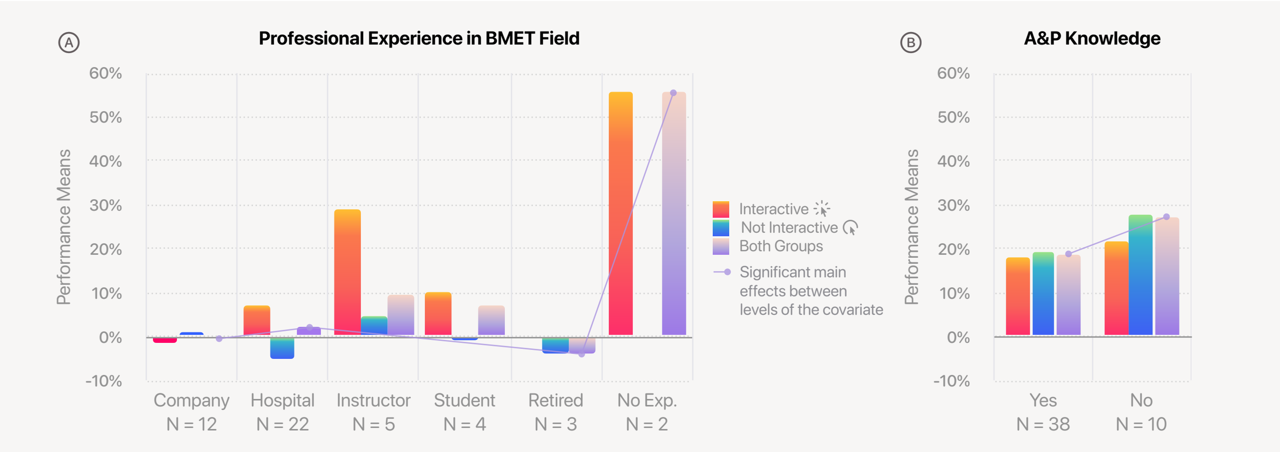

FIGURE 8.4. MAIN EFFECTS OF THE DIFFERENCES IN PERFORMANCE BETWEEN THE COVARIATES PROFESSIONAL EXPERIENCE (A) AND A&P KNOWLEDGE (B), WITH THE INDEPENDENT VARIABLE (DELIVERY METHOD)

8.3.3. Demographic Analysis

Are there significant differences in the Performance related to the delivery method and the participant's demographic background? The statistical analysis presented in this subsection will resolve which variables associated to the learners might have affected the outcome, and thus, have to be taken into consideration when building the profile of the targeted audience for the future BMET MOOC.

The analysis begun with the Location, examining the region of origin of the participants influenced the performance. The test for homogeneity of variance for this covariate was not significant (p = 0.208), indicating that this assumption underlying the application of the two-way ANOVA was met. The results for the two-way ANOVA indicated a not significant main effect for Location: $F_{Location}(4, 39) = 1.532$, p = 0.212. Besides, the outcomes of the post hoc test did not demonstrate any effects on performance from those participants from Africa as compared to those from South-East Asia, Europe, Eastern Mediterranean or Latin America. On the other hand, the results showed a significant interaction between the location and delivery method, $F_{Delivery\ Method*Location}(3, 39) = 3.344$, p = 0.029. In other words, any differences between the five regions were the participants were from, depended on which group the subjects were on, and vice versa.

To further study and understand this interaction, a line graph plotting the mean Performance score for each combination of levels of "Location" and "Delivery method" was included in **FIGURE 8.5.A**. Moreover, a simple main effect analysis was also computed for each of the independent variables individually. For the Delivery Method simple main effects, the only significant difference between Interactive and Not Interactive content groups was found in the participants from the African region. A review of the group means indicated that the interactive components ($\bar{x}$ = 17.75%) produced a significantly higher efficient performance for this group than the regular units ($\bar{x}$ =-10.42%), $F_{Africa\ (vs.)}(1, 39) = 10.539$, p = 0.002. On top of that, the Location simple main effects were also examined. In other words, the differences among the five WHO-defined regions for Interactive and Not interactive groups separately. There were significant differences among the locations for the Not Interactive group: $F_{*Location}(4, 39) = 3.292$, p = 0.030. Follow-up tests were conducted to evaluate the Locations' pairwise differences for Not Interactive, which showed that Europeans ($\bar{x}$ = 50.00%) performed simnifically higher than Africans ($\bar{x}$ =-10.42%, p = 0.007) and South-East Asians ($\bar{x}$ =3.57%, p = 0.035).

Concerning the gender variable, 89.6% of the valid participants were male, while the remaining 10.4% were female. This unbalanced distribution of genders was reflected on the sample sized for each groups, with only 2 females out of the 22 males in the Interactive group. Nonetheless, the Levene's Test for equal variances confirmed that the homoscedasticity assumption was met (p = 0.273). Thus, it was viable to proceed with the Two-way ANOVA, whose results indicated a significant main effect for gender, $F_{Gender}(1, 44) = 7.343$, p = 0.010. Additionally, the results show a significant interaction between gender and the delivery method, $F_{Delivery\ Method*Gender}(1, 44) = 5.970$, p = 0.019, indicating that any differences between each of the variables' levels were dependent upon the other's.

Because the interaction between both variables was significant, it was decided to set the two main effects aside, and instead first examine the gender simple main effects, that is, the differences between females and males for each of the two delivery method groups. The only significant difference between the genders was found in the Interactive group, where females ($\bar{x}$ = 55.85%) performed significantly better the A&P module than males ($\bar{x}$ = 6.75%), $F_{(♂ \text{ vs. } ♀)}(1, 44) = 11.276$, $p = 0.002$. When inspecting the delivery method simple main effects, a significant difference between the females involved in the interactive group ($\bar{x}$ = 55.85%) and those presented with standard content ($\bar{x}$ = 1.10%), $F_{\text{Female} ♀ (\text{vs.})}(1, 44) = 9.177$, $p = 0.004$ was found. This interaction is represented in FIGURE 8.5.B.

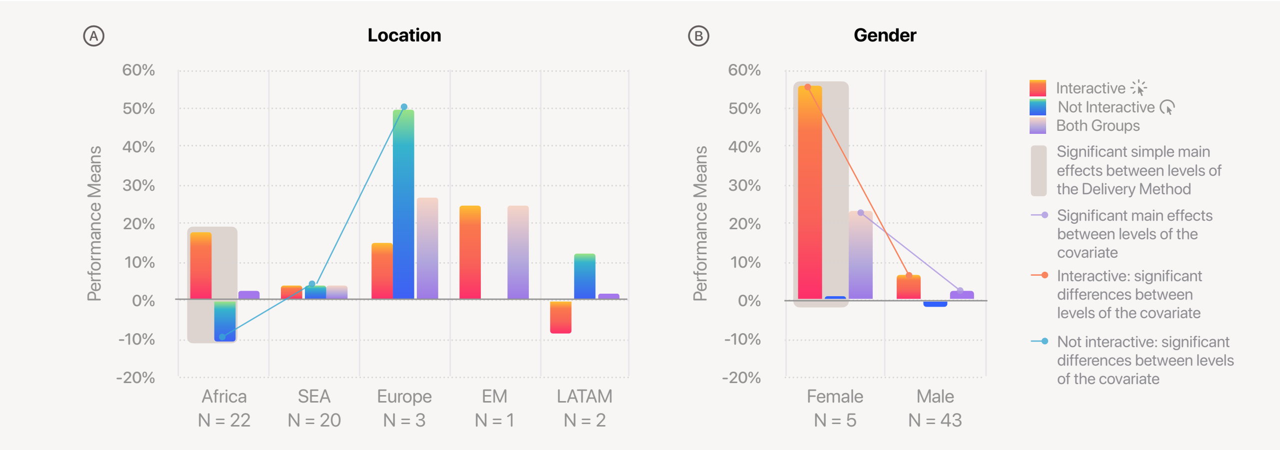

FIGURE 8.5. SIMPLE MAIN EFFECTS PLOT REPRESENTING THE INTERACTION BETWEEN THE COVARIATES LOCATION (A) AND GENDER (B) WITH THE INDEPENDENT VARIABLE (DELIVERY METHOD)

Lastly, although the Levene's test for remaining covariates (p_{Age}= 0.399, $p_{Education}$= 0.237, p_{Device}= 0.527) proved that they the assumption of homoscedasticity was held, the results of the respective two-way ANOVAS with the independent variable could not demonstrate a significant interaction between them: $F_{\text{Delivery Method*Age}}(3, 39) = 0.433$, $p = 0.731$; $F_{\text{Delivery Method*Education}}(3, 38) = 0.942$, $p = 0.430$; and $F_{\text{Delivery Method*Device}}(2, 41) = 0.259$, $p = 0.773$. Furthermore, on their own, none of the three variables obtained a statistically significant difference among the performances of their different levels: $F_{Age}(4, 39) = 0.804$, $p = 0.530$; $F_{Education}(5, 38) = 0.568$, $p = 0.724$; and $F_{Device}(3, 41) = 1.545$, $p = 0.217$. This result was sustained by the results of three Tukey's Post Hoc Tests.

8.4. Feedback from the Participants

The Entrance and End-of-Course surveys embedded in the pilot, served as the main platform to collect the inputs, feedback and evaluation of the course from the learners. All the responses presented in this section belong to the valid participants. All 48 of them, agreed on the Inform Consent Form included in both surveys, so that their answers could be used as part of the study's research. Before diving into the evaluation of the pilot and inputs for the future MOOC, it is significant to mention two variables related to the users experience with the course, and its correlation to the performance.

As it was introduced previously, one of the main challenges for e-learning in LMIC is the lack of proper infrastructures to provide a reliable internet connection to the population [18]. Since 91.6% of the pilot testers came from regions with LMICs, on the Entrance Survey they were asked to evaluate their connection to the internet at the place where they started the pilot. Taking into considerations the results of the delivery method in the previous section, the correlation between the performance and internet reliability was studied diving the subjects by Interactive and Not interactive groups.

On average the participants reported the reliability of their internet connection with a grade of 6.9 out of 10. Nonetheless, the average internet's reliability reported by the interactive group ($^{6.76}/_{10}$) was significantly lower than the one of the not interactive group ($^{7.38}/_{10}$), $t_{\text{Internet Reliability}}(46) = -1.684$, $p = 0.049$. On this account, in order to understand to which extend these variables are related, the Pearson correlation coefficient was calculated for both groups. A very weak inverse relationship between the performance and internet's reliability can observed in the scatter plot of FIGURE 8.6.A. Nonetheless, none of the delivery methods reported a significant correlation: $R_{\text{Internet}}(22) = -0.042$, $p = 0.845$; and $R_{\text{Internet}} = -0.113$, $p = 0.599$.

On another note, in the Participation Survey, the respondents set their preferred duration of the pilot course to be 6 hours maximum. On average, the 48 valid participants spent 5.85 hours. However, there was a difference of 1.21 hours between the delivery methods' groups. Even though the distribution of this variable followed a normal distribution for the Interactive group, the same did not apply for the other not interactive method, as reported by a Shapiro-Wilk test W_{Spent} (24) = 0.882, p = 0.009. Thus, to compare the mean duration of both groups, a non-parametric, Mann Whitney U test was computed: $U_{Pilot\ Duration}$ = 372.00, p = 0.001. The result shows that the time spent by the interactive group (6.46 h) is statistically significantly greater than the time reported by the non-interactive population (5.25 h).

Lastly, it was decided to check if such difference between groups had an effect or relationships with the performance. Similarly to the Internet variable, the Pearson correlation coefficient and scatter plots were computed. Although a moderate positive relationship between the performance of interactive group and time could be observed in **FIGURE 8.6.B**, the results of the test did not conclude a significant relationship between these variables, for either group: $R_{Duration}$ (22) = 0.208, p = 0.327; and $R_{Duration}$ (22) =-0.149, p = 0.487.

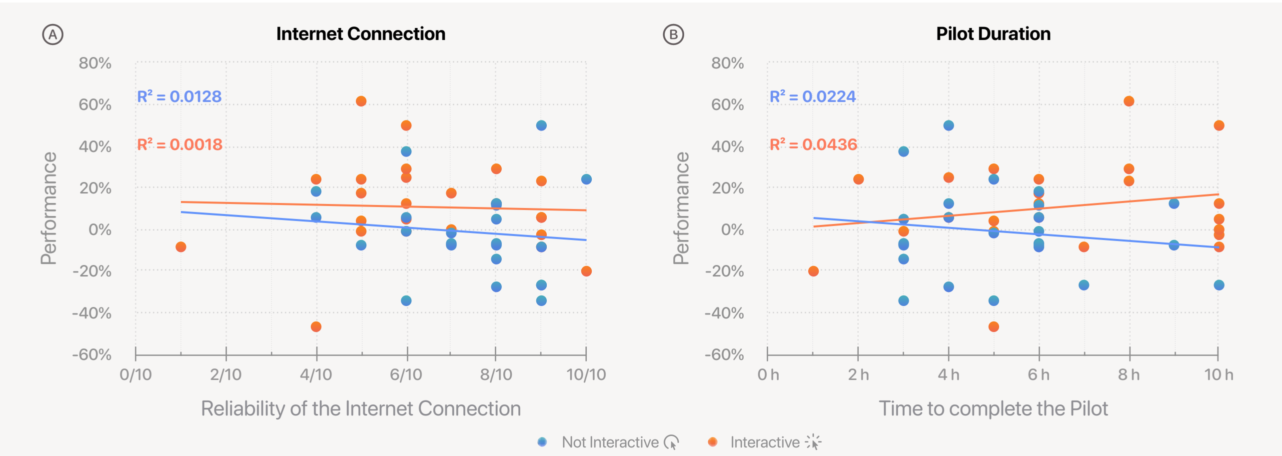

FIGURE 8.6. SCATTER PLOT REPRESENTING THE LINEAR RELATIONSHIP BETWEEN THE PERFORMANCE AND THE INTERNET RELIABILITY (A), AND THE PERFORMANCE WITH THE TIME NEEDED TO COMPLETE THE PILOT (B)

8.4.1. Evaluation of the Pilot Course

In other to build a successful online BMET course, it was important to empathise with the learners, understand their perspective and see which are the aspirations that motivate them to enrol in the course. One of the participants described their expectations of the pilot as the following: "*With this online course, I expect to have a greater understanding of the contents and troubleshoot the issues and improve the solving of the problems. Along with this, it helps to build a platform to interact with fellow colleagues within the country as well as abroad. Besides it would help to improve our knowledge and understanding of various aspects*". Similarly, other student wrote: "*I believe that I will be able to gather more knowledge and information on biomedical equipment. I hope this course will help me to interact with highly educated and successful professors and also with friends from around the globe who are part of this course. Finally, I hope this course will increase overall skill as a BMET*". These two statements serve as a great example to summarise the expectations for the remaining 46 participants. Overall, it can be seen that the main motivation to enrol in the course was the opportunity to recall and refresh their previous biomedical knowledge, while learning new methods, competencies and skills in maintenance, troubleshooting and repair; so as to deal with the equipment with confidence, and become more proficient at their profession.

However, sometimes such expectations can be hampered by sudden challenges or technical limitations, caused either by the course's logistics, or by the learners personal situation. In the case of the pilot, 58.3% of the learners did not report any limitations whilst looking at the course content. However, 16.6% found some constraints caused by their device. The issues were mainly linked to the "Drag and Drop" exercises, as they had difficulties answering those questions in small-screen devices. Another type of problem that lead to unpleasant experiences were the "Short Answer" questions, as explained by 14.5% of the participants. In these type of exercises, all the possible correct inputs need to be contemplated within the question's set up in order to be graded as correct. Hence, similar, not-included answers or spelling errors can lead to a wrong response. Lastly, for the remaining 10% of the learners, 5 reported difficulties with the internet connection, and could not play the videos or see the images; while two of them requested more linguistic availability.

DESIGN AND USER EXPERIENCE

Leaving these challenges aside, from the ratings reported in TABLE 8.5, it can be acknowledged that the overall experience in the course was pleasant, as the average grade from the 46 valid participants was 8.25/10. They rated the usefulness of the content as the main attribute of the course, with a 9.25/10. This characteristic was closely followed by its interesting aspects (8.92/10) and uniqueness (8.25/10). Furthermore, it was pleasant to discover that the design of the course, including user experience and user interface, obtained a grade higher than 8 for both groups: interactive (8.17/10) and not interactive (8.21/10).

TABLE 8.5. RATINGS FROM THE VALID PARTICIPANTS ON VARIOUS ASPECTS OF THE PILOT COURSE

DESIGN (UX AND UI)	CLARITY OF QUESTIONS AND CONTENT	USEFULNESS	UNIQUENESS	INTERESTING	OVERALL GRADE
8.18/10	7.80/10	9.25/10	8.25/10	8.92/10	8.25/10

On the other hand, an aspect that need to be worked on, is the clarity of questions and content, so that it can be understood more clearly, even for those who are not proficient at English. Besides, another facet that 25% agreed that should be improved, are the units containing the repair and troubleshooting topics, as they requested more in depth knowledge on the electrical and circuit level aspects, mentioning applied parts, leak protection, leak currents and it's potential effects on the human body. This request was coupled with the petition of 12.5% of the learners to include more videos in these units, as they rather watch the content than having to read it. Even though the vast majority of the participants agreed on the importance and usefulness of the lectures included within the Patient Monitor's Module, the easiness to follow the content, the evaluation methods and the helpfulness of the videos; 37.5% did also include the Anatomy and Physiology module as one of the most valuable components of the course, as it improved their understanding of biomedical devices. Lastly, one other aspect that has to be taken into account for the design, its the preferred problem type. Despite some users facing challenges in smaller-screen devices, 43.75% liked better the drag and drop exercises, over the multiple choice (39.58%) and drop down menus/short answers (16.67%).

DIFFICULTY LEVEL, WORKLOAD AND COURSE SET UP

The participants were also asked to evaluate certain aspects related to the course materials. One of these points, was the difficulty level of the content included in the pilot, and 75% of the participants concluded that it was appropriate based on their previous experience, with only one participant rating it "as too difficult to follow". What's more, since there was a distinction made in the method to deliver the materials to the students, it was important to evaluate if the presence of interactive content resulted redundant for this group, compared to the regular one.

