FACTORS IMPACTING COST MEASUREMENTS IN APPLIED HEALTH SCIENCES eLEARNING: A CROSS-CASE CASE SYNTHESIS

A thesis submitted to the Department of Primary Care and Public Health, School of Public Health, Faculty of Medicine

by

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in partial fulfilment of the requirements for the Degree of Doctor of Philosophy

Abstract

Background

Healthcare resourcing must be significantly increased to meet current and future demand for health professionals. eLearning presents an opportunity to optimize training through scaling, thus reducing training costs. The literature often suggests that a key benefit of eLearning is its cost-effectiveness compared with face-to-face instruction, yet few studies have compared design and production costs or investigated the establishment of standards for the budgeting of these costs.

Objectives

Determining the cost favourability of eLearning requires an understanding of the components and costs required to build an eLearning course. This thesis's research objectives are to: A) establish standard ingredients for the cost of eLearning course production; and B) determine the factors causing variances in cost budgeting.

Methods

This thesis performs a cross-case synthesis among three case studies using horizontal budget variance calculation and a qualitative interpretation of variance using total quality management themes. The various implementation-specific aspects of these cases are used to establish common principles in the composition of budgets for eLearning in the applied health sciences.

Results

Two case studies report significantly negative budget variances caused by issues surrounding the underreporting of personnel costs, inaccurate resource task estimation, lack of contingency planning, challenges in third-party resource management, and the need to update health-related materials that went out of date during course production. A third study reports a positive budget variance because of the cost-efficiency derived from previous implementation, the strong working relationship within the course project team, and the use of iterative project management methods.

Conclusions

This thesis makes an original contribution to knowledge by establishing a method of identifying costs in the design, development, and deployment of eLearning, and a way to understand the factors that influence those costs, from project inception to completion.

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List of abbreviations

ADDIE – Analysis, Design, Development, Implementation, and Evaluation

AHP – Allied Health Professional

ALS – Advanced Life Support

AP – Action Plan

BL – Blended Learning

CEng FBCS – Chartered Engineer, Fellow British Computer Society

COMP – Summary of costs with a comparator

COP21 – 21st Conference of the Parties

COREQ – Consolidated Criteria for Reporting Qualitative Research

CPD – Continuing Professional Development

CYPHP – Child and Young People's Health Partnership

EBM – Evidence-Based Medicine

ERIC – Education Resource Information Centre

EUR ING – European Engineer

F2F – Face-To-Face

GP – General Practitioner

HCP – Health Care Professional

HMIC – Health Management Information Consortium

IDD – Instructional Design Document

INC – Inclusive of comparator and non-comparator studies

IRCAD-IHU – Institute for Research into Cancer of the Digestive System-University Hospital Institute

LC – Laparoscopic Cholecystectomy

LMS – Learning Management System

MA – Master of Arts

MBA – Master of Business Administration

MeSH – Medical Subject Heading

MOOC – Massive Open Online Course

MPA – Master of Public Administration

MSc – Master of Science

N/A – Not Available/Applicable

NASA – National Aeronautics and Space Administration

NHS – National Health Service

PBRN – Practice-Based Research Network

PHI – Public Health Informatics

PICO – Problem/Patient/Population, Intervention/Indicator, Comparison, Outcome

RACI – Responsible, Accountable, Contributing, Informed

RCT – Randomised Controlled Trial

RWD – Real World Data

RWE – Real World Evidence

SPOC – Small Private Online Course

SUM – Summary of costs without a comparator

TQM – Total Quality Management

USD – United States Dollars

VR – Virtual Reality

WHO – World Health Organization

xAPI – Experience Application Program Interface

Declaration of originality and contribution

The work and research included in this thesis were initiated and completed for the purpose of examination at Imperial College London by the PhD candidate. The resultant manuscript has not been previously submitted for a degree or diploma at any other higher education institution. At the time of submission, one paper drawing from this thesis had been submitted for review in a peer-reviewed journal with the PhD candidate as first and corresponding author. A second and third paper related to this thesis had been presented at blind peer-review conferences and subsequently published in conference proceedings with the PhD candidate as senior and corresponding author. A fourth, fifth and sixth paper adapted from peer-reviewed journals have been incorporated into this thesis with the PhD candidate as first and corresponding author. A seventh paper adapted from a peer-reviewed journal had been incorporated into this thesis with the PhD candidate as senior and corresponding author. These publications are held with the Creative Commons Attribution Non-Commercial No Derivatives licence, and the PhD candidate retains full copyright for use when citing sources referenced in the manuscript.

For the research studies presented in this thesis, the PhD candidate undertook the following elements of original work, with any other work referenced within the manuscript:

- Conceptualisation, design, data collection, and analysis of the literature review
- Conceptualisation, design, data collection, and analysis of research study one
- Conceptualisation, design, data collection, and analysis of research study two
- Conceptualisation, design, data collection, and analysis of research study three

Acknowledgements

I wish to thank the following: God and his infinite blessings and considerations – εἰς τὸ ὄνομα τοῦ Πατρὸς καὶ τοῦ Υἱοῦ καὶ τοῦ Ἁγίου Πνεύματος; Mom and Dad, for all my strengths, as my limitations are my own; Dad, who never saw this work but who remains the inspiration for my path in public health research; my Brother; my extended family; Alina; my friends; colleagues in the Global Digital Health Unit, especially the Digital Education Research Team, whose teamwork made this all possible; all of my teachers and professors over the years; the institutions (and their wonderful libraries and librarians) of which I have been fortunate to be a part; the funders of my research – NHS England, the European Institute of Innovation and Technology (EIT Digital & EIT Health), and the Higher Education Funding Council for England; Barbara Cerutti; Dr Kieran Walsh; Professor Scott Reeves; Professor Azeem Majeed; and finally, my thesis primary supervisor and mentor in the world of research – Associate Professor Josip Car.

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January 2019

1. Introduction

1.1. Overview

Chapter one defines the background and context of the thesis to establish the rationale for the investigation. The study's research aims, objectives, hypothesis, and questions are set within this background to introduce the areas that will be explored by the research investigation. The chapter concludes with an overview of the three eLearning implementation cases examined as case studies and a guide to the overall thesis structure.

1.2. Background

The World Health Organization's (WHO) World Health Report (Prentice, 2006) claims that global healthcare resourcing must be significantly increased to meet current and future demand for health professionals. Current challenges to health resourcing include an ageing population with chronic disease management needs, in addition to a growing population that is increasing demand for primary care (Dakin & Gray, 2018). This increased demand on resources requires a scalable means to train health professionals. Opportunities to optimize training through alternatives to face-to-face instruction make it possible to increase the pace and breadth of education in healthcare resourcing. A 2015 WHO systematic review of eLearning for undergraduate health profession education concludes that 'computer-based and Web-based eLearning is no better and no worse than face-to-face learning with regards to knowledge and skill acquisition' (Atun et al., 2015). eLearning is defined as:

> 'an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication, and interaction and that facilitates the adoption of new ways of understanding and developing learning'. (Sangra, Vlachopoulos & Cabrera, 2012)

eLearning presents an opportunity to change and optimize training in health professions (including clinical, allied, and applied health sciences and patient education) by providing a scalable means for instruction, thus reducing the costs of delivery and implementation. If we accept that, pedagogically, eLearning can result in a positive educational effect when used under optimal circumstances, which is still subject to on-going investigation, we must

then accept that the deployment of eLearning could affect the scale, cost,[1] and reach of education in the health professions.

[1] Cost in this thesis is defined as the total costs (direct and indirect) from inception to deployment, ranging from the design, development, and delivery (or implementation) of eLearning implementation. This thesis analyses how these costs have been reported by course implementers.

1.3. Research aims, objectives, hypothesis, and questions

1.3.1. Research problem

One of the motivations for implementing eLearning is the potential long-term efficiency gain in its delivery model. A course delivered digitally can have long-term cost favourability relative to the cost of a lecturer providing face-to-face instruction (Plint, 2014). This thesis's literature review indicates that the literature often suggests that online learning is more cost-effective than face-to-face instruction; however, there is limited evidence validating its efficiency relative to other forms of instruction or standards, or in terms of budgeting for the costs of the production and execution of eLearning. Additionally, the costs of developing eLearning are significant when undertaken to a high standard (Plint, 2014). Although some studies capture data relating to the factors associated with educational costs, the measurements used in these studies are inconsistent and include a wide variety of factors (Atun et al., 2015). The research requires a systematic means of comprehensively recording costs that can enable analyses of whether eLearning has desirable economic properties and which scenarios are required (Hollin & Robinson, 2015). On one hand, this could assist in addressing the high cost of delivering education in the health professions. On the other hand, should evidence suggest it is not more cost-effective, having discrete data points will allow those involved in online health education to identify ways of optimising delivery costs. Although costing models and methods for capturing direct and indirect costs have been proposed, we still lack the data that would enable an understanding of how costs are attributed in eLearning implementation, creating a knowledge gap. Here, a primary issue is the identification of direct and indirect implementation costs and their subsequent budget recording. Ensuring that this identification is done rigorously and in a reproducible fashion will enable further high-quality economic evaluation.