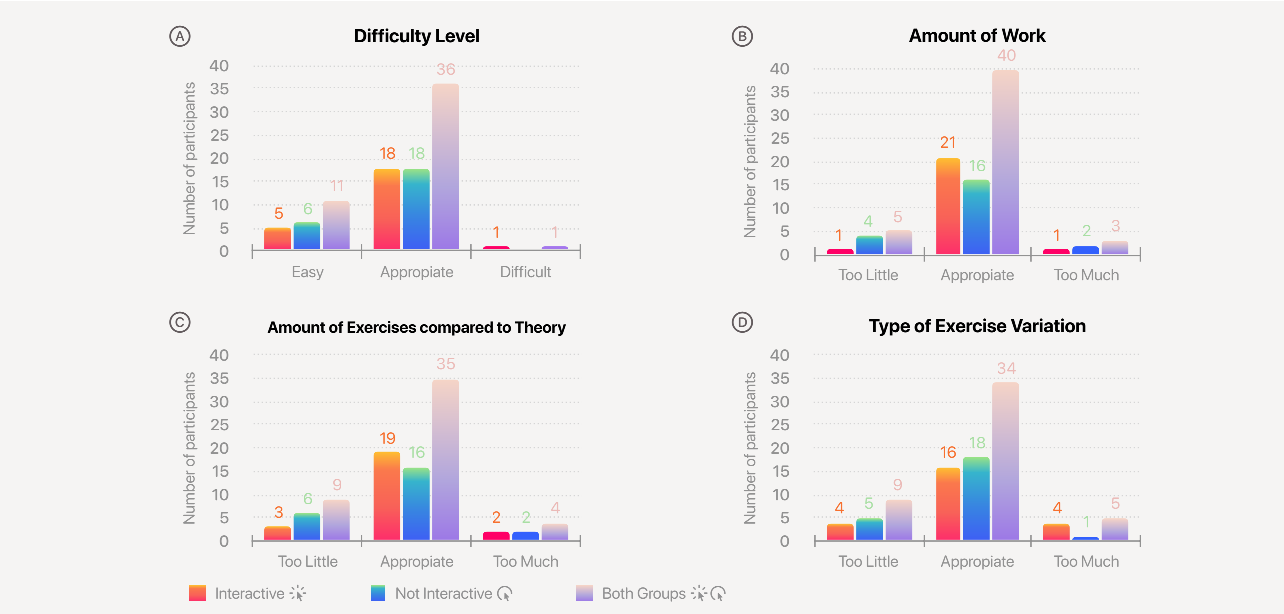

FIGURE 8.7. EVALUATION OF THE PARTICIPANTS ON DIFFICULTY LEVEL (A), WORKLOAD (B), AMOUNT OF EXERCISES (C), AND EXERCISE VARIATION (D)

As it can be seen in FIGURE 8.5.B, 83.3% of the valid participants reported that the amount of work presented in the course was appropriate, out of which 21 participants belonged to the interactive group. Additionally, the ratio between the amount of exercises and theory was graded as adequate by 73% of the participants, as shown in FIGURE 8.7.C. Similarly, 75% of the students also considered the variation in problem type as suitable. The distinctions of these four factors between the delivery method group are represented in FIGURE 8.7.

8.4.2. Inputs for the Future BMET MOOC

This subsection aims to summarise the feedback given on certain aspects which will be useful for the future BMET MOOC. To begin with, the learners were asked to rate a series of factors that would influence their decision to enrol a MOOC. The one that obtained the highest grade was the importance of the Universities involved in the creation and running of the online course, with a 8.75/10. This was closely followed by the opportunity of obtaining a certificate, the potential usefulness of the course in their studies and/or professional career, and the future perspectives offered/made possible by completing the MOOC (8.63/10, 8.58/10 and 8.54/10). Thirdly, the participants would look at the pace and flexibility offered by the course's schedule (8.50/10), followed by the curriculum and content (8.21/10) and the language of the materials (7.92/10). Finally, the factors graded as the least important included the possibility of following the course online, without the need of face-to-face lectures, and the overall duration of the MOOC (with a grade of 7.83/10 for both).

On top of that, the learners were also asked what do they considered as the biggest challenge to successfully finalise the MOOC on time. As it can be seen in FIGURE 8.8.A, the vast majority of the participants concluded that allocating sufficient time and combining their participation with other life obligations, was the most difficult task they encountered. Coming behind were the internet connection (16.6%), comprehending the course content to keep up to the level of the course (10.4%) and meeting the set deadlines (0.4%). Lastly, only one participant reported the use and understanding of the edX platform as the main inconvenient.

Regarding the optimal guidance and flexibility that the course should offer, it can be extrapolated from FIGURE 8.8.B that 77% of the participants preferred to have either no deadlines at all, or some recommended ones, so that the course could be followed at their own pace.

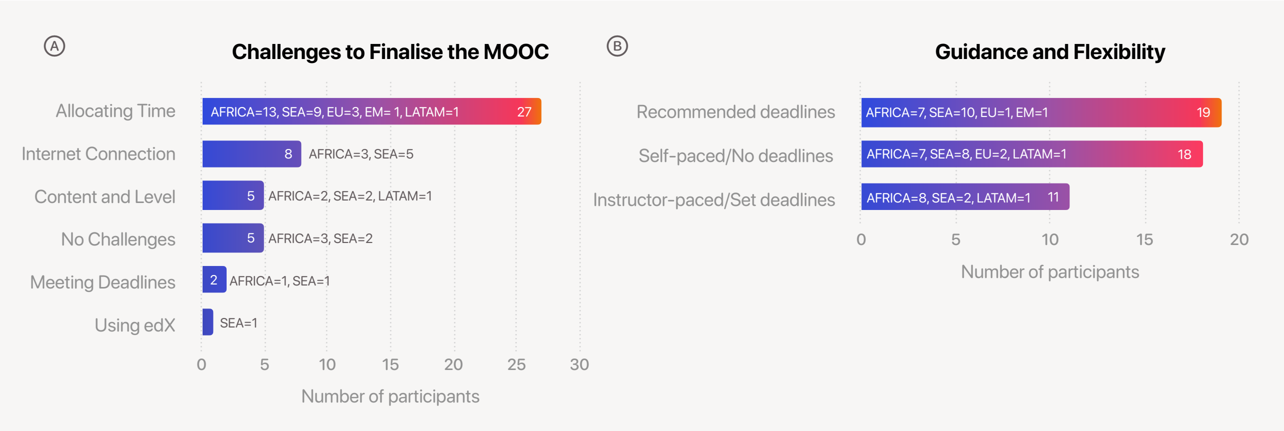

FIGURE 8.8. MAIN CHALLENGES TO FINALISE THE MOOC (A) AND PREFERRED GUIDANCE AND FLEXIBILITY IN FUTURE MOOC (B)

Lastly, the participants were asked in the End-of-Course Survey if there was a particular piece of equipment/medical device that they believed should be included in the curriculum of the final MOOC. The most common answer, repeated by 23% of the participants was the Ventilator and Oxygen Concentrators. This response was followed by another 8% that mentioned the imaging equipment, such as: x-ray machines, CT scans, MRIs and ultrasound devices. The remaining answers included the following equipment: anaesthesia machine, defibrillator, electro-surgical unit, haemodialysis machine, heath-lung machine, neonatal incubator, syringe pump and PCR instruments.

All in all, it can be concluded that the participants' experience with the pilot was pleasant, as one learner said: "*This course has been very productive and insightful for me. I have added gained a lot of knowledge. I am very thankful to all who designed this course*". A similar opinion: "*This pilot course is seems to be much useful for BMETs. We are looking forwards to its final version to gain more skills and knowledge about different equipments*". In addition, the learners provided really useful feedback and inputs which will be taken into account for the final version of the MOOC.

8.5. Non-Participation Survey

Once the course was closed, there were a total of 71 participants who initially expressed their desire to take part in the pilot but did not actually finish it, or met the requirements presented in Chapter 5 to be considered a valid participant for the study. Taking a closer look at this group, there were: 3 not valid email addresses, 43 of them who received the invitation but did not register in edX, 11 learners who only enrolled but did not engaged with the course content, 10 who stopped participating halfway through the course and 4 that only responded to one of the two surveys embedded in the pilot.

In spite of not considering them as valid participant, it was still relevant to learn from their point of view and see what did not properly work for them. Therefore, a Non-Participation Survey, in Google Forms, was distributed to those 71 individuals. The survey obtained a total of 16 responses from the non-valid participants, which means that only 22.5% of them submitted it. It is relevant to mention that they agreed on the Informed Consent Form present in this survey as well. Out of these non-participants: 43.75% reported they had issues during the registration process in edX, or with the email invitation; the time or place were not suitable for 18.75%; 12.5% misunderstood the deadlines; and the remaining 25% either had issues with the internet connection, or their devices caused limitations, or missed the End-of-Course Survey. On the other hand, they all mentioned their interest in the final version, and 43.75% also included the ventilator as a key device that should be included in the final MOOC.

PART V

EVALUATION

CHAPTER

9
Discussion & Recommendations

The aim of this research is to understand which combination of factors related to a MOOC's design, structure, logistics, content and delivery method; result in a better course performance, engagement and experience for the user; and consequently, how to translate these findings to the future design of the BMET MOOC to maximise impact. This chapter will reflect upon the results obtained after the first run of the BMET Pilot MOOC, to determine its research contribution, and to introduce an overall discussion on the topics that consolidate this thesis project; as well as the recommendations for future research. Furthermore, the most significant research limitations and contributions will also be discussed.

9.1. Discussion on the BMET Pilot MOOC

The pilot study was designed to be a small replica of the Full BMET MOOC, so that it could be tested and evaluated prior to its public release; its structure was based on the predefined MOOC's blueprint and curriculum; which were explained in Chapter 5. Moreover, its content was subdivided in four Modules, out of which one corresponded to the basis of the Patient Monitor, including the topics on repair and preventive maintenance; while the other covered the anatomical and physiological units related to the functioning of such medical device. In other words, the Patient Monitor served as the perfect example.

On another note, the units within the course were designed in a way so that two different research questions could be evaluated: the potential benefits of motivational incentives in the form of a video, by R. Rutten [70]; and the efficiency effects of changing the delivery method from standard content to interactive one, by D. G. de las Heras. The final platform, which was selected for the experimental course, was edX Edge; as it offered a controlled environment to create and run the study. As a result of this choice, all the process was supervised and supported by the TUDelft Online Learning team.

The pilot was formulated with the following attributes: (1) as a Single Blinded Study, since only the researchers were aware that the participants were being exposed to contrasting factors to evaluate the differences; (2) Between-Subjects Experiments were conducted, in which the participants were assigned to similar groups, with the only difference being that each was exposed to a contrasting delivery methods; and (3) it was a Randomised Controlled Trial, as the group allocation followed a Stratified Randomisation, balanced by two covariates, to prevent disparities between cohorts.

Lastly, all of the participants were informed of the objectives of the study, and that their results and inputs in the pilot would be used for future research. As a result, since the approval to conduct the research was granted by the Human Research Ethics Committee (HREC) from the Delft University of Technology; the one-time run of the BMET Pilot MOOC took place in the summer of 2020. After having the course content validated by 13 students and experts from the BME field, the invitations to the pilot were sent via email to 119 participants that expressed their willingness to test the preliminary content. The sections below will discuss in detail the meaning behind the findings on the platform, course participation, and performance outcomes.

EVALUATION OF EDX AS THE MOOC PLATFORM

Even though the mobile app presented in Chapter 3, offered a great deal of freedom and facilities for the design of the MOOC; it also revealed some weaknesses when it came to providing the course with sufficient credentials to be valid/accepted in most LMIC. As a result, other alternatives with more credibility and authenticity were considered. In the end, edX Edge was selected as the desired platform to continue with the project for its trusted, global framework; and the round-the-clock support and guidance offered by the TUDelft Extension School during the design process. This sections aims to evaluate the platform of choice over the criteria defined after the literature study, and discuss the main findings:

- One of the main advantages of edX is that not only it allowed the participants to follow the course and interact with the materials/exercises on the screen of smaller devices like mobile phones; but when accessing the content through their native app, it also offered them the option to download the material or make it available without an internet connection. Nonetheless, it must be highlighted that when setting up the problems and figures in the course's units, special attention has to be drawn to the dimensions of the smartphones' screens, as 16.6% of the participants reported difficulties when attempting these exercises.
- Following the same line of argumentation, an attribute which is also associated to edX its the prestige of the platform; and the possibility of obtaining a payed certificate when successfully completing one of the courses on their catalogue. For many students, a diploma which such relevance, can lead to great improvement in their professional career. This was reflected on their evaluation forms, as they rated "the universities involved in the creation and running of the online course", as the most important factor influencing their decision to enrol on a certain MOOC. Thus, such certification was offered for free to those participants of the pilot study as an incentive, if they completed all the requirements described in the invitation email.
- The Literature Study in Chapter 2 reported the importance of offering the participants a space to introduce themselves, and interact with other students around the globe. This was not only recommended to create a sense of community within the course and prevent the feeling of isolation; but also so that they can learn and help each other throughout the MOOC. As a result, two discussion forums were included in the pilot, which received a very positive response from the participants. Not only did they post on them whenever it was mandatory, but they also engaged with the posts of other participants, creating a safe space for discussion.
- Additionally, the platform offered a wide amount of design tools and components to create the interactive content with, as well as a varied list of problem types, so that they could be varied throughout the pilot. However, it was not possible to implement within the platform a tool to simulate the device and ask more practical questions on the matter, like an Augmented Reality or CAD model. That is why the assignments of the course had to be designed as more knowledge-based, rather than practical thinking. On the other hand, a BMET Library page was created as a wiki-like database, including repair manuals and books on the subjects touched upon the pilot. This collection of files served as a useful source of information to many students, who expressed their desire to see a more curated version on the future MOOC.
- Looking further on the logistical aspects, edX offers a lot of flexibility when it comes to setting up the deadlines and extensions for assignments and quizzes, as well as the grading policies. Besides, it allows the instructors to constantly update the published version of the units, even if they are already live and have students going over them. This feature solves the issue reported by the NSI of outdated materials, and opens the door to a new method to provide up-to-date content to the students, based on the latest trends and medical devices introduced to the market.
- On the downside, edX courses are opened for a limited amount of time. In other words, there is no unlimited access to the materials and the enrolment will expire, despite having finished the course or not. Therefore, an initiative is proposed in the recommendation section, so that the students can have a summary of the main ideas from the content, which they can use for future reference during their career as a BMET. Furthermore, there were some other details that edX does not provide to the instructors, such as the total time spent in the course, individualised reports on the participation in discussion forms, which participant engaged with which type of content, or who watched the videos, and to which extent. Consequently, this prevented the sourcing of specific data required for some statistical tests.

In summary, it can be acknowledged that the combination of all these factors produced an overall pleasant pilot experience for most of the students; which is reflected in the ratings on various aspects of the course presented in TABLE 8.5. Therefore, it can be said that edX was the appropriate choice for the pilot platform, and has a lot of potential for the future version of the MOOC. Nonetheless, special attention to detail has to be taken on certain aspects, to refine the way in which the BMET training will be delivered to the students.

EVALUATION OF THE COURSE'S PARTICIPATION

The Participation survey, created in Google Forms and distributed in Nepal, Kenya, and via the Infratech Forum; not only demonstrated that the study was fairly successful in reaching its targeted audience, but also that it helped build a network of BMETs from diverse backgrounds, locations, and experience, interested in participate in the Pilot study of the BMET MOOC. From the responses in the Entrance and End-of-Course surveys, one can become aware that the main motivation to enrol in the course, was the opportunity to recall and refresh the participant's previous biomedical knowledge, while learning new methods, competencies and skills in maintenance, troubleshooting and repair; so as to deal with the equipment with confidence, and become more proficient at their profession.

When it comes to assessing the engagement between the four cohorts, A to D, it can be seen in FIGURE 8.1 that there were a total of 43 participants from whom no response or participation in the course was recorded. Additionally, eleven of them registered in edX, but did not open the pilot course; while 14 dropped out or did not have sufficient time to complete every task. On the bright side, there were at least 10 students who completed the course, on each cohort; making a total of 48 students (24 per group) that fulfilled the requirements to become a valid participant for the study, and whose grades and responses in the surveys would be assessed. This translates to a balanced distribution of the engagement among the cohorts.

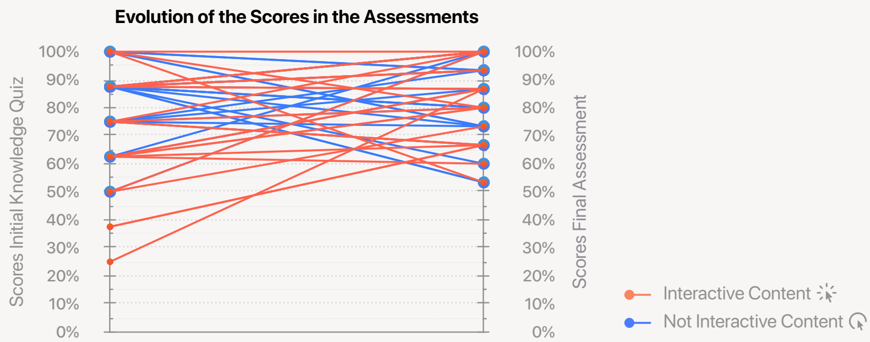

FIGURE 9.1. COMPARISON OF THE RAW SCORES IN THE INITIAL KNOWLEDGE QUIZ AND THE FINAL ASSESSMENT PER VALID PARTICIPANT

As far as the raw data is concerned, the participants were informed prior to the pilot, of the requisites needed to be considered valid for the study (refer to section 5.2). These requirements included: the submission of the three surveys (Participation S., Entrance S., and End-of-Course S.); to be registered in edX and enrolled in the course; completed the theoretical modules of the course, including the interactive content; and lastly, submitted the IKQ and Final Assessment. Unfortunately, when looking at the individual responses, edX did not provide a tool to determine whether the responses in the exams where filled in randomly by the students, or if they skipped them due to a specific motive or lack of interest. Same way it was not possible to resolve wether a drastic rise in the performance for specific learners was due to cheating in the FA, or genuine learning. That is the reason why, when looking at the individual scores on the IKQ or FA, shown in FIGURE 9.1; it was decided not to filter out any participant based on their responses or grade reports; and instead, consider every learner who met all five requirements mentioned earlier. This lead to a total of 48 valid participants on the study, 24 on each delivery group.

EVALUATION OF THE EFFECTS OF INTERACTIVE CONTENT

This last section, aims to answer one of the main research questions proposed in the beginning of the project: "*How does presenting the learning material through interactive activities and exercises, that increase the engagement with the online course content, compared to standard delivery methods (plain readings and figures); affect the performance in a BMET MOOC?*". In essence, the goal was to review if the mergence of the theoretical aspects of the course with interactive content —such as multiple choice questions, videos, drag and drop exercises and short answer activities—could take up part of the responsibility from the students, while guiding them through the content, guaranteeing that the material has been revised and completed, before reaching the assessment.

That is to say, if including interactive content through the theoretical modules could exhibit potential benefits for the students, which are directly reflected on the online course performance. The objective of the components with interactive content, was to prevent that the key concepts were skimmed over or skipped by chance, so as to boost the students' involvement in the course by promoting active engagement. Additionally, these elements were mainly used for presenting new topics, associating the correct definitions to key terms, identifying elements in figures, or responding questions from a video.

Accordingly, the hypothesis for this question was defined as: "***those participants exposed to interactive content will perform better on the MOOC, compared to those delivered with the standard units***". As a means to verify this theory, the 48 participants were divided in groups based on the delivery method they were exposed to. In agreement with **TABLE 5.1**, cohorts Ⓐ+Ⓒ formed the "Interactive group"; while cohorts Ⓑ+Ⓓ belonged to the "Not Interactive group". This segregation yielded two balanced clusters in terms of sample size, with 24 valid participants each.

Before diving into the effects caused by the delivery method on the performance, a Chi-square test for independence was computed to determine wether the presence of interactive content encouraged the learners to complete the rest of the course or not. As it was previously mentioned, the participants were not told they would be exposed to different content delivery methods. This allowed the researchers to analyse if the interactive delivery method would serve as an incentive for the learners. However, there is not enough evidence to suggest an association between the delivery method (Interactive and Not Interactive) and the motivation to complete the course. Nonetheless, it is relevant to mention that right after the modules with interactive content, there were three other regular content modules on preventive maintenance and troubleshooting, created by R. Rutten, before reaching the final assessment. Thus, further research would be needed on this matter to verify this result.

Furthermore, it has to be noticed that the set up of the pilot course led to evident differences in the final results of the interactive and not interactive groups, as described in section 6.1.1. For all these reasons, even though all of the participants passed the pilot study and obtained a grade higher than 60%, this figure should not be considered as an index of the success of the Pilot course, but rather an indicator of the engagement with the various elements, and course progress. A most promising procedure to measure the effect and potential interactive content units was selected: the performance. Following the advice from the Nick Simmons Institute, the combination of the grades from the IKQ with the Final Assessment, allowed the creation of a Pre-test/Post test design study, in which the performance would be measured as the mean of difference between their grade on each exam, across all candidates.

The performance was calculated for the valid participants, and the mean results per level of covariates and independent variables were presented in **TABLE 8.3**. Two-way ANOVA tests were use to determine the significance of these results, as they fulfilled the requirements needed to use this parametric test. The analysis were performed under the standard significance level, $\alpha=0.05$ [78, 83-85]; and from the results of the statistics, the following can be said about interactive content:

- The results displayed in **FIGURE 8.3.A**, show that the delivery method did have a statistically significant effect on the outcomes of the pilot study. In other words, the hypothesis was successfully corroborated, and it was proven that those participants presented with Interactive content in the units of the A&P Module, performed better in the Final Assessment, compared to the Initial Knowledge Quiz. The performance was improved by 11.9%, compared to those students exposed to regular content. This means that the new delivery method boosted the involvement in the A&P Module, by taking up part of the responsibility placed on the students in online education courses [17, 21, 22]; and prevented the reduction in engagement, which led to an efficient performance. A Chi-square test of independence also proved the relationship between the delivery method and the improvement in the performance; indicating a moderate association between these two categorical variables.
- Furthermore, the preventive measures taken to avoid the cross effect between this research question and R. Rutten's one, such as only including interactive content on the A&P module; demonstrated to be sufficient, as no sufficient evidence was found to claim that the motivational video displayed to cohorts Ⓐ and Ⓑ influenced the results of the performance, or that there was a significant interaction effect among these independent variables.
- The analysis of the participants' previous experience revealed that the prior BMET training had no significant effect on the performance. However, as shown in **FIGURE 8.4**, there were two other covariates that obtained significant differences among their levels and were not influenced by the delivery method: previous knowledge in A&P and work experience. The pilot course improved, by a 27.4%, the participant's understanding on the main A&P concepts required by the BMET profession. Similarly, those students with no previous experience on the field, improved their performance by 55% after the course. This means that the structure, and material provided were sufficient and successful to teach the key concepts of this module. Thus, there is no need to segregate the future MOOC in difficulty levels based on the participants previous experience as it was shown that a single level will be sufficient to report satisfactory performance from the students.
- The results of the demographic analysis indicate that when the materials were delivered via the standard methods (not interactive), the pilot showed great disparities in terms of performance (over 50%) between the high-income countries in the European region, compared to those LMIC in Africa and South-East Asia (see **FIGURE 8.5.A**). However, the same

differences were not found in the group with the interactive content. Furthermore, the delivery method simple main effects revealed that the interactive components produced a significantly 28% higher efficient performance for the African participants, compared to the regular units. These results demonstrate that the potential benefits of improving the delivery method in online courses are directly reflected on the online course performance, as it stimulated the LMIC students' involvement in the course by promoting active engagement.

- It was also revealed that the female students were more subjected to improve their performance if they were exposed to interactive content, by a 54.7%. Furthermore, when dividing the results of the 48 participants by gender, there was a 20.35% improvement in the female's performance compared to the males; and if a closer look was taken at the interactive group independently, females did also outperform males, by a 49%.
- On average, the 48 valid participants spent 5.85 hours, which lied within the limits proposed in the Participation Survey. However, there was a difference of 1.21 hours between the delivery methods' groups. This result demonstrates that the interactive content did boost the learner's engagement with the course components. Nonetheless, more research is needed to validate wether the corresponding workload intended for a week on the future MOOC, delivered as interactive content, would also require a duration of less than 6 hours.
- The remaining variables present in the pilot course, such as the age of the participants, previous education, the type of device used to access the course, and their internet reliability, did not show a significant correlation or effect on the performance, as was shown in the previous chapter. Therefore, they are not to be considered as relevant factors influencing the potential of interactive content in online education. Lastly, in order to have a reference on which were the final outcomes after the course, TABLE 9.1 presents the mean scores in the A&P Final Assessment for each of the levels of the covariates that obtained significant results on the statistical analysis.

TABLE 9.1. MEAN SCORES IN THE A&P FINAL ASSESSMENT FOR EACH OF THE SIGNIFICANT COVARIATES

		TOTAL IN THE COURSE		INTERACTIVE		NOT INTERACTIVE	
		SIZE	MEAN FA SCORE	SIZE	MEAN FA SCORE	SIZE	MEAN FA SCORE
DELIVERY METHOD	Interactive	24	81.67%	24	81.67%	0	
	Not Interactive	24	82.22%	0		24	82.22%
PROFESSIONAL EXPERIENCE	BMET in Company/Organisation	12	85.56%	5	81.33%	7	90.00%
	BMET in Hospital	22	79.09%	13	77.44%	9	81.48%
	BMET Instructor	5	77.33%	1	66.67%	4	80.00%
	BMET Student	4	95.00%	3	97.78%	1	86.67%
	Retired BMET	3	71.11%	0		3	71.11%
	No Experience	2	93.33%	2	93.33%	0	
A&P KNOWLEDGE	Had received an A&P course	38	80.53%	19	80.35%	19	80.70%
	No A&P Knowledge	10	87.33%	5	86.67%	5	88.00%
LOCATION	Africa	22	79.09%	10	84.00%	12	75.00%
	South-East-Asia	20	82.33%	10	77.33%	10	87.33%
	Europe	3	93.33%	2	90.00%	1	6.00%
	Eastern Mediterranean	1	100.00%	1	100.00%	0	
	Latin America	2	83.33%	1	66.67%	1	100.00%
GENDER	Female	5	88.00%	2	93.33%	3	84.44%
	Male	43	81.24%	22	80.61%	21	81.90%

9.2. Limitations of the Study

Despite having obtained the aforementioned results, the study was subjected to a series of limitations. This section aims to list these challenges, and propose solutions, to avoid them in future research:

- The pilot study served a double purpose, as two studies with different approaches and research questions were conducted at the same time. In order to avoid the effect of one research influencing the other, and vice-versa, some preventive measures had to be taken. In the case of the present study, the interactive content was only included in two out of the five theoretical lectures, to avoid conditioning the learning of troubleshooting, repair and preventive maintenance, as they were key for R. Rutten's thesis [70]. Additionally, the topic of the motivational video, was not related to the concepts taught in the A&P and PM.I units, to minimise the effect on this matter. On the other hand, the statistical analysis showed that these measures were sufficient, as no interaction effect was found between these independent variables, and no significant influence in the performance was observed produced by the motivational video.

- Due to these measures, right after the modules with interactive content, there were other units based on standard readings, figures and videos. Thus, it was not possible to properly asses wether the interactive content served as an incentive for the students and stimulated them to finalise the course or not. Further research on this matter is needed.
- The platform, edX, does not provide the instructors with enough tools to set up an assessment properly, to prevent cheating and dishonesty in the responses. There was no option to measure the time invested in an activity or unit. Additionally, since no simulation tool could be implemented within Edge, the questions on the assessment had to be knowledge-base, rather than practical thinking. Consequently, the students could have easily went back and forth on the units, to find the right answer; as no time or navigation restrictions could be arranged. Thus, all the 48 responses included and analysed in the research, were assumed to be genuine, and not randomly responded, to avoid the filtration and elimination of honest responses.
- The Non-participation Survey revealed that multiple students faced challenges during the enrolment process in Edge, with the invitation email; which lead to an overall reduction in the number of participants. Moreover, despite reaching a wide amount of participants, the distribution among the different levels of the certain covariates was not balanced, such as gender, location or A&P knowledge. Therefore, more research is needed, with balanced groups, to verify the results of these covariates.
- Regarding the content, most of the materials and figures used for interactive content were created specifically for the course. However, in spite of the support from the NSI, the process of creating videos with a patient monitor, faced several challenges due to Covid-19. Thus, within the scope and capabilities of this research it was opted to used existing videos from YouTube on the matter. A major consideration for the future versions of the MOOC would be to record original clips of the different medical devices [90], instead of reusing existing materials.

9.3. Recommendations for Future BMET MOOC

Based on the findings and outcomes of this research, the present section will elaborate on a series of recommendations, classified onto seven main categories, which are meaningful for the design of the future BMET MOOC.

① PLATFORM

- edX has proven its potential to be an optimal platform to host the future MOOC. This version should be created in a new instance in the public domain of edX, and not in Edge, since the goal is to reach a wider audience. In addition, by doing so, it will prevent the enrolment challenges caused by Edge. The transfer of materials/structure from one to the other, can be done via the Studio website, as it allows to import and export existing course content.
- As the access to the course is not unlimited, it is recommended to create a summary PDF document at the end of each module, so that the students can download and keep a hard/digital copy, for future reference in their career.

② TARGET AUDIENCE

- Based on the results of the pilot, participation and responses in the surveys, a profile/persona of the targeted student was created. The enrolled learner would have the following characteristics: (1) any gender; (2) between 21-35 years old; (3) from a LMIC, mainly in Africa or SEA; (4) with a High School or Bachelors Degree; (5) laptop, or smartphone would be the preferred devices to access the course; (6) might have received at least one BMET training; and (7) could already be working on the field as a BMET.

③ CURRICULUM

- It is suggested that the upcoming curriculum includes modules on the following medical devices: ventilator and oxygen concentrators, imaging equipment (x-ray machines, CT scans, MRIs and ultrasound devices); anaesthesia machine, defibrillator, electro-surgical unit, haemodialysis machine, heath-lung machine, neonatal incubator, syringe pump and PCR instruments.
- Good practices in Health Technology Management and Assessment, should also be included in the curriculum of these professionals, as research has shown its later benefits to the health system of LMIC [29]. In addition, it is encouraged to further develop the A&P module, as it was very valuable to the participants in the pilot.
- Lastly, the Modules on repair, preventive maintenance and troubleshooting should go deeper into the matter, up to the electronics level, including the use of genuine or compatible spare parts; as many LMIC face a shortage in component replacement.

④ **STRUCTURE**

- It is proposed to preserve the same blueprint of the pilot, presented in the TABLE 5.2. For the modules describing medical devices, divide the contents in five sections: device and components, preventive maintenance, troubleshooting, repair, and testing.
- Use short quizzes at the end of each lecture to test the new concepts; and final assessments at the end of the modules.
- Including a short IKQ at the beginning of each module can give the instructor an idea of the students' level and performance after the lecture.
- Lastly, it is suggested to assemble first the list of medical devices which will be included in the curriculum, and later adjust the content of the A&P Module based on the concepts which will be required to understand the functioning of those instruments.

⑤ **CONTENT**

- Extend the interactive content to every module on the course, by keeping a varied combination of exercise types across the units. Use this delivery method to present new concepts to the learners, to associate the correct definitions to key terms, to identify elements in figures, or to respond questions from a video. Avoid using plain figures and readings to prevent a reduction of the course engagement and performance, while preserving a consistent look and feel across the units, so that there is a harmonious user experience.
- Combine these components with more videos, shorter in length, ideally between 3 to 7 minutes [90]. First, film and edit the clips, and upload them later to the YouTube channel so they can be added to the course. Keep in mind that adding a transcript of the videos can enhance the understanding of the concepts.
- Consider the possibility of using an external tool, to visualise 3D models of the medical devices included in the course; as well as a simulation tool, perhaps with Augmented Reality, to test the skill acquisition process. Additionally, peer review exercises can be a great element to test knowledge and foster group work.

⑥ **LOGISTICS**

- Since the main challenge faced by the students to finalise a MOOC, is to allocate sufficient time to work on it (FIGURE 8.8); it is preferred if the amount of work load per week can be reduced to 6 hours maximum. In addition, the overall duration of each course presented in FIGURE 5.1 should be around 10 weeks. Being that the estimated that the students are willing to invest on the course.
- Most of the students would follow the MOOC on their spare time, after work or other courses. Therefore, it is recommended to set up the MOOC as self paced, while providing suggested deadlines to complete certain assignments and assessments.

⑦ **LANGUAGE & INTERNATIONAL COLLABORATORS**

- A reduced number of participants faced challenges or limitations related to the language barrier and interpretation of the materials. After the pilot, there were various participants who reached out, expressing their interest in collaborating in the design of the future MOOC, not only in revising the material, but also in the translation of the topics to other languages, like French or Spanish. Thus, it is recommended to consider, and possibly, broaden the partners involved in the MOOC and implicate those interested international collaborators.

It is believed that all these suggestions will improve the final version of the MOOC to train biomedical equipment technicians in LMIC. Furthermore, once this version is ready, it can be validated and put to the test with a group of beta participants who can be enrolled first, prior to the public release. For this trial, it is recommended to used a more balanced group in terms of age, gender, and experience on the BMET field; to properly test the outcomes and determine wether the addition of interactive content to every unit stimulates the students to complete the course. Lastly, it is recommended to revise the results and conclusions from R. Rutten's work, to understand the effects of motivational incentives in this type of course [70].

CHAPTER

10
Conclusion

The main objective of the present study was to evaluate which combination of factors related to a MOOC's design, structure, logistics, content and delivery method; result in a better course performance, engagement and experience for the user; and consequently, how to translate these findings to the design of the future BMET MOOC to maximise impact. Furthermore, the project had also a focus on determining whether the delivery of materials through interactive content could exhibit potential benefits for the students, by encouraging their involvement in the course and promoting active engagement; which could be directly reflected on the performance of the BMET online course. For this purpose, a pilot study was designed in collaboration with local experts, like the NSI, as a small replica of the upcoming MOOC, covering the topics related to the Patient Monitor. Once the course was created on edX Edge, the content was validated by expedients on the field; and the methodology behind the pilot was approved by the HREC of the Delft University of Technology.

The one-time run of the BMET Pilot MOOC took place in the summer of 2020, and from the feedback collected from the different surveys, it could be acknowledged that the pilot set-up produced an overall pleasant experience for most of the students. Therefore, it can be said that edX was the appropriate choice to run the study on, and it has proven its potential to be an optimal platform to host the future version of the MOOC. Furthermore, in spite of the limitations encountered along the way, and the lack of a simulation tool to asses the practical skills; it was still possible to design modules with interactive content and compare its efficiency agains the standard ones.

Even though not enough evidence was collected to suggest that the interactive content served as a motivational incentive for the students; it can be concluded that the differences in the delivery method, lead to an improvement in the performance of 11.9%, compared to the results of the learners exposed to regular content. The female students were the subjects more prone to the improvement, as well as the African participants, whose performance results were balanced to the level of the other regions, after being exposed to the interactive components. Besides, these findings suggest that this new delivery method not only boosted the involvement in the A&P Module, and was able to take up part of the responsibility placed on the students in online education courses [17, 21, 22]; but it also prevented the reduction in engagement.

Additionally, the structure, and material provided were sufficient and successful to teach the key concepts of this module. Moreover, there was no evidence found that suggested the need to segregate the future MOOC in difficulty levels based on the participants previous experience, as it was shown that a single level will be sufficient to report satisfactory performance from the students. Therefore, it is proposed to preserve the pilot's blueprint and lecture structure, and replicate it on the future MOOC.

Looking further on the logistical aspects, it became evident that edX offers the instructors a lot of flexibility when it comes to setting up the deadlines and extensions for assignments and quizzes, as well as the grading policies. However, since the main challenge faced by the students to finalise a MOOC, is to allocate sufficient time to work on it; it is preferred if the amount of work load per week can be reduced to 6 hours maximum. Furthermore, based on the results of the pilot and the responses in the surveys, a profile/persona of the targeted audience was created, and it was suggested that the upcoming curriculum includes modules on medical devices like ventilator, oxygen concentrators and diverse imaging equipment; while covering the essential topics on Health Technology Management and Anatomy & Physiology.

All in all, it can be said that the project benefited from a diverse group of students, who were motivated to complete the courses, and whose participation was sufficient to validate the hypothesis presented in the beginning of the thesis. The overall analysis presented in this project concluded with a series of key factors, issues, and barriers related to the design, structure, logistics, content and delivery method. The study was not only fairly successful in reaching its targeted audience, but it also built a network of BMETs from diverse backgrounds, locations, and experience, interested in the pilot, and willing to collaborate in the versions to come.

On that account, the BMET MOOC presents itself as a great alternative to prevent the great amount of out-of-service medical equipment in LMICs, and these outcomes can be of great value in eventually transferring and implementing the complete curriculum to an online platform to train these professionals on how to properly use, maintain, and repair medical devices; and therefore, have a direct impact on the maintenance of medical equipment in these countries, to ensure a proper quality of the health care delivery.

PART VI

BIBLIOGRAPHY

CHAPTER

11 Bibliography

[1] N. D. Khambete and A. Murray, "National efforts to improve healthcare technology management and medical device safety in India," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-5, doi: 10.1049/cp.2012.1474. [Online]. Available: https://ieeexplore.ieee.org/document/6458811

[2] World Health Organization, "Global atlas of medical devices," 2017.

[3] R. A. Malkin and C. Whittle, "Biomedical equipment technician capacity building using a unique evidence-based curriculum improves healthcare," *Journal of Clinical Engineering,* Article vol. 39, no. 1, pp. 37-44, 2014, doi: 10.1097/JCE.0000000000000008.

[4] J. R. Roberts, "Training biomedical engineers in developing countries," Stevenage, United Kingdom, 1995: IEE, 27 ed., pp. 3/1-3/3. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-0029472545&partnerID=40&md5=8ac0b23c2b694538032473e9b46a286e. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-0029472545&partnerID=40&md5=8ac0b23c2b694538032473e9b46a286e

[5] J. L. Eder-Van Hook and C. T. Love, "A Model for Training Biomedical Equipment Technicians in Low-Resource Settings," Transition Management Consulting, Inc., San Diego, CA, 2015.

[6] World Health Organization, Human resources for medical devices, the role of biomedical engineers. World Health Organization, 2017.

[7] F. R. Painter, "Chapter Four - Careers in Clinical Engineering," in *Careers in Biomedical Engineering*, M. Levin-Epstein Ed.: Academic Press, 2019, pp. 67-78.

[8] S. Mullally, T. Bbuku, G. Musonda, and E. Measures, "Biomedical engineering technologist (BMET) curriculum and programme development in Zambia," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-6, doi: 10.1049/cp.2012.1484. [Online]. Available: https://ieeexplore.ieee.org/document/6458819

[9] R. A. Malkin and L. Perry, "Evaluation of the impact of a new biomedical equipment technician curriculum in Rwanda," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-3, doi: 10.1049/cp.2012.1485.

[10] W. S. Topham, B. P. Gurung, and B. Muis, "Biomedical equipment technician training in Nepal," in *2008 5th IET Seminar on Appropriate Healthcare Technologies for Developing Countries*, 21-22 May 2008 2008, pp. 1-5, doi: 10.1049/ic:20080585.

[11] S. C. Daglish, M. Hilditch, and J. Okunzi, "Development of a self-sustaining biomedical engineering training course in Uganda," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-4, doi: 10.1049/cp.2012.1486.

[12] R. M. Bauer and P. K. Jaeger, "Maintenance Training Course for Biomedical/Hospital Technicians," 2006, vol. 2006, 11370 ed., pp. 73-77, doi: 10.1049/ic.2006.0663. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-78649893602&doi=10.1049%2fic.2006.0663&partnerID=40&md5=d788ce9b4407ca20cb20f884e176f6c2

[13] J. O. Wea, "Certification of Biomedical Engineering Technicians and Clinical Engineers: Important or Not," Berlin, Heidelberg, 2007: Springer Berlin Heidelberg, in 11th Mediterranean Conference on Medical and Biomedical Engineering and Computing 2007, pp. 1081-1084.

[14] T. Daradoumis, R. Bassi, F. Xhafa, and S. Caballé, "A review on massive e-learning (MOOC) design, delivery and assessment," in *2013 eighth international conference on P2P, parallel, grid, cloud and internet computing*, 2013: IEEE, pp. 208-213.

[15] L. Guàrdia, M. Maina, and A. Sangrà, "MOOC design principles: A pedagogical approach from the learner's perspective," *elearning papers,* no. 33, 2013.