1.3.2. Research aim, objectives, and hypothesis

The aim of this research is to establish an approach for identifying costs in the design, development, and deployment of eLearning for the applied health (i.e. applied health subjects) professions and to understand the factors that influence costs from project inception to completion. Understanding these costs will enable more accurate budgeting and cost capture in the production of eLearning. This study addresses a knowledge gap concerning the determination of the costs attributed to eLearning production (Atun et al., 2015). Not only are there limited cost-centred studies on eLearning for health professions education, but there are limited details on how course designers and producers are calculating the associated costs for production of these course types. Developing models will allow for adoption of data sharing and course planning for improved management in execution of this course method and for further refinement and analysis.

1.3.3. Research objectives

The thesis research objectives are as follows:

A. To establish standard components or ingredients for the cost of the production of eLearning;
B. To determine the extent to which instructional design and other implementation factors generate variances in the costs of producing eLearning.

1.3.4. Research hypothesis

This research proposes the following hypothesis: *Produced eLearning courses have implementation costs that are higher than their operational budgets.*

The basis of this hypothesis comprises evidence drawn from the research literature which indicates that the costs for implementing eLearning are not well-understood and that the associated complexity of implementing technology creates under-recorded costs (Hollin & Robinson, 2015; Meinert, 2019; Plint, 2014). This research will test this hypothesis through the use of primary and secondary research questions investigating this proposition, first emphasising cost calculation and then analysing the reasons for variances in budgeting. This proposition suggests that budgets for development of eLearning courses are probably set incorrectly due to a lack of understanding of the total implementation costs required by this learning type.

1.3.5. Research questions

Understanding budgeting in determining, estimating, and evaluating the ingredients of eLearning production will allow course designers to better compare their work against other implementations methods and enable enhanced data collection. This will permit the subsequent development of evidence that can be used to examine the cost benefits and cost-effectiveness of this form of instruction (though this latter point is outside the scope of this research).

Primary research question:	How are the total costs of the production and delivery of eLearning calculated?
Secondary research question:	What are the causes of the variance in cost budgeting in eLearning, and what can be done to mitigate it?

1.4. Theoretical background: Economic evaluation

The theoretical underpinnings of economic evaluation are derived from welfare analysis, the maximisation of utility, and societal welfare for all individuals (Trostel, 2010). Here, the focus is on an examination of the extension of maximum benefit from activities in order to determine the most efficient execution of tasks as a product of individual cost. These notions are applied by the four principal approaches of cost analysis: cost-effectiveness, cost-benefit, cost-utility, and cost-feasibility (Zerbe et al., 2013). These approaches have broad multi-disciplinary applicability and have been used extensively for health and education evaluation.

Table 1: Cost analysis overview

Table and definitions reproduced from Levin and McEwan (2001)

Type of analysis	Analytical question	Measure of cost	Measure of outcomes
Cost-effectiveness	Which alternative yields a given level of effectiveness for the lowest cost (or the highest level of effectiveness for a given cost)?	Monetary value of resources	Units of effectiveness
Cost-benefit	Which alternative yields a given level of benefit for the lowest cost (or the highest level of benefit for a given cost)? - Are the benefits of a single alternative greater than its costs?	Monetary value of resources	Monetary value of benefits
Cost-utility	Which alternative yields a given level of utility at the lowest cost (or the highest level of utility at a given cost)?	Monetary value of resources	Units of utility
Cost-feasibility	Can a single alternative be undertaken within the existing budget?	Monetary value of resources	None

In each cost analysis approach, the evaluation centres on the comparison of measured costs. As an approach to capture such costs, Levin developed the 'ingredients method' in education cost analysis, which 'aims to exhaustively describe the ingredients or resources

that are required to produce the outcomes that will be observed. All these ingredients must be carefully identified for purposes of placing a value or cost on them' (Levin & McEwan, 2001). This process involves 1) a specification of ingredients, 2) placing values on the ingredient, and 3) summarising the cost model. Calculating ingredients enables a broader evaluation that addresses specific analytic questions based on a comparison of outcomes. The main issue is the underlying cost capture – fundamental to the execution of further economic evaluation – which is the main focus of this research. The four forms of economic evaluation are critical, as they allow for different interpretative elements for analysing the impact of cost. However, the examination of effectiveness, benefit, utility, and feasibility is outside the scope of this work because its focus is on the issue of data collection and how underlying costs are defined. These costs are the foundation of all further work and are key to successful project planning and execution.

1.5. Personal reflection on research problem

I am a chartered engineer with a strong interest in the application of multidisciplinary approaches to optimising efficiency in project delivery. My mother, an accountant at the National Aeronautics and Space Administration (NASA), is the inspiration behind my interest in cost accounting. In my professional career, I have led the analysis, audit, and delivery of complex business information systems across multiple sectors.

In 2010, my father was diagnosed with stage 4 glioblastoma. At this time, I became involved with the US healthcare system and became aware of many issues in the training of healthcare professionals. I observed a particular need for continuing education on the current research and on understanding evidence on the best standard of care among health professionals. After my father passed away, I felt that I could best offer a tribute to him by becoming involved with public health research and by developing ways of applying my diverse skills and interests in order to enhance the delivery of health-related initiatives, including learning.

For many years, my thesis supervisor, Associate Professor Josip Car, has investigated the evidence on the impact of and potential for eLearning in health education. His research has created an opportunity to investigate the factors necessary to enable cost optimisation in the delivery of eLearning. In 2015, our research team participated in an evaluation of a Massive Open Online Course in quality improvement performed by NHS England. This opportunity provided my first in-depth exposure to eLearning and the cost management challenges faced by course designers and course implementers. This experience allowed me

to combine my background in software engineering and management to develop an investigation of why eLearning cost management is challenging.

I am passionate about the potential technology could make to reduce inequity and enable responsiveness from industry and government for societal needs. This belief is centred on the capability of a data-driven world, and the reduction of cost in development and implementation of information systems yet is tempered by the needs for the right approach and methods in the application of new technology. The application of this principal within the context serves the philosophical underpinning of this investigation.

1.6. Overview of case studies

This thesis examines three distinct eLearning implementation projects as case studies. They provide examples of eLearning implementation in diverse implementation contexts. The eLearning implementation projects were managed by the Global eHealth Unit (Global Digital Health Unit) at Imperial College London, led by its Digital Education Team, where the author completed research on the team's work on the development and deployment of these courses. The three projects are descried below.

Research study one – Educating Administrative Staff to Engage with Young Patients:
This project created a Small Private Online Course (SPOC) to prepare general practice administrative staff for issues in the management of adolescents. The course provided training designed to help general practice staff improve patient experience by empowering staff to feel confident in helping adolescents.

Research study two – The Impact of Climate Change on Public Health:
This course was created as a Massive Open Online Course (MOOC) to educate citizens and health professionals on the relationship between climate change and public health. It used a multidisciplinary academic framework in data science to analyse, interpret, and present its evidence. The course discussed climate change's health and economic impacts on local, regional, and national health systems.

Research study three – Data Science in Healthcare using Real World Evidence (RWE):
This course was created as a blended MOOC to make learners aware of the effect data science can have on medicine and inspire the application of these methods across various

undergraduate curriculum disciplines, the UK National Health Service (NHS) commissioning support organizations, healthcare regulation organizations, and life sciences industries (e.g. pharmaceuticals, biotechnology, and medical devices). The implementation of the blended MOOC was executed as a face-to-face course for learners. Learners first took part in the MOOC and were then offered a residential course that examined case studies. The target audience of the MOOC was allied health professionals or citizens looking to transition or enhance their skills in data science in healthcare-related industries such as the pharmaceutical industry or biotech organizations. One of the key objectives of the course was to establish a global network of people who could continue and advance the dialogue on data science in healthcare. The course outcomes included the use and application of RWE data collection and analysis techniques in healthcare settings.