[16] A. M. F. Yousef, M. A. Chatti, U. Schroeder, and M. Wosnitza, "What drives a successful MOOC? An empirical examination of criteria to assure design quality of MOOCs," in *2014 IEEE 14th International Conference on Advanced Learning Technologies*, 2014: IEEE, pp. 44-48.

[17] H. Estelami, "An Exploratory Study of the Effects of Online Course Efficiency Perceptions on Student Evaluation of Teaching (SET) Measures," *American Journal of Business Education,* vol. 9, no. 2, pp. 67-82, 2016.

[18] D. García de las Heras, "e-Learning Potential for Biomedical Equipment Technician Training in Low-/Middle-Income Countries," M.Sc. Biomedical Engineering Literature Review, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, 2020.

[19] B. Gros and F. J. García-Peñalvo, "Future Trends in the Design Strategies and Technological Affordances of E-Learning," in *Learning, Design, and Technology: An International Compendium of Theory, Research, Practice, and Policy*, M. J. Spector, B. B. Lockee, and M. D. Childress Eds. Cham: Springer International Publishing, 2016, pp. 1-23.

[20] S. Palvia *et al.*, "Online Education: Worldwide Status, Challenges, Trends, and Implications," *Journal of Global Information Technology Management,* vol. 21, no. 4, pp. 233-241, 2018/10/02 2018, doi: 10.1080/1097198X.2018.1542262.

[21] I. Jung, "Costing virtual university education," Economics of Distance and Online Learning: Theory, Practice and Research. New York: Routledge, pp. 148-161, 2008.

[22] I. E. Allen and J. Seaman, "Grade Change: Tracking Online Education in the United States," *Babson Survey Research Group,* 2014.

[23] D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, and P. G. The, "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement," *PLOS Medicine,* vol. 6, no. 7, p. e1000097, 2009, doi: 10.1371/journal.pmed.1000097.

[24] G. Wong, T. Greenhalgh, G. Westhorp, J. Buckingham, and R. Pawson, "RAMESES publication standards: meta-narrative reviews," *BMC Medicine,* vol. 11, no. 1, p. 20, 2013/01/29 2013, doi: 10.1186/1741-7015-11-20.

[25] United Nations, World Economic Situation and Prospects 2020. 2020.

[26] The World Bank. "Classifying countries by income." https://datatopics.worldbank.org/world-development-indicators/stories/the-classification-of-countries-by-income.html (accessed 26 Feb, 2020).

[27] L. Vilcahuamán and R. Rivas, "Chapter 1 - Healthcare Technology Management (HTM) & Healthcare Technology Assessment (HTA)," in *Healthcare Technology Management Systems*, L. Vilcahuamán and R. Rivas Eds.: Academic Press, 2017, pp. 1-21.

[28] L. Pecchia, N. Pallikarakis, R. Magjarevic, and E. Iadanza, "Health Technology Assessment and Biomedical Engineering: Global trends, gaps and opportunities," *Medical Engineering & Physics,* vol. 72, pp. 19-26, 2019/10/01/ 2019, doi: https://doi.org/10.1016/j.medengphy.2019.08.008.

[29] A. M. E. Worm and J. L. Mpamije, "The relevance and challenges of implementing Healthcare Technology Management in resource poor settings; experiences in Rwanda," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-3, doi: 10.1049/cp.2012.1479.

[30] L. Bielawski and D. S. Metcalf, Blended elearning: Integrating knowledge, performance, support, and online learning. Human Resource Development, 2003.

[31] R. Adanu *et al.*, "Electronic learning and open educational resources in the health sciences in Ghana," *Ghana medical journal,* vol. 44, no. 4, 2010.

[32] M. R. Davids, U. M. Chikte, and M. L. Halperin, "Development and evaluation of a multimedia e-learning resource for electrolyte and acid-base disorders," *Advances in Physiology Education,* vol. 35, no. 3, pp. 295-306, 2011.

[33] P. Fontelo, J. Faustorilla, A. Gavino, and A. Marcelo, "Digital pathology–implementation challenges in low-resource countries," *Analytical Cellular Pathology,* vol. 35, no. 1, pp. 31-36, 2012.

[34] R. Kulier *et al.*, "Effectiveness of a clinically integrated e-learning course in evidence-based medicine for reproductive health training: a randomized trial," *Jama,* vol. 308, no. 21, pp. 2218-2225, 2012.

[35] J. Varghese, M. Faith, and M. Jacob, "Impact of e-resources on learning in biochemistry: first-year medical students' perceptions," *BMC Med Educ,* vol. 12, no. 1, p. 21, 2012.

[36] D. P. de Sena, D. D. Fabricio, M. H. I. Lopes, and V. D. da Silva, "Computer-assisted teaching of skin flap surgery: validation of a mobile platform software for medical students," *PloS one,* vol. 8, no. 7, 2013.

[37] S. D. Bandhu and S. Raje, "Experiences with E-learning in ophthalmology," *Indian journal of ophthalmology,* vol. 62, no. 7, p. 792, 2014.

[38] M. R. Davids, U. Chikte, K. Grimmer-Somers, and M. L. Halperin, "Usability testing of a multimedia e-learning resource for electrolyte and acid-base disorders," *British Journal of Educational Technology,* vol. 45, no. 2, pp. 367-381, 2014.

[39] N. Gaikwad and S. Tankhiwale, "Interactive E-learning module in pharmacology: a pilot project at a rural medical college in India," *Perspectives on medical education,* vol. 3, no. 1, pp. 15-30, 2014.

[40] E. G. Martínez and R. Tuesca, "Modified team-based learning strategy to improve human anatomy learning: A pilot study at the Universidad del Norte in Barranquilla, Colombia," *Anatomical sciences education,* vol. 7, no. 5, pp. 399-405, 2014.

[41] C. C. Florescu, J. A. Mullen, V. M. Nguyen, B. E. Sanders, and P. Q.-P. Vu, "Evaluating didactic methods for training medical students in the use of bedside ultrasound for clinical practice at a faculty of medicine in Romania," *Journal of Ultrasound in Medicine,* vol. 34, no. 10, pp. 1873-1882, 2015.

[42] M. A. Kotb, H. N. Elmahdy, N. E. D. M. Khalifa, M. H. N. El-Deen, and M. A. N. Lotfi, "Pediatric online evidence-based medicine assignment is a novel effective enjoyable undergraduate medical teaching tool: A SQUIRE compliant study," *Medicine,* vol. 94, no. 29, 2015.

[43] A. Sabouni *et al.*, "Multiple strategy peer-taught evidence-based medicine course in a poor resource setting," *BMC Med Educ,* vol. 17, no. 1, p. 82, 2017.

[44] T. C. S. B. Vieira *et al.*, "Experience of an online course on sexuality during pregnancy for residents," *Sexual & Reproductive Healthcare,* vol. 12, pp. 76-81, 2017.

[45] S. Barteit, D. Guzek, A. Jahn, T. Bärnighausen, M. M. Jorge, and F. Neuhann, "Evaluation of e-learning for medical education in low- and middle-income countries: A systematic review," *Computers & Education,* vol. 145, p. 103726, 2020/02/01/ 2020, doi: https://doi.org/10.1016/j.compedu.2019.103726.

[46] R. A. Malkin, L. Gu, and B. Teninty, "Provision of biomedical equipment reference texts and manuals on e-readers in resource-poor settings," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-3, doi: 10.1049/cp.2012.1480. [Online]. Available: https://ieeexplore.ieee.org/document/6428575

[47] Medical Aid International. "Biomedical Online Training Programme." https://www.medaid.co.uk/biomedical-engineering/ (accessed 20 Feb, 2020).

[48] P. Malataras and N. Pallikarakis, "Evaluation of an E-learning Course in Biomedical Technology Management," in *Twentieth IEEE International Symposium on Computer-Based Medical Systems (CBMS'07)*, 20-22 June 2007 2007, pp. 687-692, doi: 10.1109/CBMS.2007.46. [Online]. Available: https://ieeexplore.ieee.org/document/4262728/

[49] E. Iadanza and A. Worm, "Clinical engineering online courses for Africa," 2017, vol. 65: Springer Verlag, pp. 314-317, doi: 10.1007/978-981-10-5122-7_79. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85021744410&doi=10.1007%2f978-981-10-5122-7_79&partnerID=40&md5=259b402bb9026253d646602e1d702787

[50] A. Gammie, M. Upadhayaya, S. Shrestha, and M. Zimmermann, "BMEAT Nepal - Assistant technician training for resource-poor settings," 2012, vol. 2012, 608 CP ed., doi: 10.1049/cp.2012.1478. [Online]. Available: https://ieeexplore.ieee.org/document/6458814/

[51] World Health Organization, "WHO country coperation strategy at a glance: Nepal," World Health Organization, Geneva, 2018 2018, issue CC BY-NC-SA 3.0 IGO. [Online]. Available: https://apps.who.int/iris/handle/10665/136955

[52] S. K. Pangeni, "Open and Distance Learning: Cultural Practices in Nepal," (in English), vol. 19, no. 2, p. 32, 2016, doi: https://doi.org/10.1515/eurodl-2016-0006.

[53] S. Shakya, G. Sharma, and K. Thapa, "State Education System with e-learning in Nepal: Impact and Challenges," *Journal of the Institute of Engineering,* vol. 13, p. 10, 06/22 2018, doi: 10.3126/jie.v13i1.20344.

[54] S. Frehywot *et al.*, "E-learning in medical education in resource constrained low- and middle-income countries," (in eng), *Hum Resour Health,* vol. 11, p. 4, Feb 4 2013, doi: 10.1186/1478-4491-11-4.

[55] A. D. Rogers, P. Moss, and J. Atkinson, "A virtual approach to delivering technical support to developing countries provides more effective assistance, increases sustainability and builds stronger local capacity," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-3, doi: 10.1049/cp.2012.1481. [Online]. Available: https://ieeexplore.ieee.org/document/6458816

[56] S. O'Dea, "Market share of mobile operating systems worldwide 2012-2020." [Online]. Available: https://www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/#statisticContainer

[57] S. O'Dea, "Smartphone users worldwide 2016-2021." [Online]. Available: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/

[58] *Framer Desktop for macOS*. (2020). Accessed: 13th February 2020. [Online]. Available: https://www.framer.com

[59] Delft University of Technology. "About OpenCourseWare." https://ocw.tudelft.nl/about-ocw/ (accessed May 2020.

[60] N. Ribeiro Jorge, S. M. Dopper, and W. F. van Valkenburg, "The TU Delft Online Learning Experience: From Theory to Practice," presented at the Proceedings of the European Distance and E-Learning Network 2016 Annual Conference Budapest, 14-17 June, 2016: Re-Imagining Learning Scenarios, 2016. [Online]. Available: http://resolver.tudelft.nl/uuid:92ff1334-7744-4075-b073-c369dda4255e.

[61] TUDelft Extension School, "Extension School: Impact Report 2020," Delft University of Technology, 2020. [Online]. Available: https://online-learning.tudelft.nl/media/filer_public/ea/93/ea930048-ddc1-4105-91cb-8dcb371b8d70/tu-delft-extension-school-impact-report-2020.pdf

[62] edX. "About edX: The Mission and Story." https://www.edx.org/about-us (accessed May 2020).

[63] edX. edX101: Overview of Creating an edX Course [Online] Available: https://www.edx.org/course/edx101-overview-of-creating-an-edx-course

[64] edX. StudioX: Creating a Course with edX Studio [Online] Available: https://www.edx.org/course/studiox-creating-a-course-with-edx-studio

[65] edX, *Building and Running an edX Course*, Published Online, 2020. [Online]. Available: https://edx.readthedocs.io/projects/edx-partner-course-staff/en/latest/index.html.

[66] C. Stanco, "Identifying the Information Needs of Biomedical Equipment Technicians in the Developing World," 2016.

[67] *Google Forms*. (2020). Accessed: 23rd June 2020. [Online]. Available: https://www.google.com/forms/about/

[68] N. Pallikarakis, R. Magjarevic, L. Pecchia, and A. Dermitzakis, "Biomedical Engineering Education: Need for Harmonisation," Singapore, 2018: Springer Singapore, in EMBEC & NBC 2017, pp. 888-891.

[69] J. C. F. de Winter and D. Dodou, "Experimental Design," in *Human Subject Research for Engineers : A Practical Guide*. Cham: Springer International Publishing, 2017, pp. 17-39.

[70] R. Rutten, "Bringing Technology to Life: Increasing the amount of in-service medical equipment by developing a MOOC to train Biomedical Equipment Technicians in LMIC," M.Sc. Biomechanical Design Graduation Thesis, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology 2020.

[71] J. Dewey, "Thinking in education. Democracy and education: An introduction to the philosophy of education," ed: The Free Press, New York, 1916.

[72] World Health Organization, "Core medical equipment," World Health Organization, Geneva, 2011 2011. [Online]. Available: https://apps.who.int/iris/handle/10665/95788

[73] World Health Organization, WHO compendium of innovative health technologies for low-resource settings: 2016-2017: medical devices, eHealth/mHealth, medical simulation devices, personal protective equipment, assistive products, other technologies. Geneva: World Health Organization (in en), 2018.

[74] M. Kang, B. G. Ragan, and J.-H. Park, "Issues in outcomes research: an overview of randomization techniques for clinical trials," *Journal of athletic training,* vol. 43, no. 2, pp. 215-221, 2008.

[75] T. M. Therneau, "How many stratification factors are "too many" to use in a randomization plan?," *Controlled clinical trials,* vol. 14, no. 2, pp. 98-108, 1993.

[76] *Numbers*. (2020). Accessed: 27th July 2020. [Online]. Available: https://www.apple.com/numbers/

[77] *SPSS Statistics 25*. (2020). Accessed: 1st Septermber 2020. [Online]. Available: https://www.ibm.com/products/spss-statistics

[78] A. Field, Discovering statistics using IBM SPSS statistics. sage, 2013.

[79] L. J. Gurak and A. H. Duin, "The impact of the internet and digital technologies on teaching and research in technical communication," *Technical communication quarterly,* vol. 13, no. 2, pp. 187-198, 2004.

[80] R. Coe, J. Searle, P. Barmby, K. Jones, and S. Higgins, "Relative Difficulty of Examinations in Different Subjects," *CEM Centre, Durham University),* 01/01 2008.

[81] A. Gebejes and A. Khokhlova. "Learning Curve Theory." Valamis. https://www.valamis.com/hub/learning-curve#application (accessed Sep 2020.

[82] J. C. F. de Winter and D. Dodou, "Scientific Method, Human Research Ethics, and Biosafety/Biosecurity," in *Human Subject Research for Engineers : A Practical Guide*. Cham: Springer International Publishing, 2017, pp. 1-16.

[83] J.R.Vizmanos and R.Asensio, *Bioestadística*. Madrid, Spain(in Spanish), 1976.

[84] Curso Atención Primaria Asturias, *Principios de Atención Primaria*. Oviedo, Asturias, Spain(in Spanish), 2005.

[85] J. C. F. de Winter and D. Dodou, "Statistics," in *Human Subject Research for Engineers : A Practical Guide*. Cham: Springer International Publishing, 2017, pp. 41-65.

[86] SPSS Tutorials. "SPSS Chi-Square Independence Test." https://www.spss-tutorials.com/spss-chi-square-independence-test/ (accessed Oct 2020).

[87] S. S. Shapiro and M. B. Wilk, "An analysis of variance test for normality (complete samples)," *Biometrika,* vol. 52, no. 3-4, pp. 591-611, 1965, doi: 10.1093/biomet/52.3-4.591.

[88] P. Mishra, U. Singh, C. M. Pandey, P. Mishra, and G. Pandey, "Application of student's t-test, analysis of variance, and covariance," (in eng), *Ann Card Anaesth,* vol. 22, no. 4, pp. 407-411, Oct-Dec 2019, doi: 10.4103/aca.ACA_94_19.

[89] SPSS Tutorials. "SPSS Two-Way ANOVA." https://www.spss-tutorials.com/spss-two-way-anova-basics-tutorial/ (accessed Oct 2020).

[90] P. J. Guo, J. Kim, and R. Rubin, "How video production affects student engagement: An empirical study of MOOC videos," in *Proceedings of the first ACM conference on Learning@ scale conference*, 2014, pp. 41-50.

PART VII

APPENDICES

APPENDIX

A
Scientific Paper

This appendix presents a scientific paper written for this project. The article is a concept paper based on the main results regarding the interactive content. Therefore, it should be seen as a supplementary material, as it does not represents the overall work behind this master thesis.

Interactive Content: a Comparative Study on the Performance of a Pilot MOOC To Train Biomedical Equipment Technicians in LMIC

DANIEL G. DE LAS HERAS, JENNY DANKELMAN, ARJAN J. KNULST
Delft University of Technology. Mechanical, Maritime and Materials Engineering Faculty. Biomechanical Engineering Department. Delft, The Netherlands

ABSTRACT

OBJECTIVES: In order to contribute to the research concerning the large quantities of out-of-service medical equipment in LMIC, the goal of this study is to evaluate whether the delivery of materials through interactive content in a MOOC to train Biomedical Equipment Technicians (BMET) could exhibit improvements in the performance.

METHODS: A single blinded pilot study was created on edX Edge, in collaboration with local experts (NSI). It covered topics related to the Patient Monitor in 4 modules. To validate the hypothesis, the participants were allocated in two groups, based on the delivery method they were exposed to, following a stratified randomisation. Following a Pre-test/Post test design, the performance was measured as the mean of difference between the grades on each test, across all candidates. The corresponding statistical analyses on the independent variables and covariates were performed.

RESULTS: The distinctions in the delivery method, lead to a significant improvement in the performance of 11.9%, compared to regular content. The female students were more prone to this enhancement, as well as the African participants. Besides, the findings suggest that the interactive content not only boosted the involvement in the course, and was able to take up part of the responsibility placed on the students in online education courses; but it also prevented the reduction in engagement.

CONCLUSIONS: The BMET MOOC presents itself as a great alternative to conventional face-to-face training. The outcomes on the interactive content can be of great value when transferring the training to an online course; and therefore, have a direct impact on the maintenance of medical devices in LMIC, to ensure a proper quality of the health care delivery.

KEYWORDS: Interactive Content, Biomedical Equipment Technician (BMET), MOOC, edX, LMIC

INTRODUCTION

With the recent advances in the field of healthcare technologies, the provision of effective and safe use of medical devices is considered a crucial aspect of any healthcare system in the world. However, reaching these standards is exceptionally hampered in low-/middle-income countries (LMIC), as they lack the proper resources, facilities and knowledge to operate such intricate devices. In certain areas of the South-East Asian region, it is estimated that almost 30% of medical equipment is out of service [1]. Meanwhile, according to the World Health Organisation, only in sub-Saharan Africa, 70% of the medical equipment stands idle [2].

Biomedical Equipment Technicians or BMETs, are the professionals responsible for the maintenance, repair, and troubleshooting of medical devices; to ensure its safety and adequate use for the diagnosis and treatment of patients [3-5]. However, the role of BMETs is relatively new in LMICs; and in some cases, they are not properly trained. This produces a scarcity of technicians in this field, which is considered the primary cause of inoperable equipment, as it also means that fewer technicians are unavailable to train the medical staff on the proper use of the technology [3].

In response to this issue, various government agencies, NGOs, and private sector companies are trying to solve it by developing training programs and workshops to provide technicians in LMIC with a basic understanding and skills for handling and repairing medical equipment in health care facilities. Some examples are found in India [1], Zambia [6], Rwanda [7], Nepal [8], and Uganda [9]. These trainings, with curated curriculums [10], provide a variety of educational opportunities for the learners, and include a certificate, to validate their qualifications upon its completion [11].

Even though these programs are increasing the number of available academically oriented BMET in LMIC, the educational process via face-to-face learning is slow, and the volume of graduating trainees is not sufficient to overcome this issue. Besides, these training programs often face other obstacles, like the availability of an adequate number of qualified instructors to teach the courses, or the existence of proper infrastructure and materials to provide the students with hands-on experience.

Therefore, in order to further grow the number of quality trained BMETs in these settings, distance learning methods like e-learning, should be considered [12]. The most common form of e-learning are "Massive Open Online Courses", also known as MOOCs [13-16]. These online courses aim at a large audience in an open manner, and are accessible at a reduced cost to anyone in the world with internet connection and a laptop or smartphone.

In light of these possibilities, a literature review was conducted in early 2020, under the title: "e-Learning potential for Biomedical Equipment Technician Training in Low-/Middle-Income Countries" [17]. The goal was to understand the advantages and capabilities of e-learning, its current adoption in LMIC, while determining the main aspects that could be learned from existing BMET courses and MOOCs in medical education; in order to elaborate a list of key considerations for the design of a BMET MOOC.

The findings indicated that, while there has been much research on the traditional education of BMETs, specially in LMIC [1, 3, 6-10], as well as, in the potential of e-learning and the creation of MOOCS [13-16, 18, 19]; few studies have taken into consideration the feasibility of transferring to a fully online platform this training discipline, which has always been taught in situ, as it requires skills and hands-on experience. Nevertheless, some authors are sceptical about the benefits of e-learning, as the bulk of the burden of learning is directly passed onto the student, since they are the ones accountable for deciding whether to gain exposure to the learning material and process it meticulously before completing the corresponding assignments/assessments, or if they opt for skipping them [16, 20, 21].

RESEARCH GOAL

In order to contribute to the research concerning the large quantities of out-of-service medical equipment in LMIC, this article will evaluate whether the delivery of materials through interactive content, in a BMET MOOC, could exhibit potential benefits for the students, by encouraging their involvement in the course and promoting active engagement; which could be directly reflected on the results of the performance.

Therefore, the research question can be formulated as : "**How does presenting the learning material through interactive activities and exercises, that increase the engagement with the online course content, compared to standard delivery methods (plain readings and figures); affect the performance in a BMET MOOC?**". Accordingly, the hypothesis is defined as: "**those participants exposed to interactive content will perform better on the MOOC, compared to those delivered with the standard units**".

METHODS

THE PILOT STUDY

It was designed in collaboration with experts from the Nick Simons Institute, to be a small replica of the upcoming BMET MOOC, so that it could evaluate the potential of interactive content on this training. It was formulated with the following attributes: (1) as a **Single Blinded Study**, since only the researchers were aware that the participants were being exposed to contrasting factors to evaluate the differences; (2) Between-Subjects Experiments the participants were assigned to similar groups, with the only difference being that each was exposed to a contrasting delivery methods; and (3) it was a Randomised Controlled Trial, as the cohort allocation followed a Stratified Randomisation, balanced by two covariates to prevent disparities between cohorts. The variables were the participant's previous BMET training experience and location, as it can be seen in **Figure 1**.

The units within the course were designed in a way so that two different research questions could be answered: the potential benefits of motivational incentives in the form of a video, by R. Rutten [22]; and the efficiency effects of changing the delivery method from standard content to interactive one, presented in this article. For more details on the effects of the motivation video refer to R. Rutten's thesis [22].

The two-by-two combination of these variables, resulted in four cohorts. The learners in Cohort Ⓐ had access to the motivational video and the units with the interactive content. Whereas those in Cohort Ⓑ or Cohort Ⓒ, were only exposed to one of the factors independently. Finally, Cohort Ⓓ had access to standard content units, with no motivational video. For the purpose of this work, the cohorts Ⓐ+Ⓒ were combined in a group called "**Interactive**"; while cohorts Ⓑ+Ⓓ formed the "**not interactive**" group. The effects of the motivational video on these groups were studied.

THE COURSE: LOGISTICS AND INTERACTIVE CONTENT

The platform selected for the experimental course, was edX Edge ; as it offered a controlled environment to create and run the study [23]. The creation process was supervised and supported by the TUDelft Online Learning team. The structure was based on the predefined upcoming MOOC's blueprint and curriculum. Its content focused on topics related to the Patient Monitor, divided in four modules. To avoid the effect on R. Rutten's study, the interactive content was included only in the A&P Module, which covered the anatomical and physiological topics related to the functioning of the Patient Monitor.

In each of these units, there were components that contained the materials presented as regular/standard lecture readings and figures, visible to cohorts Ⓑ and Ⓓ exclusively; while the interactive components referred to the same materials, but with elements such as multiple choice questions, drag and drop exercises, that captured the learners' attention, guaranteed its completion; and they were only visible to cohorts Ⓐ and Ⓒ.The main objective behind the interactive elements was to prevent that the key concepts were skimmed over or skipped by chance. They were mainly used for presenting new concepts, associating the correct definitions to key terms, identifying elements in figures, or responding questions from a video. For more details on how the course was created and run, refer to D. G. De las Heras' thesis [24].

VARIABLES AND METHOD OF ANALYSIS

The independent variables were the delivery method and motivational video. In addition, the covariates were included in the study obtained from two data sources: the responses in two Google Forms surveys, and the grade reports downloaded from edX. These covariates included: the location of the learners, if they had received previous BMET training, their work experience in the BMET field, knowledge in the subject of anatomy, the device used to access the pilot course, their education level, gender and age.

To measure the effect of the interactive content, a Pre-test/Post test design was followed and the dependent variable, the performance, was defined as the difference in the grade obtained in the A&P Final Assessment (FA), versus the Initial Knowledge Quiz (IKQ). To determine wether the difficulty level of these exams affected affect the results, a separate study was conducted [24], and it was concluded that the A&P questions on both test were on the same level of difficulty.

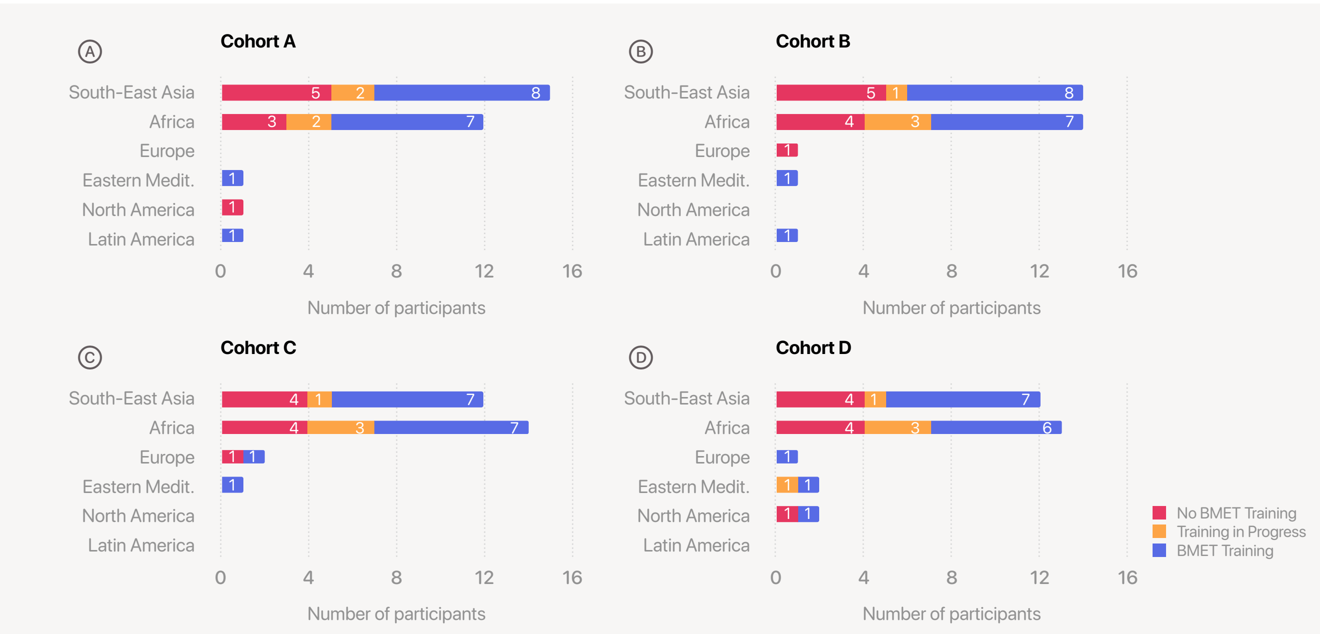

FIGURE 1. Cohort Distribution After the Stratified Randomisation: BMET Training Level vs. Location

The participants were informed before the pilot, of the requisites needed to be considered valid for the study. These requirements included: the submission of the surveys; to be registered in edX and enrolled in the course; having completed the theoretical modules of the course, including the interactive content; and lastly, submitted the IKQ and Final Assessment. These results were downloaded in CSV format, and filtered in a spreadsheet using **Numbers** for MacOS [25]. The corresponding statistical analyses were performed using the **IBM SPSS Statistics 25** software [26], under the standard Significance Level α = 0.05 [78, 83-85].

The one-time run of the BMET Pilot MOOC took place in the summer of 2020. After having the course content validated by 13 students and experts from the BME field, the invitations to the pilot were sent via email to 119 participants that expressed their willingness to test the preliminary content.

ETHICAL ASPECTS

Lastly, all of the participants were informed of the objectives of the study, and that their results and inputs in the pilot would be used for future research. As a result, the approval to conduct the research was granted by the Human Research Ethics Committee (HREC) from the Delft University of Technology.

RESULTS

Once the pilot closed, 48 participants met the requirements mentioned above and were considered valid: 24 belonged to the interactive group, and 24 to the not interactive. The participants that were not in these two groups, were classified as "not valid", and accounted for almost 60% of the pilot testers. **Figure 2**.A presents the evolution from the results of the IKQ and FA, while Figure 2.B showed the analysis of the performance for all the participants, and segregated by delivery method. Three independent Shapiro-Wilk tests [27] proved that the samples followed a normal distribution was used to test the normality of the three distributions

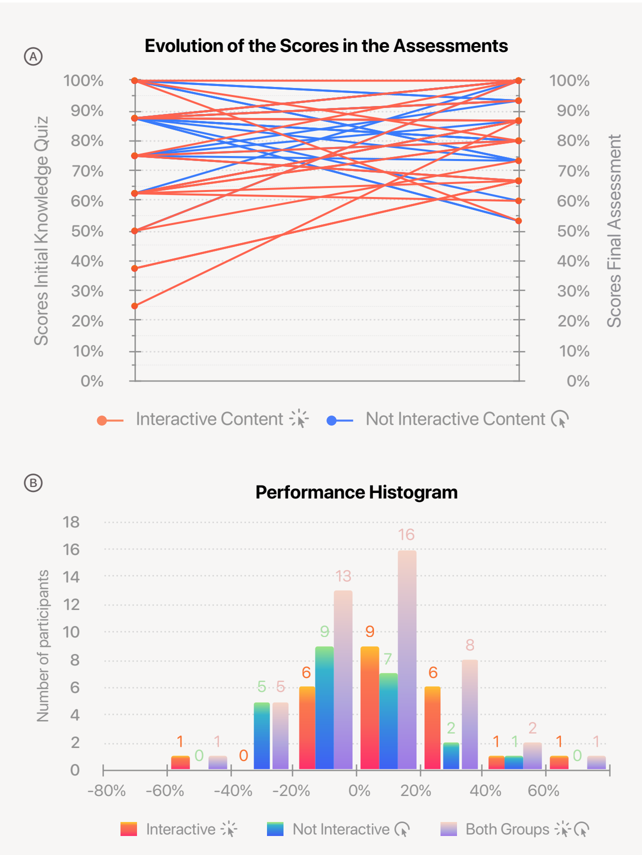

FIGURE 2. Raw Data From the IKQ and FA, and Histogram of the Performance

Table 1 presents the number of valid participants within each of the levels of the variables, as well as the performance mean from each group, extracted from SPSS. It can be seen that each cell combination of variables within the delivery method holds a similar number of participants, implying a balanced design. Moreover, the standard deviations σ (the square root of the variance) were not included in the table, as individual Levene's test proved that each sample was homoscedastic, meaning that the standard deviation of the dependent variable was equal for each group combination of respondents.

TABLE 1. Distribution of Performance and Valid Participants Through the Different Independent Variables and Covariates

		TOTAL GROUP		INTERACTIVE		NOT INTER.	
		N	PERFORM	N	PERFORM	N	PERFORM
DELIVERY METHOD	Interactive	24	10.84%	24	10.84%	0	
	Not Interactive	24	-1.12%	0		24	-1.12%
MOTIVATION VIDEO	Motivation Video	27	1.54%	14	10.90%	13	-8.53%
	Not Motiv. Video	21	9.12%	10	10.70%	11	7.64%
BMET TRAINING	One BMET Training	31	2.76%	14	7.51%	17	-1.14%
	Training in Progress	5	-2.02%	3	8.03%	2	-17.10%
	No Training	12	13.13%	7	18.70%	5	5.30%
PROFESSIONAL EXPERIENCE	BMET in Company	12	0.13%	5	-1.16%	7	1.06%
	BMET in Hospital	22	2.38%	13	7.25%	9	-4.64%
	BMET Instructor	5	9.84%	1	29.20%	4	5.00%
	BMET Student	4	7.50%	3	10.26%	1	-0.80%
	Retired BMET	3	-3.90%	0		3	-3.90%
	No Experience	2	55.85%	2	55.85%	0	
A&P KNOWLEDGE	Had prior A&P Course	38	18.98%	19	18.12%	19	19.41%
	No A&P Knowledge	10	27.36%	5	22.00%	5	27.78%
LOCATION	Africa	22	2.38%	10	17.75%	12	-10.42%
	South-East-Asia	20	3.58%	10	3.60%	10	3.57%
	Europe	3	26.66%	2	15.00%	1	50.00%
	Eastern Mediterranean	1	25.00%	1	25.00%	0	
	Latin America	2	2.10%	1	-8.30%	1	12.50%
GENDER	Female	5	23.00%	2	55.85%	3	1.10%
	Male	43	2.75%	22	6.75%	21	-1.43%
AGE	21 - 25 years old	14	1.90%	6	10.00%	8	-4.17%
	26 - 30 years old	9	0.65%	6	0.7%	3	0.56%
	31 - 35 years old	10	10.99%	3	28.63%	7	3.42%
	36 - 40 years old	2	23.35%	2	23.35%	0	
	More than 40 years old	13	3.40%	7	9.05%	6	-3.20%
EDUCATION	Elementary School	1	-34.20%	0		1	-34.20%
	High School	14	4.22%	6	9.86%	8	0.02%
	Bachelor's Degree	19	4.38%	10	8,84%	9	-0.55%
	Master's Degree	10	11.09%	6	10.71%	4	11.65%
	PhD's	1	-7.50%	0		1	-7.50%
	Postgraduate	3	7.20%	2	24.15%	1	-26.70%
DEVICE	Desktop	6	19.03%	3	19.46%	3	18.60%
	Laptop	27	3.39%	11	12.28%	16	-2.71%
	Smartphone	14	-0.12%	9	4.16%	5	-7.84%
	Tablet	1	29.20%	1	29.20%	0	

This data was later used to compute the different two-way ANOVAs, with the purpose of understanding whether there are any interrelationships between the factors presented in **Table 1**, and the dependent variable [28]. For significant main effects of those variables with more than two levels, a Post Hoc was included; while for significant interactions between covariates and delivery method, a simple main effects study was performed.

MOTIVATION TO FINISH THE COURSE

Did the presence of interactive content encourage the learners to complete the rest of the course? The data showed that 58 participants reached the A&P module and engaged with the interactive components, out of which only 48 finished the pilot. To check this relationship, a Chi-square test for independence was computed with the null hypothesis H_0, being that the two categorical variables are independent from each other. The results of the statistical test ($\chi^2(1) = 0.234$, $p = 0.628$) concluded that there is not enough evidence to suggest an association between the delivery method and the motivation to complete the course.

DELIVERY METHOD AND MOTIVATIONAL VIDEO

A two-way ANOVA was conducted to examine the effect of delivery method and motivational video [29] on the performance of the pilot study. The outcomes did not demonstrate an interaction between the independent variables of the study, delivery method and motivational video , $F(1, 44) = 1.721$, $p = 0.196$. On the other hand, the results of the F statistic proved that those participants presented with Interactive content in the units of the A&P Module performed better in the Final Assessment, compared to the Initial Knowledge Quiz; than those students with regular/non interactive content: $F(1, 46) = 3.644$, $p = 0.031$ (see **Figure 3.A**). However, the motivational video did not present a significant effect on the performance: $F(1, 46) = 1.374$, $p = 0.247$ (**Figure 3.B**).

PARTICIPANT'S PREVIOUS EXPERIENCE

The learners also reported the BMET Training Experience they had before enrolling the pilot. A two-way ANOVA was conducted to examine the differences in performance by delivery method and BMET Training Experience. The results from the test did not indicate a significant interaction between these variables: $F(2, 42) = 0.305$, $p = 0.739$. Additionally, there was not a statistically significant difference between training groups: $F(2, 42) = 1.139$, $p = 0.330$. The results of the Post Hoc test also demonstrated that the average performance was equal for the three training groups.

During the pilot, the beta testers were asked wether they had received a course on A&P before enrolling in edX. The answers were recorded: 79.16% learners did have previous knowledge on this subject, while 20.8% were new to it. The distribution per groups presented equal variances, so the two-way ANOVA was computed. An interaction between Interactive/Non Interactive components and Knowledge on A&P could not be demonstrated, $F(1, 44) = 1.589$, $p = 0.214$. On the other hand, **Figure 3.D** shows that the participants with no A&P education performed better than those with prior knowledge on the subject: $F(1, 44) = 8.251$, $p = 0.006$. In other words, the pilot course improved, by a 27.36%, the participant's performance on the main A&P concepts required by the BMET profession.