1.7. Structure of thesis

The research aim and objectives having been defined, this section will provide an overview of the research framework used to meet those goals. Figure 1 details the three eLearning implementation cases investigated in this research. The figure is intended to provide a reference point for the case under review and its relationship to the rest of the thesis.

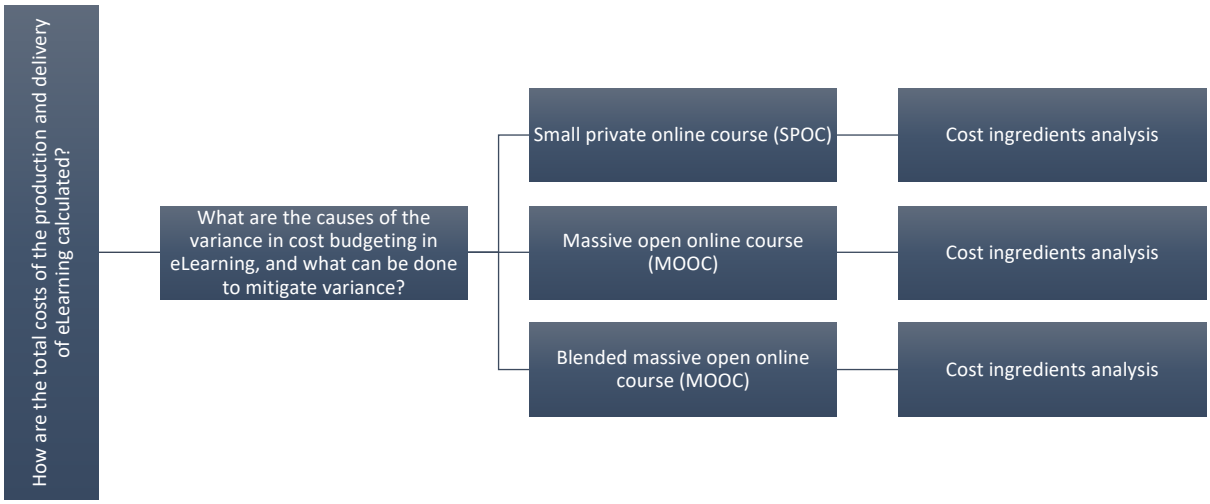

Figure 1: Structure of the thesis – overview of primary and secondary research question set for each case study

The thesis is organised into five chapters. Chapter One describes the background of the research, the primary research questions, the study's theoretical background, and the study's cases. Chapter Two provides a comprehensive overview of the state of the literature, establishing the need for this investigation. Chapter Three presents the methods, analytical framework, and research design for each case and a case synthesis. Chapter Four details each case, the results of the investigation, and the principal findings. Chapter Five

discusses the principal findings and their impact on budgeting; it then explores the study's limitations and implications for future research, and finally summarises the key conclusions of the thesis.

2. Literature review: Cost and value of eLearning within health professions education

At the time of thesis submission, aspects of Chapter Two had been drawn from a blind peer-reviewed conference paper and a publication submitted to a peer-reviewed journal:

Banks C. & Meinert E. (2016) The acceptability of MOOC certificates in the workplace. *International Association for Development of the Information Society, Paper presented at the International Association for Development of the Information Society (IADIS) International Conference on e-Learning (Madeira, Portugal, Jul 1-4, 2016)*

Meinert E., Reeves S., Eerens J., Banks C., Maloney S., Rivers G., Ilic D., Walsh K., Majeed A., Car J. (2019) Exploring the cost of eLearning within the field of health professions education: key findings from a systematic scoping review. *JMIR Medical Education (In peer review)*.

2.1. Introduction

Chapter One of this thesis introduced the study's overarching rationale, its research questions, the setting of the investigation, and the structure of the thesis. Chapter Two provides a survey of the state of the literature concerning cost calculation and value in eLearning. The research on the costs of delivering eLearning courses is limited (Reeves et al., 2013). There is a poor understanding of how these learning platforms compare in terms of cost to face-to-face learning. This lack of data has made it difficult to evaluate whether the investments by organisations in online learning are effective in comparison to face-to-face instruction. This review aims to provide a broad overview of the state of evidence concerning the measurement of costs in eLearning. Understanding these costs will enable better planning in the design and production of eLearning.

Scoping reviews are a form of rapid knowledge synthesis intended to identify the sources and evidence available to address research questions systematically (Tricco et al., 2018). The established scoping review methodology of Levac, Colquhoun, and O'Brien (2010) was chosen for this review, as the research questions aim to provide a broad understanding of the literature available in this field to inform subsequent reviews and research agendas.

2.2. Methods

2.2.1. Identifying the relevant research question

To establish a comprehensive understanding of the costs (Hollin & Robinson, 2015) associated with eLearning, this scoping review (Arksey & O'Malley, 2005; Levac, Colquhoun & O'Brien, 2010) assesses the available literature that quantifies the costs required to deliver eLearning in health profession education. The research question under investigation is 'What is known in the literature about cost calculations related to eLearning in health professions education regarding a) practical cost analysis, cost per learner, and a comparison to face-to-face instruction; and b) the choices of practices for costing methods and models?' A secondary question is 'How has the frequency of publication on this issue developed over time?' The key aim of this literature review is to better understand the state of evidence about whether eLearning demonstrates cost advantages over face-to-face instruction. Specifically, this review investigates the extent to which the literature can provide details on the calculation of the costs of eLearning design, development, and delivery.

The research questions were derived using the Problem/Patient/Population, Intervention/Indicator, Comparison, Outcome (PICO) framework (Higgins & Green, 2011). In this case, the **population** is defined as learners working in the health professions in all countries; this decision was made to ensure comprehensive coverage of all health professionals in order to understand the state of the evidence on an international level. The **intervention** instrument being evaluated is eLearning in health professions education (inclusive of various forms of training, including basic and advanced continuing professional development, university-level training, patient education, and various other forms of

training provided by an equally broad group of education training providers). The **comparison** conducted in this study evaluates costs between eLearning and other methods of instruction, such as face-to-face learning, alternate approaches to eLearning, and studies that do not make use of a comparator. The **outcome** was a quantification and analysis of the differences between the methods' implementation costs. We defined costs based on cost calculations used in economic evaluation, including cost-consequence analysis, cost-minimization analysis, cost-effective analysis, cost-utility analysis, and cost-benefit analysis (Gray, 2011).

2.2.2. Identifying relevant studies

Following a consultation on literature search approaches with an information scientist (RJ) at the Imperial College London Medical School Library, a search of the following databases was performed in December 2015 and repeated in December 2018: PubMed, Scopus, the Education Resource Information Centre (ERIC), Web of Science, Embase, Global Health, Health Management Information Consortium (HMIC), Prospero, and OVID. In a second search completed in December 2018, new papers were added to the original dataset but did not undergo exhaustive data charting; the data that were included provided a high-level summary of the contents and their relevance to previously categorized themes (the studies in these papers were conducted between 2016 and 2018).

The search strategy included the use of Medical Subject Heading (MeSH) terms and related keywords centred on eLearning and cost calculation with a population scope of health professionals in all countries. The search was limited to English language studies. No restriction was placed on the publication date. Although online technologies have changed rapidly over a short period of time, the author felt that a comprehensive overview of the

literature required an initial exploration of the research with no date restriction. The primary research questions were kept broad to ensure the inclusion of all studies that assessed the costs of delivering eLearning globally. A high-level summary of the search strategy is provided in Table 2; a full summary of the search strategy used for each database is detailed in the appendix.

Table 2: Sample search terms

Category	Search Terms
Cost	• Costs and cost analysis [MeSH Terms] • Cost-benefit analysis [MeSH Terms] • Costs and cost analysis [MeSH Terms] • Cost* • Economic*
Learning	• Learning [MeSH terms] • eLearning • Blended learning • Online learning

2.2.3.Study selection

Following the process used in this review method, study selection was based on study identification with data, centred on studies that identified the cost factors and variables in health professions education eLearning. The literature was reviewed independently by two researchers (JE, EM) in order to identify a set of articles. A third researcher, CB, adjudicated disagreements when necessary. Article abstracts were first scanned for relevance to the research question, and full articles were then downloaded to verify their appropriateness.

The inclusion criteria included studies and reviews that examined eLearning in health professions education and captured data concerning design, development, and production costs. Papers that provided a synthesis or editorializing of issues without including data (i.e. opinion pieces and commentaries) were excluded.

2.2.4. Charting the data

The definition of 'cost' in this review is based on the hypothesized cost-savings derived from a possible reduction in labour costs by scaling teaching via digital technology – the cost definition being the production and delivery costs (direct and indirect) of online learning (Deming et al., 2015). The studies included in this thesis were classified to explore different ways to compare and analyse the factors influencing these costs. The studies were charted into two groups: (1) studies detailing costs for eLearning implementation and (2) studies detailing with costing methods (approaches to capturing costs) for eLearning studies without implementation-specific data. Group 1 was further charted into two separate groups: (A) studies with a comparison to other learning types and (B) studies without. From these two sub-categories, we excluded studies that disclosed that the cost data provided were incomplete.

2.2.5. Collating, summarizing, and reporting the results

Each study was reviewed individually in order to glean an understanding of the implementation aspects of each reported eLearning instance. The studies were then summarized into four categories: (1) studies that detail eLearning costs without using a comparator, (2) studies that detail eLearning costs using a comparator, (3) studies that offer related data from two related systematic reviews, and (4) studies that detail costing approaches. The results are presented as a narrative summary of the principal aspects of

each study organized according to the main classification themes in order to present evidence useful for informing the development and deployment of eLearning by defining the factors influencing implementation costs and the criteria that should be considered when exploring cost optimization.

2.3. Results

2.3.1. Study overview

A total of 7344 articles were returned from the literature search (see Figure 2). Of these, 232 were relevant to the associated keywords or abstract references to cost following screening. The full-text review led to the exclusion of 168 studies. Of these, 61 were excluded because they were unrelated to eLearning and focused on general education. One-hundred and three studies were excluded because they lacked detailed information regarding costs. These studies referred to costs in ways that indicated either cost favourability or unfavourability, but without offering data to support their findings. Finally, four studies were excluded because their cost data were insufficient for analysis. In total, 42 studies (see Table 3) were found to provide data and analyses of the impact of cost and value in health professions education. The completeness of the data extracted from the search varied. Thus, some of the datasets in the final inclusion data charts were designated 'Not Available/Applicable' ('N/A') to reflect the inability to abstract usable information from them. However, these remained in the inclusion set because they provided partial data that contributed to the narrative analysis. These studies differed from the studies excluded at the earlier screening stage because cost was a secondary outcome of their investigations, and cost data were more of a focus for them than they were for the excluded studies. The most common data source was total cost of training (n = 29). Other sources included cost per learner, meaning the cost per student (n = 13). The population most frequently cited was medical students (n = 15), although one group of articles focused on multiple populations (n = 12). A further 22 studies provide details on costing approaches for the production and delivery of eLearning. These studies provide insights into the ways eLearning has been budgeted and its projects managed through implementation.

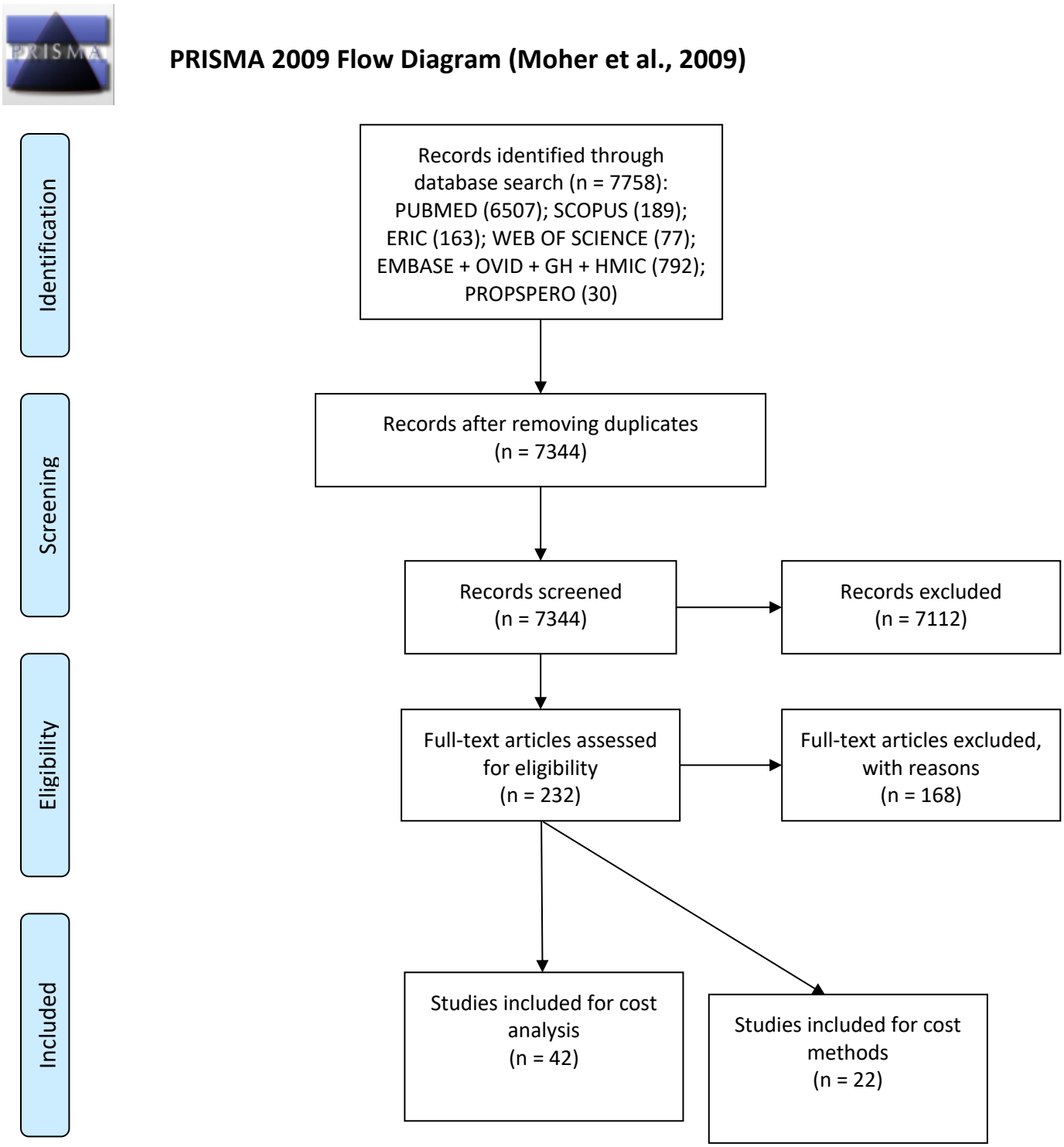

Figure 2: PRISMA flow diagram of search and screening for costs of eLearning implementation within literature review

Table 3: Studies that provide cost analysis for eLearning implementation

Prefix	Number	First Author	Year	Comparison	Subject	Cost source	Population (HCPs)
INC	1	Allan	2008	None	Evidence-based Medicine	Total cost	Clinicians
INC	2	Bandla	2012	None	Sleep Medicine	Total cost	Medical Students
INC	3	Berger	2009	Face to Face	Patient Education	Per learner	Nurses
INC	4	Butler	2013	None	Behaviour Change Counselling	Per learner	Clinicians, Nurses
INC	5	Choi	2008	Other learning	Surgical Anatomy	Total cost	Medical Students
INC	6	Collins	2018	None	Nutrition	Total cost	AHPs, Medical Students
INC	7	Downer	2018	None	Leadership and Management in Health	Total cost	AHPs, Medical Students, Clinicians
INC	8	Dumestre	2014	Other learning	Microsurgical Skill-acquisition	Per learner	Clinicians, Medical Students
INC	9	Glasbey	2017	Face to face	Surgical training	Total cost	Medical Students
INC	10	Grayson	2018	None	Hand Hygiene	Total cost	AHPs, Medical Students, Clinicians
INC	11	Hardwick	2011	None	Pathology	Total cost	Clinicians
INC	12	Jerin	2005	None	Emergency Medicine	Per learner	Allied Health Professionals
INC	13	Joshi	2012	Other learning	Public Health Informatics	Total cost	Allied Health Professionals