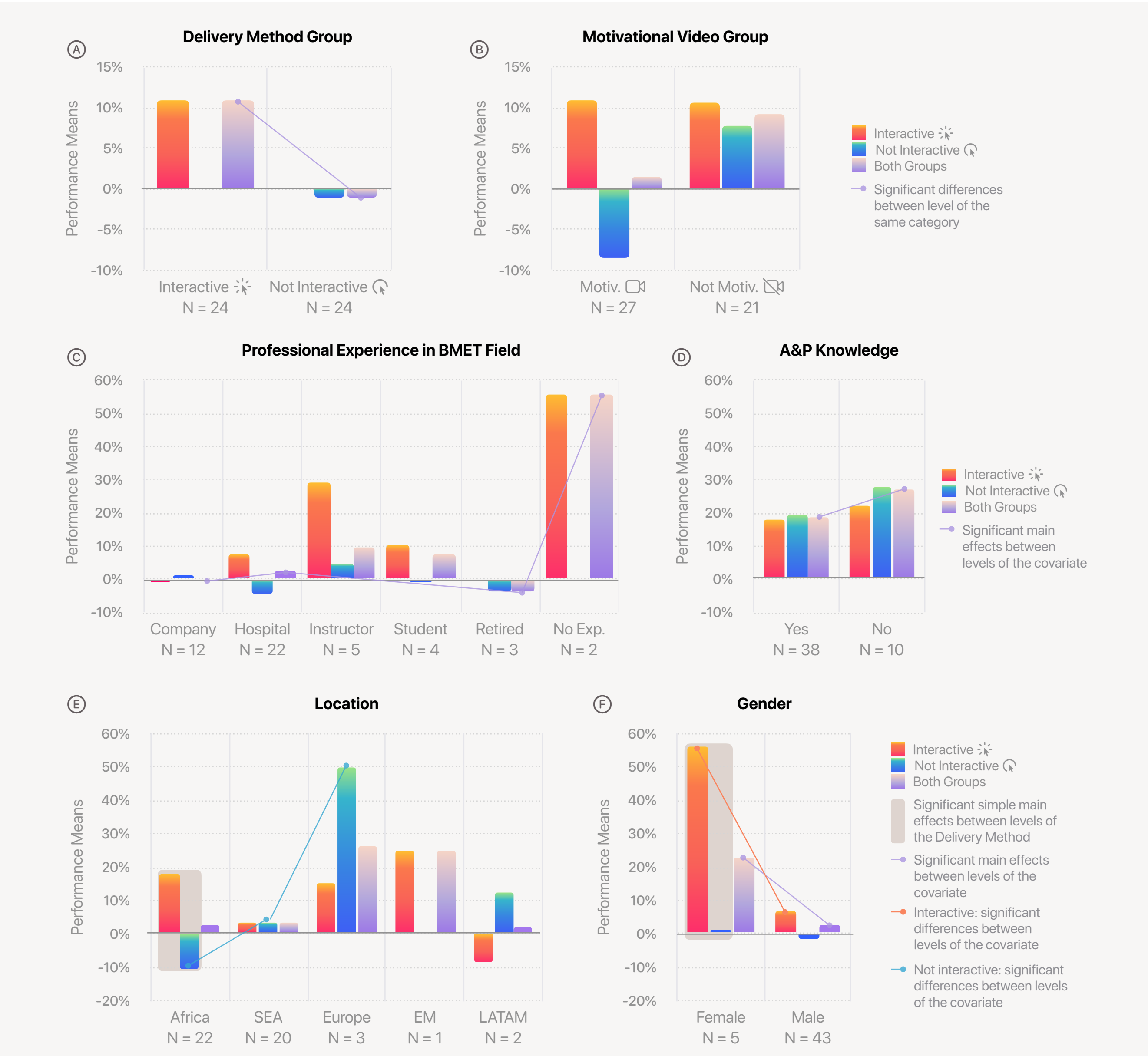

FIGURE 3. Series of Bar Plots Representing the Difference in Performance of the Independent Variables, and the Covariates With Significant Results

Finally, the students' professional experience was also analysed. Although the two-way ANOVA did not show an interaction between both variables ($F(2, 42) = 0.471, p = 0.704$), there was a statistically significant difference in performance between the different experience levels of the covariate: $F(3, 38) = 2.451, p = 0.049$ (see **Figure 3.C**). Tukey's post hoc test revealed that the performance in the A&P Module was statistically significantly lower for the learners working on a Company ($\bar{x}$ = 0.13% , p = 0.013), on a Hospital ($\bar{x}$ = 2.38%, p = 0.014), and retired BMET ($\bar{x}$ =-3.90%, p = 0.032) compared to those with no experience on the field ($\bar{x}$ = 55.85%). There was no statistically significant difference between the BMET Instructors and students with the other groups.

DEMOGRAPHIC ANALYSIS

The analysis begun with the Location, examining the region of origin of the participants influenced the performance. The results for the two-way ANOVA indicated a not significant main effect for Location: $F(4, 39) = 1.532, p = 0.212$. Besides, the outcomes of the post hoc test did not demonstrate any effects on performance from those participants from Africa as compared to those from South-East Asia, Europe, Eastern Mediterranean or Latin America. On the other hand, the results showed a significant interaction between the location and delivery method, $F(3, 39) = 3.344, p = 0.029$. In other words, any differences between the five regions were the participants were from, depended on which group the subjects were on, and vice versa.

To further study this interaction, a line graph plotting the mean Performance score for each combination of levels of "Location" and "Delivery method" was included in **Figure 3.E**. Moreover, a simple main effect analysis was computed for each of the variables individually. For the Delivery Method simple main effects, the only significant difference between Interactive and Not Interactive content groups was found in the participants from the African region. A review of the group means indicated that the interactive components ($\bar{x}$ = 17.75%) produced a significantly higher efficient performance for this group than the regular units ($\bar{x}$ =-10.42%), $F(1, 39) = 10.539, p = 0.002$. On top of that, the differences among the five WHO-defined regions for Interactive and Not interactive groups were also examined separately. There were significant differences among the locations for the Not Interactive group: $F(4, 39) = 3.292, p = 0.030$. Follow-up tests showed that Europeans ($\bar{x}$ = 50.00%) performed simnifically higher than Africans ($\bar{x}$ =-10.42%, p = 0.007) and South-East Asians ($\bar{x}$ =3.57%, p = 0.035).

Concerning the gender variable, 89.6% of the valid participants were male, while the remaining 10.4% were female. This unbalanced distribution of genders was reflected on the sample sized for each groups, with only 2 females out of the 22 males in the Interactive group. The results of its two-way ANOVA indicated a significant main effect for gender, $F(1, 44) = 7.343, p = 0.010$. Additionally, the results show a significant interaction between gender and the delivery method, $F(1, 44) = 5.970, p = 0.019$, indicating that any differences between each of the variables' levels were dependent upon the other's.

The gender simple main effects were studied, that is, the differences between females and males for each delivery method. The only significant difference between the genders was found in the Interactive group, where females ($\bar{x}$ = 55.85%) performed significantly better the A&P module than males ($\bar{x}$ = 6.75%), $F(1, 44) = 11.276, p = 0.002$. When inspecting the delivery method simple main effects, a significant difference between the females involved in the interactive group ($\bar{x}$ = 55.85%) and those presented with standard content ($\bar{x}$ = 1.10%), $F(1, 44) = 9.177, p = 0.004$ was found. This interaction is represented in **Figure 3.F**.

Lastly, the results of the two-way ANOVAs on the remaining covariates (age, education level and device) did not report a significant interaction with the independent variable. Furthermore, on their own, none of the three variables obtained a statistically significant difference among the performances of their different levels. These results were sustained by the results of three Tukey's Post Hoc Tests.

INTERNET RELIABILITY AND DURATION

One of the main challenges for e-learning in LMIC is the lack of proper infrastructures to provide a reliable internet connection [17]. Since 91.6% of the pilot testers came from regions with LMICs, on the pilot they evaluated their internet connection at the place where they started the course. On average, the connection graded with 6.9/10. Nonetheless, the average internet's reliability reported by the interactive group (6.76/10) was significantly lower than the one of the not interactive group (7.38/10), $t(46) = -1.684, p = 0.049$. On this account, the Pearson correlation coefficient was calculated for both groups. A very weak inverse relationship between the performance and internet's reliability can observed in the scatter plot of **Figure 4.A**. Nonetheless, none of the delivery methods reported a significant correlation.

On another note, the 48 participants spent on average 5.85 hours. However, there was a difference of 1.21 hours between the delivery methods' groups. A non-parametric, Mann Whitney U test was computed to compare the mean duration of both groups, since the samples did not follow a normal distribution: $U=372.00, p = 0.001$. The result shows that the time spent by the interactive group (6.46 h) was statistically significantly greater than the non-interactive population (5.25 h). Lastly, the Pearson correlation coefficient and scatter plots were computed. Although a moderate positive relationship could be observed in **Figure 4.B**, the results of the test did not conclude a significant relationship between these variables, for either group.

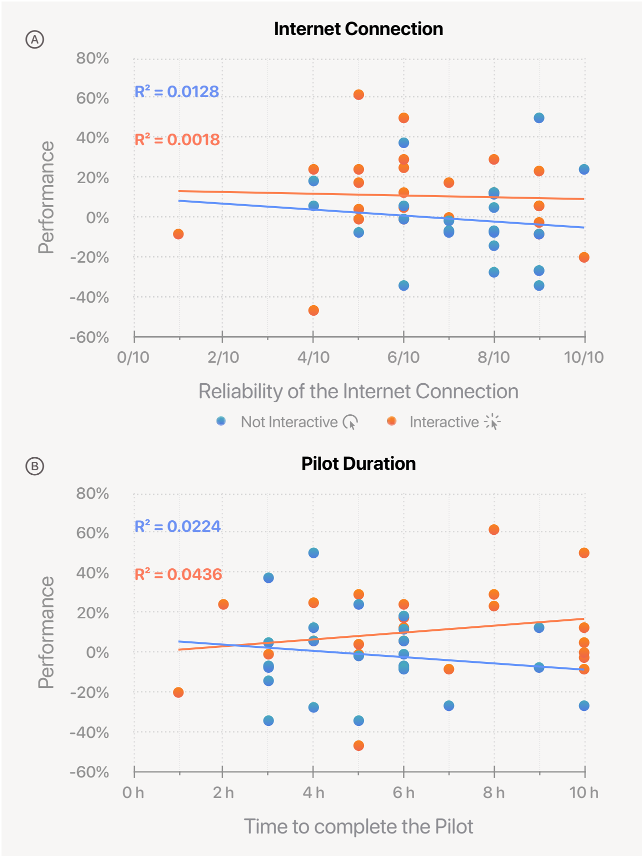

FIGURE 4. Linear Relationship Between the Performance With the Internet Reliability (A),and the Time Needed To Complete the Pilot (B)

DISCUSSION

The aim of this study is to evaluate whether the delivery of materials through interactive content could exhibit improvements in the performance. Before diving into the effects caused by the delivery method on the performance, a Chi-square test for independence was computed to determine wether the presence of interactive content encouraged the learners to complete the rest of the course or not. As it was previously mentioned, the participants were not told they would be exposed to different content delivery methods. This allowed the researchers to analyse if the interactive delivery method would serve as an incentive for the learners. However, there was not enough evidence to suggest an association between the delivery method and the motivation to complete the course. Nonetheless, it is relevant to mention that right after the modules with interactive content, there were three other regular content modules on preventive maintenance and troubleshooting, created by R. Rutten, before reaching the final assessment. Thus, further research would be needed on this matter to verify this result, or prove otherwise.

The results displayed in Figure 3.A, show that the delivery method did have a statistically significant effect on the outcomes of the pilot study. In other words, the hypothesis was successfully corroborated, and it was proven that those participants presented with Interactive content in the units of the A&P Module, performed better in the Final Assessment, compared to the Initial Knowledge Quiz. The performance was improved by 11.9%, compared to those students exposed to regular content. This means that the new delivery method boosted the involvement in the A&P Module, by taking up part of the responsibility placed on the students in online education courses [16, 20, 21]; and prevented the reduction in engagement, which led to an efficient performance.

Furthermore, the preventive measures taken to avoid the cross effect between this research question and R. Rutten's one, such as only including interactive content on the A&P module; demonstrated to be sufficient, as no sufficient evidence was found to claim that the motivational video displayed to cohorts Ⓐ and Ⓑ influenced the results of the performance, or that there was a significant interaction effect among these independent variables.

The analysis of the participants' previous experience revealed that the prior BMET training had no significant effect on the performance. However, as shown in Figure 3.C/D, there were two other covariates that obtained significant differences among their levels and were not influenced by the delivery method: previous knowledge in A&P and work experience. The pilot course improved, by a 27.4%, the participant's understanding on the main A&P concepts required by the BMET profession. Similarly, those students with no previous experience on the field, improved their performance by 55% after the course. This means that the structure, and materials provided were sufficient and successful to teach the key concepts of this module. In other words, there is no need to segregate the future MOOC in difficulty levels based on the participants previous experience as it was shown that a single level will be sufficient to report satisfactory performance from the students.

The results of the demographic analysis indicated that when exposed to standard delivery method, there were great disparities in terms of performance (over 50%) between countries in the European region, compared to those LMIC in Africa and South-East Asia (Figure 3.E). However, the same differences were not found in the group with the interactive content. Furthermore, the delivery method simple main effects revealed that the interactive components produced a significantly 28% higher performance for the African participants, compared to the regular units.

These results demonstrate that the potential benefits of improving the delivery method in online courses are directly reflected on the online course performance, as it stimulated the LMIC students' involvement in the course by promoting active engagement. It was also revealed that the female students were more subjected to improve their performance if they were exposed to interactive content, by a 54.7%. Furthermore, when dividing the results of the 48 participants by gender, there was a 20.35% improvement in the female's performance compared to the males; and if a closer look was taken at the interactive group independently, females did also outperform males, by a 49%.

On average, the 48 valid participants spent 5.85 hours, which lied within the limits proposed in the Participation Survey. However, there was a difference of 1.21 hours between the delivery methods' groups. This result demonstrates that the interactive content did boost the learner's engagement with the course components. Nonetheless, more research is needed to validate wether the corresponding workload intended for a week on the future MOOC, delivered as interactive content, would also require a duration of less than 6 hours.

The remaining variables present in the pilot course, such as the age of the participants, previous education, the type of device used to access the course, and their internet reliability, did not show a significant correlation or effect on the performance, as was shown in the previous chapter. Therefore, they are not to be considered as relevant factors influencing the potential of interactive content in online education. Lastly, Table 2 presents the mean Final Assessment scores for each of the levels of the covariates that obtained significant results, as a reference on the final outcomes.

TABLE 2. Mean Final Assessment Scores of the Significant Covariates

		TOTAL GROUP		INTERACTIVE		NOT INTER.	
		N	MEAN FA SCORE	N	MEAN FA SCORE	N	MEAN FA SCORE
DELIVERY METHOD	Interactive	24	81.67%	24	81.67%	0	
	Not Interactive	24	82.22%	0		24	82.22%
PROFESSIONAL EXPERIENCE	BMET in Company	12	85.56%	5	81.33%	7	90.00%
	BMET in Hospital	22	79.09%	13	77.44%	9	81.48%
	BMET Instructor	5	77.33%	1	66.67%	4	80.00%
	BMET Student	4	95.00%	3	97.78%	1	86.67%
	Retired BMET	3	71.11%	0		3	71.11%
	No Experience	2	93.33%	2	93.33%	0	
A&P KNOWLEDGE	A&P course	38	80.53%	19	80.35%	19	80.70%
	No A&P Knowledge	10	87.33%	5	86.67%	5	88.00%
LOCATION	Africa	22	79.09%	10	84.00%	12	75.00%
	South-East-Asia	20	82.33%	10	77.33%	10	87.33%
	Europe	3	93.33%	2	90.00%	1	6.00%
	Eastern Medit.	1	100.00%	1	100.00%	0	
	Latin America	2	83.33%	1	66.67%	1	100.00%
GENDER	Female	5	88.00%	2	93.33%	3	84.44%
	Male	43	81.24%	22	80.61%	21	81.90%

LIMITATIONS

Despite having obtained the aforementioned results, the study was subjected to a series of limitations. Firstly, when looking at the individual responses, edX does not provide a tool to determine whether the responses in the exams where filled in randomly by the students, or if they skipped them due to a specific motive. Same way it was not possible to resolve wether a drastic rise in the performance for specific learners was due to cheating in the FA, or genuine learning. That is why it was decided not to filter out any participant based on their responses or grade reports.Thus, all the 48 responses included and analysed in the research, were assumed to be genuine, and not randomly responded, to avoid the filtration and elimination of honest responses.

Secondly, as the pilot study served a double purpose, some preventive measures had to be taken. The interactive content was only included in two out of the five theoretical lectures, to avoid conditioning the learning of troubleshooting, repair and preventive maintenance, as they were key for R. Rutten's thesis [29]. Additionally, the topic of the motivational video, was not related to the concepts taught in the A&P and PM.I units, to minimise the effect on this matter. On the other hand, the statistical analysis showed that these measures were sufficient, as no interaction effect was found between these independent variables, and no significant influence in the performance was observed produced by the motivational video.

Lastly, due to these measures, right after the modules with interactive content, there were other units based on standard readings, figures and videos. Thus, it was not possible to properly asses wether the interactive content served as an incentive for the students and stimulated them to finalise the course or not. Further research on this matter is needed. On another note, for a detailed description on the recommendations based on these findings, refer to the main thesis [24].

CONCLUSION

Even though not enough evidence was collected to suggest that the interactive content served as a motivational incentive for the students; it can be concluded that the differences in the delivery method, lead to an improvement in the performance of 11.9%, compared to the results of the learners exposed to regular content. The female students were the subjects more prone to the improvement, as well as the African participants, whose performance results were balanced to the level of the other regions, after being exposed to the interactive components. Besides, these findings suggest that this new delivery method not only boosted the involvement in the A&P Module, and was able to take up part of the responsibility placed on the students in online education courses [16, 20, 21]; but it also prevented the reduction in engagement.

Additionally, the structure, and material provided were sufficient and successful to teach the key concepts of this module. Moreover, there was no evidence found that suggested the need to segregate the future MOOC in difficulty levels based on the participants previous experience, as it was shown that a single level will be sufficient to report satisfactory performance from the students. Therefore, it is proposed to preserve the pilot's blueprint and lecture structure, and replicate it on the future MOOC.

All in all, it can be said that the project benefited from a diverse group of students, who were motivated to complete the course, and whose participation was sufficient to validate the hypothesis presented in the beginning. On that account, the BMET MOOC presents itself as a great alternative to prevent the great amount of out-of-service medical equipment in LMICs, and these outcomes on interactive content can be of great value when eventually transferring the complete curriculum to an online platform; and therefore, have a direct impact on the maintenance of medical equipment in these countries, to ensure a proper quality of the health care delivery.

ACKNOWLEDGEMENTS

This study would not have been possible without the help various collaborators and supervisors. Particular thanks go to R. Rutten, A. Chauhan, J. Madete, N. Wahls and N. Wylie for their help and dedication to this study; specially to Prof. Dr. Jenny Dankelman and Dr. Ir. Arjan Knulst for entrusting me with this project, as well as their time, professional guidance and continuous support.

BIBLIOGRAPHY

[1] N. D. Khambete and A. Murray, "National efforts to improve healthcare technology management and medical device safety in India," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-5, doi: 10.1049/cp.2012.1474. [Online]. Available: https://ieeexplore.ieee.org/document/6458811

[2] World Health Organization, "Global atlas of medical devices," 2017.

[3] J. L. Eder-Van Hook and C. T. Love, "A Model for Training Biomedical Equipment Technicians in Low-Resource Settings," Transition Management Consulting, Inc., San Diego, CA, 2015.

[4] World Health Organization, Human resources for medical devices, the role of biomedical engineers. World Health Organization, 2017.

[5] F. R. Painter, "Chapter Four - Careers in Clinical Engineering," in *Careers in Biomedical Engineering*, M. Levin-Epstein Ed.: Academic Press, 2019, pp. 67-78.

[6] S. Mullally, T. Bbuku, G. Musonda, and E. Measures, "Biomedical engineering technologist (BMET) curriculum and programme development in Zambia," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-6, doi: 10.1049/cp.2012.1484. [Online]. Available: https://ieeexplore.ieee.org/document/6458819

[7] R. A. Malkin and L. Perry, "Evaluation of the impact of a new biomedical equipment technician curriculum in Rwanda," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-3, doi: 10.1049/cp.2012.1485.

[8] W. S. Topham, B. P. Gurung, and B. Muis, "Biomedical equipment technician training in Nepal," in *2008 5th IET Seminar on Appropriate Healthcare Technologies for Developing Countries*, 21-22 May 2008 2008, pp. 1-5, doi: 10.1049/ic:20080585.

[9] S. C. Daglish, M. Hilditch, and J. Okunzi, "Development of a self-sustaining biomedical engineering training course in Uganda," in *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*, 18-19 Sept. 2012 2012, pp. 1-4, doi: 10.1049/cp.2012.1486.

[10] R. M. Bauer and P. K. Jaeger, "Maintenance Training Course for Biomedical/Hospital Technicians," 2006, vol. 2006, 11370 ed., pp. 73-77, doi: 10.1049/ic.2006.0663. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-78649893602&doi=10.1049%2fic.2006.0663&partnerID=40&md5=d788ce9b4407ca20cb20f884e176f6c2

[11] J. O. Wea, "Certification of Biomedical Engineering Technicians and Clinical Engineers: Important or Not," Berlin, Heidelberg, 2007: Springer Berlin Heidelberg, in 11th Mediterranean Conference on Medical and Biomedical Engineering and Computing 2007, pp. 1081-1084.