INC	14	Kaufman	2010	None	Treatment of diabetes	Per learner	Patients (Patient education used by HCP)
INC	15	Knapp	2011	Face to face	HIV detection	Total cost	AHPs, Clinicians
INC	16	Kumpu	2016	Face to face	Global Health	Total cost	AHPs, Medical Students, Clinicians
INC	17	Letterie	2003	None	Computer-assisted Medical Education	Total cost	AHPs, Medical Students, Clinicians
INC	18	Likic	2013	None	Rational Therapeutics	Total cost	Medical Students
INC	19	Manring	2011	None	Psychotherapy	Total cost	Clinicians
INC	20	McConnell	2009	None	Pharmacy CPD	Per learner	Pharmacists
INC	21	McDuffie	2011	None	Experiential Pharmacy Training	Per learner	Pharmacists
INC	22	Moreno-Ger	2010	No Intervention	Practical Skills Simulation	Per learner	Medical Students
INC	23	Nickel	2015	Other learning	Laparoscopic Cholecystectomy	Total cost	Medical Students
INC	24	Nicklen	2016	None	Physiotherapy	Total cost	Undergraduate AHPs
INC	25	Padwal	2017	Other learning	Weight Management	Total cost	Patients (Patient education used by HCP)
INC	26	Padwal	2013	Other learning	Weight Management (Study Protocol)	Total cost	Patients (Patient education used by HCP)
INC	27	Palmer	2015	None	Clinical Skills	Total cost	Medical Students
INC	28	Pentiak	2013	None	Surgical Skills	Per learner	Clinicians
INC	29	Perkins	2012	Face to face	Advanced Life Support Training	Per learner	Allied Health Professionals

INC	30	Reeves	2013	Other learning	Interprofessional Education	Total cost	Allied Health Professionals
INC	31	Schopf	2011	None	Interprofessional Training – Dermatology	Total cost	Clinicians, Nurses
INC	32	Shepler	2014	None	Advanced Pharmacy Practice Experience	Total cost	Pharmacy Students
INC	33	Sivamalai	2011	None	Pathology	Total cost	Medical Students
INC	34	Spanou	2010	Face to face	Behaviour Change Counselling	Total cost	Clinicians, Nurses
INC	35	Stansfeld	2015	Other learning	Employee Well-being	Total cost	Allied Health Professionals
INC	36	Stromberg	2012	None	Heart Failure Nursing	Total cost	Nurses
INC	37	Thomas	2010	None	Family Planning	Total cost	Allied Health Professionals
INC	38	De Ruijter	2015	None	Business Eng. Surgical Tech.	Total cost	Medical Students
INC	39	Weiss	2011	Other learning	Antibiotic Prescribing	Total cost	Clinicians, Pharmacists
INC	40	Williams	2009	None	Practice Based Research Networks	Per learner	Clinicians
INC	41	Young	2017	None	Research Skills	Per learner	Allied Health Professionals
INC	42	Zhou	2018	None	Resource Stewardship	Per learner	Medical Students, Clinicians

Note: The prefix 'INC' indicates that this group was inclusive of comparator and non-comparator studies (for eLearning costs), and the combination of the prefix and number can be used to provide a unique ID with which to refer to the studies. This prefix approach is also used in all data tables below.

2.3.2.Studies that detail eLearning costs without a comparator

Several studies analysed eLearning implementation costs without a comparison to other learning platforms (i.e. Allan et al., 2008; Butler et al., 2013; Downer et al., 2018; Grayson et al., 2018; Kaufman, 2010; Hardwick., Sinard & Silva, 2011; Likic et al., 2013; Manring et al., 2011; McConnell, Newlon & Dickerhofe, 2009; McDuffie et al., 2011; Moreno-Ger et al., 2010; Palmer et al., 2015; Pentiak et al., 2013; Schopf & Flytkjær, 2011; Shepler, 2014; Sivamalai et al., 2011; Stromberg et al., 2012; Thomas et al., 2010; De Ruijter et al., 2015; Williams et al., 2009; Young, McLaren & Maden, 2017; Zhou et al., 2018). These studies primarily reported total costs and cost per learner (see Table 4). The studies suggested that eLearning should be less costly than face-to-face learning. Absent a comparator, however, it is not possible to substantiate these claims. Despite these deficiencies, the studies provide varying cost calculation means across different forms of instructional design.

Table 4: Studies that quantify eLearning costs

Prefix	ID	First Author	Year	Instructional Design	Sample	Total Cost (USD)	Cost/Learner	Notes
SUM	1	Allan	2008	Asynchronous, Blended	304	$8,209	$24	No blended learning costs
SUM	2	Butler	2013	Blended	80	$2,075	$26	No explicit cost methodology/technique described
SUM	3	Downer	2018	Asynchronous	53	$23,000	$394	No explicit cost methodology/technique described
SUM	4	Grayson	2018	Asynchronous	1989713	N/A	$.04	Provided aggregate cost per leaner
SUM	5	Kaufman	2010	Asynchronous	787	N/A	$1,453	Reported overall cost per learner
SUM	6	Hardwick	2011	Asynchronous	N/A	N/A	N/A	Provided cost modelling approach
SUM	7	Likic	2013	Asynchronous	393	$10,000	$23	Cost of using online course deemed lower than F2F Problem Based Learning
SUM	8	Manring	2011	Blended	35	$5,250	$137	Only costs of physical implementation
SUM	9	McConnell	2009	Asynchronous	8120	$610	$.07	No explicit cost methodology/technique described

SUM	10	McDuffie	2011	Blended	382	$23.50	$21	No explicit cost methodology/technique described
SUM	11	Moreno-Ger	2010	Asynchronous	400	$2,630	$6	No explicit cost methodology/technique described
SUM	12	Palmer	2015	Synchronous	9	$5,000	$506	No explicit cost methodology/technique described
SUM	13	Pentiak	2013	Asynchronous	N/A	$32,685	N/A	Total Curriculum Delivery
SUM	14	Schopf	2011	Asynchronous	88	$84,229	$858	No explicit cost methodology/technique described
SUM	15	Shepler	2014	Asynchronous	580	N/A	N/A	$148 USD savings per intervention
SUM	16	Sivamalai	2011	Asynchronous	200	$392,468	$1782	Cost of digital microscopy found to be 1/3 cost of physical microscopy
SUM	17	Stromberg	2012	Asynchronous	183	N/A	N/A	Total cost reduction compared to previous methods
SUM	18	Thomas	2010	Asynchronous	273	$21,000.00	$70	No explicit cost methodology/technique described
SUM	19	De Ruijter	2015	Asynchronous	803	$44,986	$49	No explicit cost methodology/technique described

SUM	20	Williams	2009	Asynchronous	103	$3,732	$33	No explicit cost methodology/technique described
SUM	21	Young	2017	Asynchronous	679	N/A	$38	Did not report total cost
SUM	22	Zhou	2018	Asynchronous	48	N/A	$148	Did not report total cost

Note: Costs have been set to US dollars for comparability on the basis of currency conversion in January 2019.

Note: The prefix ‘SUM’ indicates that this group was a summary of costs without a comparator; the prefix and number can be used to provide a unique ID to refer to the studies.

Although the studies in this set focused on the costs associated with eLearning in health professions education, they lacked the comparison variable of the PICO framework. While these studies suggest that eLearning implementation could provide high value through low cost delivery and thus cost-effectiveness, they offer no comparative framework by which to justify these assertions. Three groups emerged among the studies that quantify eLearning costs. The first included studies that demonstrated that eLearning was low-cost but had little or no evidence of educational impact (Allan et al., 2008; Butler et al., 2013). The second group demonstrated that eLearning was low-cost and had high education impact (Likic et al., 2013; De Ruijter et al., 2015; Hardwick, Sinard & Silva, 2011; Manring et al., 2011; McConnell, Newlon & Dickerhofe, 2009; McDuffie et al., 2011; Moreno-Ger et al., 2010; Schopf & Flytkjær, 2011; Shepler, 2014; Sivamalai et al., 2011; Stromberg et al., 2012; Thomas et al., 2010; Williams et al., 2009; Young, McLaren & Maden, 2017; Zhou et al., 2018). A third group (Downer et al., 2018; Grayson et al., 2018; Kaugman, 2010; Palmer et al., 2015; Pentiak et al., 2013) demonstrated that eLearning was high-cost and had high educational impact.

Allan et al. (2008) and Butler et al. (2013) present examples of low-cost eLearning delivery but without demonstrating educational impact, with the 'low cost' in these studies presented from the perspective of cost per learner. In Allan et al. (2008), the key research question was whether this research group could implement an evidence-based medicine (EBM) curriculum for clinicians. Allan et al. (2008) suggest that, despite compelling arguments for the use of EBM, its implementation at universities is not well-executed. The researchers' response was to develop a comprehensive approach that used self-paced eLearning, face-to-face instruction, online-tool skills, and the establishment of a community

in the practice of EBM. Although these portions of the programme could have provided comparative data, the study did not compare among implementation cases. The purpose of the study was to develop a well-executed course in EBM in terms of time, quality, and cost. A key aspect was the use of eLearning to facilitate individual, self-directed learning, although this was not the sole purpose of the study. The study used face-to-face workshops, a journal club, training in the use of online tools to support EBM, and a self-paced desktop application for EBM training. The study employed a case study approach using qualitative surveys. The surveys (with a response rate of 60% out of a total sample size of 304) focused on evaluating student satisfaction and assessing knowledge acquisition and had no relevance to costs. Although quantifying costs was an aspect of the reported results, it was not the primary focus (like for many of the studies in this review) and was undertaken informally, without an explicit unit cost breakdown or a listing of all the components that would impact learning production. A key outcome of this study was to identify how to implement an evidence-based medicine curriculum, thereby creating cost-efficiency. However, the study admits that it did not include the costs of the management of curriculum development or for the administrative management of a journal club to facilitate an understanding of EBM. The pervasive issue in the literature is the lack of cost accounting for all aspects of education delivery and of comparative data that could prove cost-effectiveness. Without these details, it is not possible to provide a comprehensive view of education delivery costs.

In contrast to the use of a comprehensive programme that includes multiple forms of learning and the establishment of a learning community, Butler et al. (2013) used only blended learning in a course. The research purpose was to evaluate the effect of training

primary care health professionals in behaviour-change counselling related to four risk behaviours (both psychological and physiological). Although this objective is not related to cost, the study did record the associated costs of developing this training method. The training was facilitated by the use of self-paced online courses, with further facilitation through a face-to-face workshop (to establish the learning blend). The study participants included 53 general practitioners and nurses from 27 general practices, who saw 1,827 patients who had screened positive for at least one type of risk behaviour over five months in 2007. The study was a Randomised Controlled Trial (RCT), and the findings showed that there was no effect on primary behaviour after three months, nor were there any physiological changes after 12 months. Butler et al. (2013) reveal that total training costs are not captured when creating online and/or blended courses in primary care. Despite comprehensively capturing the unit costs of delivery in the implementation of the study (by providing a segmentation of costs across administrators, actors, trainers, clinicians, nurses, and costs per practice), the study treats eLearning as a single group cost reflecting the time each participant takes to complete the eLearning. No accounting is made of the system implementation time and production time required for the creation of eLearning. Like Allan et al. (2008), Butler et al. (2013) highlight the cost omissions that are endemic in the studies in this review.

A second group of studies demonstrate that eLearning has low costs and high educational impact (Likic et al., 2013; De Ruijter et al., 2015; Hardwick, Sinard & Silva, 2011; Manring et al., 2011; McConnell, Newlon & Dickerhofe, 2009; McDuffle, 2011; Moreno-Ger et al., 2010; Schopf & Flytkjær 2011; Shepler, 2014; Sivamalai et al., 2011; Stromberg et al., 2012; Thomas et al., 2010; Williams et al., 2009; Young, McLaren & Maden, 2017; Zhou et al.,

2018). Of these studies, Likic et al. (2013), McConnell Newlon and Dickerhofe (2009), McDuffle (2011), De Ruijter et al. (2015), Moreno-Ger et al. (2010), Thomas et al. (2010), Williams et al. (2009), and Young, McLaren, and Maden (2017) each analyse online courses by investigating asynchronous online learning at a low cost per learner (below £50/learner). One study in this group (Likic et al., 2013) focused on a self-paced online course and was led by a clinician scientist at the University of Zagreb School of Medicine in Croatia. The primary research objective was to investigate the efficacy of creating online and low-cost teaching resources to instruct medical students in therapeutic skills. They conducted a cohort study ('cohorts' being defined as a group of students) distributed across two student populations in two different countries with a sample size of 393 medical students. The study found that it was possible to achieve lower costs in the production of online courses with positive impacts on student learning outcomes. These cost reductions were associated with travel and resource reductions obtained by using online rather than face-to-face instructors. This is a standard approach for demonstrating cost-effectiveness; however, given the lack of a comparison set, the strength of such claims remains untested. This study (Likic et al., 2013) suggested that it was possible to translate a course on rational therapeutics from face-to-face to online learning with good course design and student satisfaction outcomes in an international context. It provided data on the total costs of implementation and demonstrated a low cost of implementation per learner (£17.81/learner). The basis of its arguments for cost-effectiveness was this low cost and the assumption that it is lower than that of face-to-face instruction; however, the study's weakness is that it did not offer any data reflecting the total costs of delivery for face-to-face instruction. This highlights a key weakness that is common among many studies in this literature cluster: Although they may provide evidence of low cost per learner, that lack a comparison point to comparable face-

to-face delivery and thus cannot assert with any certainty that eLearning is a lower-cost option.

Another study in this group (De Ruijter et al., 2015) differs from the others because it dealt with instruction to both a clinical and a non-clinical audience. A group of researchers at IRCAD-IHU in France led this study. The research objective was to create a programme for teaching technology innovation in surgical science in a multidisciplinary context, including engineering and surgery. Furthermore, it would do so at a low cost (i.e. £37.86/learner, although this is higher than this set's average). However, as is the case in many of the studies in this cluster, the 'low-cost' parameters are not defined or used as a basis of comparison with face-to-face learning to test this claim. The programme was conducted from November 2011 to September 2013 with 803 participants from 79 different countries in an asynchronous online course and 60 participants in the face-to-face course to create a blended delivery format. The study used a case method, and the findings revealed that blended learning enabled the capability to teach a complex subject to diverse audiences at low cost.

Computer scientists at the Complutense University of Madrid led a study demonstrating the application of asynchronous online learning in the use of surgical simulation (Moreno-Ger et al., 2010). The research objective was to investigate the use of low-cost simulation to allow medical students to rehearse procedures online. The method was a case-control study using an experimental group of 66 and a control group of 77. The study found that the perceived difficulties of the procedure were lower in the experimental group than in the control group, demonstrating the success of this form of low-cost simulation training delivered via

the internet. The study suggests that the use of low-cost, online simulation improves students' understanding of a surgical procedure. Extensive background research informed the development of the online learning platform. The weakness of this study is that, due to its limited data and lack of analysis, it failed to provide sufficient data points by which to understand the impact of the study fully. Although the simulation clearly assisted student understanding, why and to what degree it did so remain unclear. This study highlights the need for detailed data collection and an analysis of how the intervention achieves its results, demonstrating that observing student satisfaction or knowledge acquisition results is an over-simplified way to conduct cost evaluation research. Most of the studies in this group suffer from such limitations.

Williams et al. (2009) also demonstrated cost optimisation. The research objective was to describe the use and costs of an online platform in support of a research protocol across a practice-based research network (PBRN). The sample comprised 103 participating clinicians across four PBRNs. The methodology was a cohort study. The study found that the internet could be a cost-effective alternative method for training clinicians in support of PBRN research, owing to the significant reduction of costs associated with managing a large distributed workforce during face-to-face instruction. Williams et al. (2009) suggested that clinicians demonstrated significant increases in knowledge acquisition for individual topics across scores in assessments during practice-based training, although the sample was small. However, an issue with this study is that the cost analysis was based on the investment effort of participants and did not consider eLearning development.

McConnell, Newlon, and Dickerhofe (2009) differ from Likic et al. (2013), De Ruijter et al. (2015), Moreno-Ger et al. (2010), and Williams et al. (2009) in that they explicitly measured cost favourability as an outcome of the study itself (favourability was defined as lower cost and not effectiveness, as this would imply the explicit method), whereas previous studies did not focus on the cost of delivery. The objective of the study was to implement a continuing pharmacy education programme delivered by an online learning management system to provide asynchronous learning content. A case study method was used, and the sample consisted of 3,570 participants. The evaluation was conducted by measuring the degree to which learners retained knowledge. The study found that the programme had developed a high-quality and cost-favourable system by demonstrating that the total cost per learner was low (£427) and that the pre- and post-programme knowledge assessments consistently demonstrated a recorded increase in knowledge on the assessment tests. However, the key problem with this conclusion, which is shared by many other studies, is its claim of low costs without providing evidence to substantiate it via comparison with other learning methods. Additionally, the cost per learner is higher than the average in other sets, but it is not possible to validate this figure without developing a comparative unit cost.