[12] J. R. Roberts, "Training biomedical engineers in developing countries," Stevenage, United Kingdom, 1995: IEE, 27 ed., pp. 3/1-3/3. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-0029472545&partnerID=40&md5=8ac0b23c2b694538032473e9b46a286e. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-0029472545&partnerID=40&md5=8ac0b23c2b694538032473e9b46a286e

[13] T. Daradoumis, R. Bassi, F. Xhafa, and S. Caballé, "A review on massive e-learning (MOOC) design, delivery and assessment," in *2013 eighth international conference on P2P, parallel, grid, cloud and internet computing*, 2013: IEEE, pp. 208-213.

[14] L. Guàrdia, M. Maina, and A. Sangrà, "MOOC design principles: A pedagogical approach from the learner's perspective," *elearning papers,* no. 33, 2013.

[15] A. M. F. Yousef, M. A. Chatti, U. Schroeder, and M. Wosnitza, "What drives a successful MOOC? An empirical examination of criteria to assure design quality of MOOCs," in *2014 IEEE 14th International Conference on Advanced Learning Technologies*, 2014: IEEE, pp. 44-48.

[16] H. Estelami, "An Exploratory Study of the Effects of Online Course Efficiency Perceptions on Student Evaluation of Teaching (SET) Measures," *American Journal of Business Education,* vol. 9, no. 2, pp. 67-82, 2016.

[17] D. García de las Heras, "e-Learning Potential for Biomedical Equipment Technician Training in Low-/Middle-Income Countries," M.Sc. Biomedical Engineering Literature Review, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, 2020.

[18] B. Gros and F. J. García-Peñalvo, "Future Trends in the Design Strategies and Technological Affordances of E-Learning," in *Learning, Design, and Technology: An International Compendium of Theory, Research, Practice, and Policy*, M. J. Spector, B. B. Lockee, and M. D. Childress Eds. Cham: Springer International Publishing, 2016, pp. 1-23.

[19] S. Palvia *et al.*, "Online Education: Worldwide Status, Challenges, Trends, and Implications," *Journal of Global Information Technology Management,* vol. 21, no. 4, pp. 233-241, 2018/10/02 2018, doi: 10.1080/1097198X.2018.1542262.

[20] I. Jung, "Costing virtual university education," Economics of Distance and Online Learning: Theory, Practice and Research. New York: Routledge, pp. 148-161, 2008.

[21] I. E. Allen and J. Seaman, "Grade Change: Tracking Online Education in the United States," *Babson Survey Research Group,* 2014.

[22] R. Rutten, "Bringing Technology to Life: Increasing the amount of in-service medical equipment by developing a MOOC to train Biomedical Equipment Technicians in Low-/ Middle Income Countries," M.Sc. Biomechanical Design Graduation Thesis, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, 2020.

[23] edX, *Building and Running an edX Course*, Published Online, 2020. [Online]. Available: https://edx.readthedocs.io/projects/edx-partner-course-staff/en/latest/index.html.

[24] D. García de las Heras, "Pilot Study for the Design of a MOOC to train Biomedical Equipment Technician in Low-/Middle-Income Countries. A Comparative Evaluation of the Course Performance in terms of the Delivery Method," M.Sc. Biomedical Engineering, Master Thesis, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, 2020.

[25] *Numbers*. (2020). Accessed: 27th July 2020. [Online]. Available: https://www.apple.com/numbers/

[26] *SPSS Statistics 25*. (2020). Accessed: 1st Septermber 2020. [Online]. Available: https://www.ibm.com/products/spss-statistics

[27] S. S. Shapiro and M. B. Wilk, "An analysis of variance test for normality (complete samples)," *Biometrika,* vol. 52, no. 3-4, pp. 591-611, 1965, doi: 10.1093/biomet/52.3-4.591.

[28] P. Mishra, U. Singh, C. M. Pandey, P. Mishra, and G. Pandey, "Application of student's t-test, analysis of variance, and covariance," (in eng), *Ann Card Anaesth,* vol. 22, no. 4, pp. 407-411, Oct-Dec 2019, doi: 10.4103/aca.ACA_94_19.

[29] R. Rutten, "Educate biomedical equipment technicians via an online platform in low-/middle-income countries whilst stimulating intrinsic motivation," M.Sc. Biomechanical Design Graduation Thesis, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, 2020.

B

BMET Pilot MOOC Results

Progress Data

Total Invitations	Failed Emails	edX Log in	Not Registered	Initial Feedback	Final Feedback	Only Enrolled	In Progress	Completed All	Valid Participant	Not Valid Particip.
132	3	86	46	68	57	14	15	57	57	70

Group A

Number	Valid	Only Enrolled	In Progress	Finished	Ratio
30	29	2	6	14	48%

Group B

Number	Valid	Only Enrolled	In Progress	Finished	Ratio
31	29	1	4	13	44.8%

Group C

Number	Valid	Only Enrolled	In Progress	Finished	Ratio
29	29	2	3	10	34.5%

Group D

Number	Valid	Only Enrolled	In Progress	Finished	Ratio
29	29	6	1	11	37.9%

Validation Group

Number	Valid	Only Enrolled	In Progress	Finished	Ratio
13	13	3	1	9	69.2%

Legend

Icon	Meaning	Icon	Meaning
✓	Completed		Valid Participant for Study
⊗	Not Completed/Error		Not Valid Participant for Study
?	Pending Response		Pending Response or Material
Ⓐ	In Progress/To be finished		Improvement in grade by 5%
@	Only Enrolled		Reduction in grade by 5%
⊖	No Response/No Participation		Barely no Modification
	Interactive Content Group		Validation Content Group
	Not-Interactive Content Group		R.Rutten's Motivation Video

Results

Participants ID / Progress / Grade Report

ID	Cohort	Delivery	Motivation	Status	Valid	edX Log in	Entrance S.	End-of-Course	No-participation	Participation Level	Discussion	Entrance S.	A&P	PM.I	PM.II	PM.III	Initial Exam	Final Exam	End-of-Course	Final Grade	Performance
132																					
▼ Validation					13															0	0
1	General	Validation	Validation	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	0.67	1.0	1.0	0.95	0.82	1.0	⊖	
2	General	Validation	Validation	✓	Valid	✓	?	✓	⊖	Browsed Through	1.0	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	⊖	
3	General	Validation	Validation	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	Ⓐ	1.0	1.0	1.0	0.9	0.78	0.34	Ⓐ	⊖	
6	General	Validation	Validation	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.62	0.86	1.0	⊖	
7	General	Validation	Validation	✓	Valid	✓	✓	?	⊖	Browsed Through	1.0	1.0	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	⊖	
8	General	Validation	Validation	✓	Valid	✓	✓	✓	⊖	Browsed Through	1.0	1.0	0.54	1.0	0.0	1.0	0.71	0.58	1.0	⊖	
9	General	Validation	Validation	✓	Valid	✓	✓	✓	⊖	Participated Halfway	1.0	1.0	1.0	1.0	0.0	1.0	0.92	0.9	1.0	⊖	
10	General	Validation	Validation	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	0.0	1.0	0.73	0.81	1.0	⊖	
12	General	Validation	Validation	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.75	0.93	1.0	0.62	0.55	0.71	1.0	⊖	
4	General	Validation	Validation	@	Not valid	✓	?	?	⊖	Browsed Through	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	⊖	
5	General	Validation	Validation	@	Not valid	✓	?	?	⊖	Browsed Through	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	⊖	
11	General	Validation	Validation	Ⓐ	Not valid	✓	?	?	⊖	Browsed Through	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	⊖	
13	General	Validation	Validation	Ⓐ	Not valid	✓	?	?	⊖	Browsed Through	0.0	1.0	Ⓐ	Ⓐ	Ⓐ	Ⓐ	0.03	Ⓐ	Ⓐ	⊖	
▼ Interactive					24															88.64%	10.83%
17	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.92	0.96	1.0	0.75	0.94	0.85	1.0	88.50%	-0.83%
20	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Halfway	1.0	1.0	1.0	1.0	1.0	1.0	0.82	0.84	1.0	91.10%	17.50%
29	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.92	1.0	0.0	0.75	0.77	0.89	1.0	80.05%	24.17%
34	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.95	1.0	0.0	1.0	0.78	0.83	1.0	79.90%	17.50%
36	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.97	1.0	1.0	1.0	0.78	0.83	1.0	90.10%	4.17%
38	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.91	0.78	1.0	1.0	0.64	0.86	1.0	88.10%	24.17%
40	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.85	1.0	1.0	0.9	0.92	0.87	1.0	90.60%	-20.00%
43	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.81	0.81	1.0	89.55%	-8.33%
51	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.97	0.96	1.0	1.0	0.65	0.75	1.0	85.05%	29.17%
61	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.92	1.0	1.0	1.0	0.86	0.83	1.0	90.00%	-0.83%
63	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.97	1.0	1.0	1.0	0.77	0.77	1.0	87.05%	-2.50%
67	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.81	0.97	1.0	97.55%	25.00%
77	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.89	0.84	1.0	1.0	0.73	0.79	1.0	85.45%	29.17%
82	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.96	1.0	1.0	1.0	0.91	0.91	1.0	94.65%	5.83%
85	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.99	1.0	99.00%	0.00%
86	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Only Mandatory Items	0.0	1.0	0.83	0.96	1.0	0.9	0.73	0.82	1.0	85.55%	23.33%
92	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.86	0.89	1.0	1.0	0.75	0.88	1.0	90.25%	5.00%
98	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.78	0.81	1.0	0.75	0.89	0.75	1.0	80.35%	-46.67%
104	Group C	Interactive	No video	✓	Valid	✓	✓	✓	✓	Only Mandatory Items	1.0	1.0	0.59	0.33	1.0	0.5	0.63	0.71	1.0	67.85%	-8.33%
106	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.97	1.0	1.0	1.0	0.78	0.89	1.0	93.10%	50.00%
108	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.97	0.96	1.0	1.0	0.63	0.88	1.0	91.45%	61.67%
115	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.94	1.0	1.0	0.75	0.85	0.85	1.0	88.65%	12.50%
121	Group A	Interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.76	0.98	1.0	97.80%	12.50%
128	Group C	Interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.97	1.0	1.0	1.0	0.89	0.93	1.0	95.65%	5.83%
▼ Non-interactive					24															89.79%	-1.11%
21	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.87	0.94	1.0	96.35%	37.50%
22	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	0.7	0.76	0.91	1.0	91.30%	18.33%
33	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.88	1.0	1.0	1.0	0.64	0.86	1.0	90.00%	11.67%
37	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.92	1.0	1.0	1.0	0.76	0.88	1.0	92.00%	5.83%
45	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	0.5	0.77	0.89	1.0	88.35%	-7.50%
54	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.85	0.91	1.0	94.75%	12.50%
59	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.91	0.91	1.0	95.05%	12.50%
60	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.92	1.0	1.0	1.0	0.86	0.91	1.0	94.00%	-7.50%
62	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	0.75	0.81	0.9	1.0	91.55%	5.83%
66	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Only Mandatory Items	1.0	1.0	1.0	1.0	1.0	1.0	0.68	0.95	1.0	95.90%	50.00%
68	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	0.0	1.0	1.0	1.0	1.0	1.0	0.85	0.85	1.0	90.75%	-14.17%
73	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.74	1.0	1.0	1.0	0.79	0.8	1.0	86.35%	-1.67%
75	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	✓	Participated Fully	1.0	1.0	0.69	0.8	1.0	1.0	0.79	0.59	1.0	73.35%	-34.17%
78	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.92	1.0	1.0	1.0	0.86	0.84	1.0	90.50%	-8.33%
81	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.95	0.76	1.0	87.75%	-26.67%
88	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.94	0.94	1.0	96.70%	-6.67%
95	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Browsed Through	1.0	1.0	1.0	1.0	1.0	1.0	0.85	0.74	1.0	86.25%	-27.50%
103	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.87	0.9	1.0	94.35%	-6.67%
118	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	0.33	1.0	0	0.6	0.81	0.64	1.0	60.35%	-34.17%
124	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.78	0.9	1.0	93.90%	-0.83%
126	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	0.88	0.88	0.87	1.0	91.70%	-7.50%
127	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.91	0.86	1.0	92.55%	5.00%
130	Group D	Non-interactive	No video	✓	Valid	✓	✓	✓	⊖	Only Mandatory Items	1.0	1.0	0.96	1.0	1.0	1.0	0.72	0.87	1.0	91.70%	24.17%
132	Group B	Non-interactive	Video	✓	Valid	✓	✓	✓	⊖	Participated Fully	1.0	1.0	1.0	1.0	1.0	1.0	0.98	0.79	1.0	89.40%	-26.67%
▼					71															0	0
16	Group A			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
23	Group B			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
27	Group C			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
28	Group D			@	Not valid	✓	?	?	✓	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
69	Group D			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
94	Group D			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
96	Group D			@	Not valid	✓	?	?	?	?	Ⓐ	0.0	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
111	Group D			@	Not valid	✓	?	?	✓	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
114	Group D			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
120	Group C			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		
123	Group A			@	Not valid	✓	?	?	?	?	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ		

Participants' Information & Demographics / Participants' Experience / Course Feedback / Evaluation / Scores A&P