The final group of studies in this set (Downer et al., 2018; Grayson et al., 2018; Kaufman, 2010; Palmer et al., 2015; Pentiak et al., 2013) indicate that eLearning was higher-cost and had high educational impacts. This group had data-recording issues similar to those of the previous set but also provide evidence of high start-up costs associated with eLearning production.

Pentiak et al.'s (2013) research objective was to identify barriers to the implementation of the standardized skills curriculum for surgical residents of the American College of Surgeons and Association of Programme Directors in Surgery. The study conducted a clinical review of all data on the programme available from the programme website. The study analysed all participants and the total cost for implementation. The findings showed that the programme had high resource requirements and that these costs made it difficult for institutions to deliver the programme's vision fully. Therefore, the authors recommended a re-analysis of the scope and breadth of the programme. This study explored why the programme was difficult to deliver and concluded that it had to do with the high cost of simulation. A key strength of this study is its detailed cost accounting of various considerations in the simulation design, including cost ingredients, location, and a breakdown of resource costing per learning activity (i.e. activity-based costing). The study's contribution is its finding that eLearning can create negative cost outcomes, in contrast to simulation training; therefore, eLearning cannot be more cost-effective than other forms of simulation training. Additionally, the start-up costs of developing sophisticated surgical simulations and ensuring their continued relevance is a problem that requires cost-calculation when analysing this online platform in surgical training.

It is challenging to draw strong inferences based on an aggregation of studies that summarise eLearning costs because of the different methods used in the cost calculations, the differences among the subjects instructed, rapid changes in online platforms for learning, different contexts and other factors affecting how costs were calculated. However, it is possible to observe some trends from this grouping. For pure online courses, the studies suggest that the total cost per learner is low; however, studies often acknowledge that not

all implementation costs have been captured in the cost calculations. This lack of included costs, including sunk costs, indicates that the reported costs are not accurate. Although some studies identify the costs not captured, many do not, and these gaps are evident only to researchers possessing a background in and an understanding of the issues involved in eLearning delivery. Additionally, most studies analyse cases of specific instances of eLearning implementation, making it difficult to gauge what the results mean in comparison to face-to-face learning. Furthermore, it is difficult to generalise the results of case studies. Some studies have found high total costs, but, in those instances (Pentiak et al., 2013), eLearning costs were embedded in total curriculum delivery.

2.3.3. Studies that detail eLearning costs with a comparator.

Seventeen studies compared eLearning costs to the costs of face-to-face learning or other types of learning (Bandla et al., 2012; Berger et al., 2009; Choi, Tamblyn & Stringer, 2008; Glasbey et al., 2017; Jerin & Rea, 2005; Joshi & Perin, 2012: Knapp et al., 2011; Kumpu et al., 2016: Moreno-Ger et al., 2010; Nickel et al., 2015; Nicklen et al., 2016; Padwal et al., 2017; Padwal et al., 2013; Perkins et al., 2012; Spanou et al., 2010; Stansfeld et al., 2015; Weiss et al., 2011). These comparative studies (see Table 5) provided more evidence that using eLearning demonstrated cost efficiencies, unlike the studies in the previous group, which provided no comparative data.

Table 5: Studies that detail eLearning costs with a comparator

Prefix	ID	First Author	Year	Instructional Design	Comparison	Sample Size	eLearning	Face to face	Notes from Study
							Cost (USD)		
COMP	1	Bandla	2012	Asynchronous Online	Face to face	173	$21,752	$21,752	
COMP	2	Berger	2009	Blended	Face to face	1661	$4	$110	Cost per learner
COMP	3	Choi	2008	Asynchronous Online	Other learning	34	N/A	N/A	Provided costs of online platforms without complete cost comparison
COMP	4	Glasbey	2017	N/A	N/A	570	N/A	N/A	Online curriculum embedded; core costs not separated in study
COMP	5	Jerin	2005	Asynchronous Online	Asynchronous Online	9353	$3	$52	Cost per learner
COMP	6	Joshi	2012	Asynchronous Online	Other learning	15	$14,085	$20,714	Online v. F2F total costs
COMP	7	Knapp	2011	Asynchronous Online	Face to face	91	$157	$4,386	
COMP	8	Kumpu	2016	Blended	Face to face	28	$2,431	$1,054	
COMP	9	Moreno-Ger	2010	Asynchronous Online	Face to face	400	$7	$2,630	
COMP	10	Nickel	2015	Virtual Reality	Other learning	84	$3,900	$82,500	Virtual reality v. blended learning
COMP	11	Nicklen	2016	Blended	Face to face	78	$5,904	$6,856	

COMP	12	Padwal	2017	Asynchronous Online	Face to face	651	$11,727	$477,000	
COMP	13	Padwal	2013	Asynchronous Online	Face to face	N/A	N/A	N/A	Protocol
COMP	14	Perkins	2012	Blended	Face to face	3732	$438	$935	
COMP	15	Spanou	2010	Asynchronous Online	Face to face	N/A	N/A	N/A	Protocol
COMP	16	Stansfeld	2015	Asynchronous Online	Face to face	350	N/A	N/A	Captured approach to total costs but incomplete comparison data for non-online approach
COMP	17	Weiss	2011	Asynchronous Online	Other learning	N/A	N/A	N/A	Cost reduction per inhabitant, following the education programme

Note: Costs have been set to US dollars for comparability on the basis of currency conversion in January 2019.

Note: The prefix 'COMP' indicates that this group was a summary of costs with a comparator; the prefix and number can be used to provide a unique ID with which to refer to the studies.

The studies in this set can be divided into two groups: studies demonstrating that eLearning was lower-cost but had no or limited evidence of self-reported educational impact and studies that demonstrated that eLearning was lower-cost and had high self-reported educational impact (Joshi & Perin, 2012; Weiss et al., 2011).

Among the studies demonstrating that eLearning had lower costs but had limited or no evidence of its education impact, Berger et al. (2009), Nickel et al. (2015), and Perkins et al. (2012) were the most relevant, as Choi, Tamblyn, and Stringer (2008) merely provided a summary analysis of internet resources for surgery, treating cost as merely a means of describing subscription costs for online resources (while this is relevant as a supplementary method, it is not implemented the same way as a module delivered for a course). The key issue with the data used in this set is that, although they suggested that eLearning had lower costs, they continued to omit key components in the design and production of eLearning, creating an incomplete cost profile of the total costs of delivery.

Finding that eLearning was lower-cost but offering limited or no evidence of education impact, Berger et al. (2009) investigated the difference in outcomes between online training and face-to-face training concerning patient education within a hospital setting. The study reviewed records of 1,661 registered nurses who completed the training course via one of the two methods in a case control study. They found no significant differences in learning outcomes between the two course types. Costs were reduced due to increased sessions in online training. Similar to Berger et al. (2009), Nickel et al.'s (2015) research objective was to

compare virtual reality[2] (VR) training with low cost-blended (BL) training in a structured training programme to teach laparoscopic cholecystectomy (LC). The methodology used was an RCT, in which medical students were randomized into two groups. The BL group (n = 42) used eLearning, and the VR (n = 42) used VR simulation. The study found that the VR group completed the LC curriculum significantly faster than the BL group. Students in the VR group performed operations better, while blended learning students demonstrated better knowledge acquisition. While the study demonstrated the strengths and weaknesses of VR and BL, no further comparison was made to instruction without eLearning. Additionally, the studies failed to quantify the production costs of both VR and BL, thus omitting information required for an understanding of the total costs of implementation.

In Perkins et al. (2012), the research objective was to determine whether a blended approach to training centred on Advanced Life Support (ALS), produces outcomes similar to those of instructor-led training. The study design was an RCT, implemented across 31 ALS centres in the UK and Australia, where 3,732 health care professionals participated from December 2008 to October 2010. The findings showed that, compared to conventional ALS training, eLearning-based training led to slightly lower pass rates on cardiac arrest simulation tests and similar scores on knowledge tests; overall, this reduced cost implementation. This study suggests that ALS training via eLearning resulted in slightly lower skills capability than face-to-face learning. This study offers stronger evidence than do the

[2] Virtual reality (VR) is defined as a computer-generated environment developed for engagement by a learner. Within such VR environments, the learner is immersed within this computer-generated environment and able to perform actions to modify and extend experience as one would achieve in the physical world.

other studies in this review by capturing total production costs, creating a unit cost of production, and discussing cost-effectiveness.