ID	Age	Gender	Education	Location	Device	Professional Experience in BMET Field	BMET Training	Experience with the Patient Monitor	Prior A&P	Difficulty Level	Exercise vs. Theory	Expected h	Spent h	Internet	Clarity	Design	Overall	A&P Initial	A&P Final
▼ Validation													2.08	0.00	0.00	0.00	0.00		
1	31-35	Male	Master's Degree	South-East Asia	Laptop	BMET Instructor at LMIC	BMET Training	PM Experience from Training	⊖	About right	About right	4	3					⊖	⊖
2	?	?	?	Europe	?	Clinical Engineer and Consultant	BMET Training	?	⊖	Too difficult	About right	⊖	1					⊖	⊖
3	36-40	Female	PhD's	Africa	Laptop	Biomedical Engineer and Lecturer	BMET Training	No PM Experience	⊖	?	?	6	⊖					⊖	⊖
6	31-35	Male	Bachelor's Degree	South-East Asia	Laptop	BMET in United Mission Hospital Tan	BMET Training	PM Experience from Training	⊖	About right	About right	5	5					⊖	⊖
7	26-30	Female	PhD's	Europe	Desktop	PhD TUDelft	No BMET Training	No PM Experience	⊖	?	?	4	⊖					⊖	⊖
8	26-30	Male	Master's Degree	Europe	Laptop	No relevant experience	No BMET Training	No PM Experience	⊖	About right	About right	4	2					⊖	⊖
9	21-25	Female	Bachelor's Degree	Europe	Laptop	Biomedical Engineer	No BMET Training	No PM Experience	⊖	About right	About right	5	5					⊖	⊖
10	21-25	Female	Bachelor's Degree	Europe	Laptop	BME and MSc student	No BMET Training	No PM Experience	⊖	About right	About right	4	4					⊖	⊖
12	31-35	Female	Bachelor's Degree	South-East Asia	Laptop	BMET Instructor	BMET Training	PM Experience from Work	⊖	About right	About right	5	7					⊖	⊖
4	?	?	?	Europe	?	BMET at UMC	BMET Training	?	⊖	?	?	⊖	⊖					⊖	⊖
5	?	?	?	Europe	?	BMET at UMC	BMET Training	?	⊖	?	?	⊖	⊖					⊖	⊖
11	?	?	?	South-East Asia	?	BMET Instructor	BMET Training	?	⊖	?	?	⊖	⊖					⊖	⊖
13	?	?	?	South-East Asia	?	BMET Instructor	BMET Training	?	⊖	?	?	⊖	⊖					⊖	⊖
▼ Interactive													6.46	6.46	7.63	8.17	8.17		
17	31-35	Male	Bachelor's Degree	South-East Asia	Laptop	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	About right	6	3	5	6	7	8	87.50%	86.67%
20	26-30	Male	Bachelor's Degree	South-East Asia	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	About right	5	6	5	8	8	8	62.50%	80.00%
29	21-25	Male	High School Diploma	South-East Asia	Laptop	BMET in Hospital	No BMET Training	PM Experience from Work	No	Too easy	About right	3	6	5	8	8	8	62.50%	86.67%
34	36-40	Male	Bachelor's Degree	South-East Asia	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	About right	4	6	7	9	8	9	62.50%	80.00%
36	26-30	Male	Master's Degree	South-East Asia	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	Too little exercises	7	5	5	7	7	8	62.50%	66.67%
38	26-30	Male	Bachelor's Degree	South-East Asia	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	About right	2	2	4	8	8	8	62.50%	86.67%
40	>40	Male	Bachelor's Degree	Europe	Laptop	BMET in Company/Organisation	BMET Training	PM Experience from Training	Yes	Far too easy	About right	4	1	10	3	1	1	100.00%	80.00%
43	>40	Male	Master's Degree	Latin America	Desktop	BMET in Company/Organisation	BMET Training	PM Experience from Training	Yes	Too easy	About right	8	7	9	10	9	9	75.00%	66.67%
51	>40	Male	Master's Degree	Africa	Laptop	BMET Instructor	BMET Training	PM Experience from Work	Yes	About right	About right	8	8	6	7	8	8	37.50%	66.67%
61	26-30	Male	High School Diploma	South-East Asia	Laptop	BMET in Hospital	BMET Training	PM Experience from Work	Yes	About right	About right	6	5	6	6	7	7	87.50%	86.67%
63	>40	Male	Master's Degree	Africa	Laptop	BMET in Company/Organisation	BMET Training	PM Experience from Work	Yes	About right	About right	6	10	9	9	10	10	62.50%	60.00%
67	31-35	Male	Postgraduate Degree	Eastern Mediterranean	Laptop	BMET in Company/Organisation	BMET Training	PM Experience from Work	Yes	Far too easy	Too little exercises	4	4	6	7	8	7	75.00%	100.00%
77	36-40	Male	Bachelor's Degree	Africa	Tablet	BMET in Hospital	No BMET Training	PM Experience from Work	No	About right	About right	6	5	8	7	10	7	37.50%	66.67%
82	26-30	Male	Bachelor's Degree	Africa	Smartphone - Android	BMET in Hospital	Training in Progress	PM Experience from Work	Yes	About right	About right	5	6	9	9	8	8	87.50%	93.33%
85	21-25	Male	Bachelor's Degree	Africa	Smartphone - Android	BMET in Company/Organisation	No BMET Training	PM Experience from Training	Yes	About right	Too little exercises	4	10	7	9	10	10	100.00%	100.00%
86	>40	Male	Postgraduate Degree	Africa	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	About right	10	8	9	9	9	9	50.00%	73.33%
92	21-25	Male	High School Diploma	South-East Asia	Desktop	BMET in Hospital	BMET Training	PM Experience from Work	Yes	About right	About right	4	10	6	9	10	9	75.00%	80.00%
98	26-30	Male	Bachelor's Degree	South-East Asia	Smartphone - Android	BMET in Hospital	No BMET Training	PM Experience from Work	Yes	About right	About right	4	5	4	8	9	7	100.00%	53.33%
104	>40	Male	Master's Degree	South-East Asia	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training	Yes	Too difficult	Too much exercises	?	10	1	1	10	10	75.00%	66.67%
106	>40	Female	Master's Degree	Europe	Laptop	No Experience	No BMET Training	PM Experience from Work	No	About right	About right	7	10	6	8	7	7	50.00%	100.00%
108	31-35	Female	Bachelor's Degree	Africa	Desktop	No Experience	No BMET Training	PM Experience from Work	No	About right	Too much exercises	5	8	5	9	7	10	25.00%	86.67%
115	21-25	Male	High School Diploma	Africa	Laptop	BMET Student	Training in Progress	PM Experience from Training	Yes	About right	About right	10	10	8	9	10	10	87.50%	100.00%
121	21-25	Male	High School Diploma	Africa	Laptop	BMET Student	No BMET Training	No PM Experience	Yes	About right	About right	5	6	6	9	9	9	87.50%	100.00%
128	21-25	Male	High School Diploma	Africa	Laptop	BMET Student	Training in Progress	PM Experience from Work	No	Too easy	About right	4	4	9	8	8	9	87.50%	93.33%
▼ Non-interactive													5.25	7.38	8.21	8.21	8.46		
21	21-25	Male	High School Diploma	South-East Asia	Desktop	BMET in Company/Organisation	No BMET Training	PM Experience from Training	Yes	Too easy	Too little exercises	2	3	6	7	9	8	62.50%	100.00%
22	31-35	Male	Bachelor's Degree	South-East Asia	Laptop	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	About right	6	6	4	7	8	9	75.00%	93.33%
33	26-30	Male	Bachelor's Degree	South-East Asia	Laptop	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	Too much exercises	?	6	8	9	9	10	75.00%	86.67%
37	31-35	Male	Bachelor's Degree	South-East Asia	Laptop	BMET in Hospital	BMET Training	No PM Experience	Yes	About right	About right	3	4	6	8	10	10	87.50%	93.33%
45	>40	Male	PhD's	Africa	Laptop	BMET Instructor	BMET Training	PM Experience from Training	Yes	Too easy	About right	4	9	8	9	7	7	87.50%	80.00%
54	>40	Male	High School Diploma	Latin America	Desktop	BMET in Company/Organisation	BMET Training	No PM Experience	No	About right	About right	6	4	8	8	8	8	87.50%	100.00%
59	>40	Male	Bachelor's Degree	Africa	Laptop	BMET in Company/Organisation	BMET Training	PM Experience from Training	Yes	About right	Too little exercises	8	9	8	8	7	8	87.50%	100.00%
60	21-25	Male	High School Diploma	South-East Asia	Laptop	BMET in Hospital	No BMET Training	PM Experience from Training	Yes	About right	About right	3	3	5	7	6	7	87.50%	80.00%
62	21-25	Female	High School Diploma	South-East Asia	Desktop	BMET in Hospital	BMET Training	PM Experience from Work	No	About right	About right	6	6	4	8	7	8	87.50%	93.33%
66	31-35	Male	Master's Degree	Europe	Laptop	Retired BMET	BMET Training	No PM Experience	No	Too easy	About right	4	4	9	7	8	7	50.00%	100.00%
68	31-35	Male	High School Diploma	Africa	Laptop	BMET in Company/Organisation	BMET Training	PM Experience from Training	Yes	About right	Too little exercises	?	3	8	9	7	8	87.50%	73.33%
73	>40	Male	Master's Degree	Africa	Smartphone - Android	BMET Instructor	BMET Training	PM Experience from Work	No	About right	About right	4	5	7	8	10	10	75.00%	73.33%
75	26-30	Male	Bachelor's Degree	Africa	Laptop	BMET in Hospital	BMET Training	PM Experience from Training	Yes	Too easy	About right	?	5	9	10	10	9	87.50%	53.33%
78	>40	Male	Bachelor's Degree	Africa	Laptop	BMET in Hospital	BMET Training	PM Experience from Training	Yes	About right	About right	5	6	9	8	8	9	75.00%	66.67%
81	>40	Male	Postgraduate Degree	Africa	Laptop	BMET in Hospital	Training in Progress	PM Experience from Training	Yes	About right	About right	6	10	9	10	10	10	100.00%	73.33%
88	21-25	Male	High School Diploma	South-East Asia	Laptop	BMET in Company/Organisation	BMET Training	No PM Experience	Yes	About right	About right	2	3	7	8	8	9	100.00%	93.33%
95	21-25	Male	Bachelor's Degree	South-East Asia	Laptop	Retired BMET	BMET Training	PM Experience from Training	Yes	Too easy	About right	7	4	8	8	6	6	87.50%	60.00%
103	31-35	Male	Master's Degree	South-East Asia	Laptop	BMET in Hospital	BMET Training	PM Experience from Training	Yes	Too easy	About right	5	6	8	8	8	8	100.00%	93.33%
118	31-35	Male	Elementary School Diploma	Africa	Smartphone - Android	Retired BMET	BMET Training	PM Experience from Training	Yes	About right	About right	7	3	6	8	8	8	87.50%	53.33%
124	21-25	Male	High School Diploma	Africa	Smartphone - Android	BMET Student	No BMET Training	No PM Experience	Yes	About right	Too much exercises	6	6	6	9	9	9	87.50%	86.67%
126	21-25	Female	Bachelor's Degree	Africa	Smartphone - Android	BMET in Company Organisation	Training in Progress	No PM Experience	Yes	About right	Too little exercises	7	6	7	8	8	9	87.50%	80.00%
127	31-35	Female	Master's Degree	South-East Asia	Smartphone - iOS	BMET Instructor	BMET Training	PM Experience from Training	Yes	About right	Too little exercises	4	3	8	9	9	9	75.00%	80.00%
130	26-30	Male	Bachelor's Degree	Africa	Laptop	BMET Instructor	No BMET Training	PM Experience from Work	Yes	About right	Too little exercises	4	5	10	8	8	8	62.50%	86.67%
132	21-25	Male	High School Diploma	Africa	Laptop	BMET in Company/Organisation	No BMET Training	PM Experience from Training	No	About right	About right	2	7	9	8	9	9	100.00%	73.33%
▼													0.04	0.00	0.00	0.00	0.00		
16	?	?	?	South-East Asia	?	BMET Student	Training in Progress	?		?	?	⊖	⊖					Ⓐ	Ⓐ
23	?	?	?	South-East Asia	?	BMET Student	Training in Progress	?		?	?	⊖	⊖					Ⓐ	Ⓐ
27	?	?	?	South-East Asia	?	BMET in Company/Organisation	No BMET Training	?		?	?	⊖	⊖					Ⓐ	Ⓐ
28	?	?	?	South-East Asia	?	BMET in Hospital	No BMET Training	?		?	?	⊖	⊖					Ⓐ	Ⓐ
69	?	?	?	Africa	?	BMET in Company/Organisation	No BMET Training	?		?	?	⊖	⊖					Ⓐ	Ⓐ
94	?	?	?	South-East Asia	?	BMET in Hospital	No BMET Training	?		?	?	⊖	⊖					Ⓐ	Ⓐ
96	?	?	?	Africa	?	BMET in Hospital	BMET Training	?		?	?	⊖	⊖					Ⓐ	Ⓐ
111	?	?	?	Africa	?	BMET in Hospital	BMET Training	?		?	?	⊖	⊖					Ⓐ	Ⓐ
114	?	?	?	Africa	?	BMET in Company/Organisation	Training in Progress	?		?	?	⊖	⊖					Ⓐ	Ⓐ
120	?	?	?	Africa	?	BMET Student	Training in Progress	?		?	?	⊖	⊖					Ⓐ	Ⓐ
123	?	?	?	Africa	?	BMET Student	Training in Progress	?		?	?	⊖	⊖					Ⓐ	Ⓐ

Participants ID						Progress					Grade Report											Participants' Information & Demographics					Participants' Experience				Course Feedback					Evaluation			Scores A&P	
ID 132	Cohort	Delivery	Motivation	Status	Valid	edX Log in	Entrance S.	End-of-Course	No-participation	Participation Level	Discussion	Entrance S.	A&P	PM.I	PM.II	PM.III	Initial Exam	Final Exam	End-of-Course	Final Grade	Performance	Age	Gender	Education	Location	Device	Professional Experience in BMET Field	BMET Training	Experience with the Patient Monitor	Prior A&P	Difficulty Level	Exercise vs. Theory	Expected h	Spent h	Internet	Clarity	Design	Overall	A&P Initial	A&P Final
39	Group C			Ⓐ	👤✗	✓	✓	?	?	?	1.0	1.0	0.56	0.49	1.0	Ⓐ	0.95	Ⓐ	Ⓐ			36-40	Female	Master's Degree	Africa	Laptop	BMET in Company/Organisation	No BMET Training	PM Experience from Training		?	?	2	⋯					87.5%	Ⓐ
41	Group A			Ⓐ	👤✗	✓	✓	?	?	?	1.0	1.0	Ⓐ	Ⓐ	Ⓐ	Ⓐ	0.9	Ⓐ	Ⓐ			26-30	Male	Bachelor's Degree	Africa	Laptop	BMET Instructor	BMET Training	PM Experience from Training		?	?	4	⋯					100%	Ⓐ
53	Group B			Ⓐ	👤✗	✓	✓	?	?	?	1.0	1.0	1.0	1.0	1.0	Ⓐ	0.79	Ⓐ	Ⓐ			26-30	Male	Master's Degree	South-East Asia	Laptop	BMET in Company/Organisation	No BMET Training	No PM Experience		?	?	3	⋯					87.5%	Ⓐ
57	Group B			Ⓐ	👤✗	✓	✓	?	✓	?	1.0	1.0	0.67	Ⓐ	Ⓐ	Ⓐ	0.77	0.04	Ⓐ			>40	Male	Master's Degree	Europe	Laptop	Retired BMET	No BMET Training	PM Experience from Training		?	?	5	⋯					87.5%	Ⓐ
58	Group A			Ⓐ	👤✗	✓	✓	?	?	?	1.0	1.0	0.8	1.0	Ⓐ	Ⓐ	0.74	Ⓐ	Ⓐ			>40	Male	High School Diploma	North America	Laptop	BMET in Company/Organisation	No BMET Training	PM Experience from Training		?	?	6	⋯					87.5%	Ⓐ
70	Group A			Ⓐ	👤✗	✓	✓	?	?	?	1.0	1.0	0.22	Ⓐ	Ⓐ	Ⓐ	0.81	Ⓐ	Ⓐ			>40	Male	Bachelor's Degree	Africa	Smartphone - Apple	BMET Instructor	BMET Training	PM Experience from Training		?	?	4	⋯					75%	Ⓐ
97	Group C			Ⓐ	👤✗	✓	✓	?	✓	?	1.0	1.0	Ⓐ	Ⓐ	Ⓐ	Ⓐ	0.8	Ⓐ	Ⓐ			26-30	Male	Bachelor's Degree	South-East Asia	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training		?	?	6	⋯					87.5%	Ⓐ
109	Group B			Ⓐ	👤✗	✓	✓	?	✓	?	0.0	1.0	Ⓐ	Ⓐ	Ⓐ	Ⓐ	0.7	Ⓐ	Ⓐ			>40	Male	Bachelor's Degree	Africa	Smartphone - Android	BMET in Hospital	No BMET Training	PM Experience from Work		?	?	4	⋯					50%	Ⓐ
117	Group A			Ⓐ	👤✗	✓	✓	?	?	?	1.0	1.0	0.64	Ⓐ	Ⓐ	Ⓐ	0.81	Ⓐ	Ⓐ			21-25	Male	High School Diploma	Africa	Laptop	BMET Student	BMET Training	No PM Experience		?	?	5	⋯					87.5%	Ⓐ
24	Group A			Ⓐ	👤?	✓	?	?	✓	?	1.0	Ⓐ	0.83	1.0	1.0	0.75	Ⓐ	0.58	1.0			?	?	?	South-East Asia	?	BMET in Hospital	BMET Training	?		?	?	⋯	⋯					Ⓐ	⋯
35	Group B			Ⓐ	👤?	✓	?	?	?	?	1.0	1.0	0.33	1.0	1.0	0.5	0.69	0.58	?			?	?	?	South-East Asia	?	BMET in Hospital	BMET Training	?		?	?	⋯	⋯					75%	66.7%
83	Group C			Ⓐ	👤?	✓	✓	?	✓	?	1.0	1.0	0.97	0.78	0.0	1.0	0.6	0.77	?			31-35	Male	Master's Degree	South-East Asia	Laptop	No Experience	BMET Training	No PM Experience		?	?	10	⋯					50%	93.3%
101	Group A			Ⓐ	👤?	✓	✓	✓	?	Browsed Through	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	0.7	Ⓐ			>40	Male	Master's Degree	Africa	Smartphone - Android	BMET in Hospital	BMET Training	PM Experience from Training		About right	About right	?	3					Ⓐ	66.7%
122	Group D			Ⓐ	👤?	✓	✓	?	?	?	1.0	1.0	1.0	1.0	0.0	0.25	0.85	0.36	?			21-25	Female	Bachelor's Degree	Africa	Smartphone - Apple	BMET Student	Training in Progress	PM Experience from Work		?	?	3	⋯					75%	53.3%
18	Group B			⊗	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
74	Group A			⊗	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET Instructor	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
79	Group B			⊗	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Hospital	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
14	Group A			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
15	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Eastern Mediterranean	?	BMET Student	Training in Progress	⋯		⋯	⋯	⋯	⋯					⋯	⋯
19	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Eastern Mediterranean	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
25	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET Student	Training in Progress	⋯		⋯	⋯	⋯	⋯					⋯	⋯
26	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET Student	Training in Progress	⋯		⋯	⋯	⋯	⋯					⋯	⋯
30	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Company/Organisation	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
31	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
32	Group C			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
42	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	North America	?	Retired BMET	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
44	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET Instructor	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
46	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET Student	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
47	Group A			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET Student	Training in Progress	⋯		⋯	⋯	⋯	⋯					⋯	⋯
48	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Company/Organisation	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
49	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	Retired BMET	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
50	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Company/Organisation	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
52	Group A			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Company/Organisation	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
55	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Eastern Mediterranean	?	BMET in Company/Organisation	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
56	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Company/Organisation	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
64	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Company/Organisation	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
65	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	Retired BMET	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
71	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Company/Organisation	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
72	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	Retired BMET	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
76	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
80	Group A			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
84	Group B			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
87	Group A			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
89	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Company/Organisation	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
90	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Company/Organisation	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
91	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	Retired BMET	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
93	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Eastern Mediterranean	?	BMET in Company/Organisation	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
99	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
100	Group D			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
102	Group A			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
105	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
107	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
110	Group D			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
112	Group C			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET Instructor	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
113	Group A			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	South-East Asia	?	BMET in Hospital	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
116	Group D			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET Student	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
119	Group B			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET Student	Training in Progress	⋯		⋯	⋯	⋯	⋯					⋯	⋯
125	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	Retired BMET	BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
129	Group C			⋯	👤✗	⋯	⋯	⋯	?	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	No Experience	No BMET Training	⋯		⋯	⋯	⋯	⋯					⋯	⋯
131	Group D			⋯	👤✗	⋯	⋯	⋯	✓	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯	⋯			⋯	⋯	⋯	Africa	?	BMET Student	Training in Progress	⋯		⋯	⋯	⋯	⋯					⋯	⋯

APPENDIX

C

Storyboard of the Pilot

Chapter 5 introduced the importance of the Pilot Study, as well as the structure and content of the course that would be tested. This Appendix aims to further support the information that was given, by presenting a detailed description of the storyboard that was presented. It focuses mainly on the lectures and units that were considered to obtain the results and draw the conclusions presented in this thesis. For more details on the lectures of Patient Monitor II-V, refer to R. Rutten's work [70].

MODULE	DESCRIPTION	MATERIALS	COHORTS	DURATION	AUTHOR
① Introduction to the Pilot Course				45 min	
WELCOME!					
• Welcoming Message • Meet the lecturers • Technical Recommendations • Outline of the course	Welcoming message to the course explaining the reasoning behind it, the structure and contents of it.	READING VIDEO	Ⓐ Ⓑ Ⓒ Ⓓ	5min	D. G.H & R. R.
WHY BECOME A BMET					
• Job description • The story of Mr. Uttam Pokhrel	The motivation group was exposed to the motivational video in this unit. The video can be found in this link.	VIDEO	Ⓐ Ⓑ	5min	R. Rutten
INTRODUCE YOURSELF!					
• Discussion Forum	To encourage the bonding between students, they were asked to introduced themselves in the discussion forum	FORUM	Ⓐ Ⓑ Ⓒ Ⓓ	7min	D. G.H & R. R.
ENTRANCE SURVEY					
• Google Forms - Entrance Survey	This was the first survey to complement the information on the participants, gathered in the Participation S.	SURVEY	Ⓐ Ⓑ Ⓒ Ⓓ	7min	D. G.H & R. R.
INITIAL KNOWLEDGE QUIZ					
• Pre-Test	The participants were asked to complete a series of questions on the topics of the pilot, to asses their level and knowledge before starting.	ASSESSMENT	Ⓐ Ⓑ Ⓒ Ⓓ	15min	D. G.H & R. R.
② Module 1: General Biomedical Engineering Skills				2 hours	
ANATOMY AND PHYSIOLOGY					
• The Cardiovascular System • The Heart and Electrocardiography • Blood Vessels and Blood Pressure • The Respiratory System • Body Temperature	This module focused on explaining the main topics of the A&P that related to the functioning of the Patient Monitor. Each unit had a combination of theory and practice activities, with videos. Moreover, the distinction between delivery method was made here.	READINGS VIDEOS ACTIVITIES INTEACTIVE CONT.	Ⓐ Ⓑ Ⓒ Ⓓ Ⓐ Ⓒ	2 hours	D. G de las Heras
③ Module 2: Diagnostic Medical Equipment					
PATIENT MONITOR.I - DEVICE AND COMPONENTS					
• Introduction to the Patient Monitor • Patient Monitor: System Block Diagram • ECG and Respiration Monitoring • Pulse Oximetry Monitoring • Non-Invasive Blood Pressure Monitoring • Temperature Monitoring	This module focused on the patient monitor, Health Problem Addressed and Environment of Use, Product Components and Relationship to Physiology Device Workflow System Diagram	READINGS VIDEOS ACTIVITIES INTEACTIVE CONT.	Ⓐ Ⓑ Ⓒ Ⓓ Ⓐ Ⓒ	40 min	D. G de las Heras

MODULE	DESCRIPTION	MATERIALS	COHORTS	DURATION	AUTHOR
PATIENT MONITOR.II - PREVENTIVE MAINTENANCE		Refer to R. Rutten thesis for a detailed explanation [70]			
PATIENT MONITOR.III - TROUBLESHOOTING		Refer to R. Rutten thesis for a detailed explanation [70]			
PATIENT MONITOR.IV - REPAIR		Refer to R. Rutten thesis for a detailed explanation [70]			
PATIENT MONITOR.V - TESTING		Refer to R. Rutten thesis for a detailed explanation [70]			
④ End of Course				30 min	
FINAL ASSESSMENT					
• Post-Test	The participants were asked to complete the final exam including questions on the topics above, to asses their level and knowledge.	ASSESSMENT	ⒶⒷⒸⒹ	20 min	D. G.H & R. R.
END-OF-COURSE SURVEY					
• Google Forms - End-of-Couse Survey	This was the last survey to complement the information on the participants, gathered in the previous ones.	SURVEY	ⒶⒷⒸⒹ	10min	D. G.H & R. R.

*The colour legend for the Materials is: Assimilative | Experiential | Finding & Handling Information | Communication | Assessment

APPENDIX

D

HREC Letter of Approval

Date 04-09-2020
Contact person Ir. J.B.J. Groot Kormelink, secretary HREC
Telephone +31 152783260
E-mail j.b.j.grootkormelink@tudelft.nl

Human Research Ethics Committee
TU Delft
(http://hrec.tudelft.nl/)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Pilot MOOC for Biomedical Equipment Technicians in LMIC
Applicant: Garcia de las Heras, Daniel

Dear Daniel Garcia de las Heras,

It is a pleasure to inform you that your application mentioned above has been approved.

Good luck with your research!

Sincerely,

Dr. Ir. U. Pesch
Chair HREC
Faculty of Technology, Policy and Management