Two studies in this set demonstrated that eLearning had lower costs and high education impact but did so in different ways. The objective in Joshi and Perin (2012) was to explore public health informatics training programmes. The study identified 15 Public Health Informatics (PHI) programmes across 13 different institutions, the majority being US-based. The study concluded that there is a need for online-contextual and cost-effective PHI training programmes to meet the needs of professionals in public health. Owing to the high costs associated with delivering public health teaching, there is an argument for using online learning methods to increase affordability. Although this study provides a comprehensive overview of training costs – specifically, an analysis that establishes the effectiveness of online training – it lacks a rigorous economic evaluation via high-level summary details of the associated costs and an analysis of how those costs are identified.

Weiss et al. (2011) arrived at conclusions similar to those of Joshi and Perin (2012), finding that eLearning can be low-cost and have high educational impact. However, the research objective of that study was to determine the effectiveness of a global education programme teaching physicians and pharmacists about antibiotic overuse, as opposed to a specific medical curriculum. Thus, Weiss et al. (2011) focused on health economics rather than education evaluation. The method was a cohort study completed during two time periods: pre-intervention (January 2003 to December 2004) and post-intervention (February 2004 to December 2007). The results showed that programme implementation reduced antibiotic consumption per capita in the intervention region of Quebec. The study suggests that the

use of online training affected the prescription of antibiotics, which affected antibiotic disbursements among the Quebec population. Although Weiss et al. (2011) offers stronger evidence of pre- and post-intervention through data and analysis concerning the impact of the intervention on costs, it focuses less than other studies in this set on education delivery. This study focuses on how education can affect the management of prescriptions by health professionals, whereas the other studies focus on how education is delivered to teach broad skills or specific activities. The intent of this study was to improve a specific clinical activity and the associated cost-efficiencies gained through this training.

Although each study conducted a full comparison demonstrating a reduction in costs (in some instances, a dramatic reduction), they suffer from a lack of methodological consistency in how they capture costs and evaluate effectiveness. As was the case in the previous set of study classifications, the continued differences in cost accounting, learning delivery platforms, and various forms of assessments make synthesis challenging.

2.3.4. Literature reviews that quantify eLearning costs

Two review studies (Dumestre, Yeung & Temple-Oberle, 2014; Reeves et al., 2013) analysed the use of training wherein eLearning was used as a delivery platform. Both studies revealed a lack of sufficient evidence with which to analyse whether training methods using aspects of online learning were more or equally pedagogically effective. The studies were also unable to provide a holistic understanding of associated cost ingredients. Dumestre, Yeung, and Temple-Oberle (2014) suggested that many methods of implementing instruction are available in the field of microsurgical training and that cost is the determining selection factor. In the one instance of online learning included in the study results, the data suggested that online intervention had stronger pedagogical results than the face-to-face

control group (however, this is not overwhelming evidence of the strength of the method, as it was applicable to only one study). Reeves et al. (2013) performed a Cochrane systematic review protocol that included 15 studies. This study found that, due to the small number of studies (n = 15) and the heterogeneity among the interventions and outcome measures, it was not possible to draw inferences about the key elements of inter-professional education and its effectiveness. Such an evaluation would require the implementation of a cost-benefit analysis, the separation of reviews within specific professions, and the use of qualitative methods to evaluate effectiveness. Although both studies examined the evaluation of the effectiveness of a specific kind of education training, they engaged with the literature review question in a limited manner, as both studies collected limited information on eLearning and gave only broad summary generalisations about cost reductions in their respective fields of study. Costs were identified by examining the total costs of programme delivery; however, as the costs were not described as units, it is not possible to examine the extent and quality of the results. No accommodation was made for differential timing or the impact of the consequences of cost decisions. These issues are similar to the weaknesses in the cost analyses of the other studies examined in this review.

2.3.5. Studies detailing costing approaches

In all, 22 studies (Brown & Bullock, 2014; Buntrock et al., 2014; Pettit, Kinney & McCoy, 2017; Carlson et al., 2008; Carpenter, 2016; Chambers et al., 2017; Chhabra et al., 2013; Cousineau et al., 2008; Curran, Fleet & Kirby, 2006; Cook, 2014; Delgaty, 2012; Djukic et al., 2015; Gallimore et al., 2012; Isaacson et al., 2014; Lonsdale et al., 2016; Papadatou-Pastou et al., 2017; Pardue, 2001; Pickering & Joynes, 2016; Rondags et al., 2015; Sharma et al., 2018; Tung & Chang, 2008; Zary et al., 2006) examined economic evaluation (analyses of

cost benefits or cost-effectiveness) or used the ingredients method to calculate costs in the production of eLearning. Considering the broader set of studies in this review (see Table 6), it is important to note that many studies argue the cost-effectiveness of eLearning, yet only five studies conducted cost-effectiveness analyses on eLearning. Regarding specific cost approaches, the ingredients method is referenced often in this set (12 times), although the mechanisms for cost capture and subsequent project delivery management within this group are inconsistent, despite their use of the same methods.

Table 6: Studies detailing costing approaches or economic evaluation

Prefix	ID	First Author	Year	Subject	Costing approach
COS	1	Brown	2014	General practice training	Cost benefit analysis
COS	2	Buntrock	2014	Depression	Cost effectiveness analysis
COS	3	Pettit	2017	Community health	Ingredients cost method
COS	4	Carlson	2008	Cardiovascular health	Ingredients cost method
COS	5	Carpenter	2016	Graduate nursing training	Ingredients cost method
COS	6	Chambers	2017	Cancer management	Cost utility analysis
COS	7	Chhabra	2013	Spinal cord injury management	Cost effectiveness analysis
COS	8	Cousineau	2008	Fertility support	Cost effectiveness analysis
COS	9	Curran	2006	Rural health care	Ingredients cost method
COS	10	Cook	2014	Magnetic resonance imaging	Ingredients cost method
COS	11	Delgaty	2013	Postgraduate clinical education	Ingredients cost method
COS	12	Djukic	2015	Virtual nursing teams	Ingredients cost method
COS	13	Gallimore	2012	Pharmacotherapy laboratory revisions	Ingredients cost method
COS	14	Isaacson	2014	Alzheimer's prevention education	Ingredients cost method
COS	15	Lonsdale	2016	Physical activity intervention	Cost effectiveness analysis
COS	16	Papadatou-Pastou	2017	Mental health support	Multiple; survey of methods
COS	17	Pardue	2001	Poultry science	Ingredients cost method
COS	18	Pickering	2016	General technology-enhanced learning resources	Multiple; survey of methods
COS	19	Rondags	2015	Diabetes patient education	Cost effectiveness analysis
COS	20	Sharma	2018	Sexual health	Ingredients cost method
COS	21	Tung	2008	Nursing education	Perceived financial cost
COS	22	Zary	2006	Patient case simulation	Ingredients cost method

2.4. Discussion

2.4.1. Principal findings

This review sought to identify the literature that attempts to define the associated costs in the delivery of eLearning in health professions education. Broadly, this task was achieved, as the review collected data documenting a trend of reporting eLearning costs per learner and arguing their generally low costs. However, this review raises questions about the conclusiveness of these data due to issues concerning the consistency of the cost data capture, the lack of standard mechanisms for cost data collection in online learning, and the lack of primary studies focusing on cost analysis as a primary research objective. The review findings were consistent with the finding in previous research that our understanding of the relationship between cost and eLearning is not well-developed (Atun et al., 2015; Car et al., 2019; George et al., 2014). The review did not identify any studies focused on identifying the strengths and weaknesses of cost evaluation for eLearning, which points to the need for both this review and creating effective cost-comparison methods. The studies examined provide a cross-section of various instances of eLearning across many disciplines in health professions education. This collection of studies allowed a deeper understanding of the various ways eLearning can be used and the cost considerations involved in different education delivery platforms. The key limitation of the studies was the lack of consistency among their cost analysis methodologies. The cost evidence provided by the studies makes comparison challenging due to these deficiencies.

2.4.2. Strengths and limitations

The main strength of this review is that it conducted a comprehensive search of the research question using major literature databases to provide a comprehensive dataset of relevant studies. The search question and the associated terms provided a broad scope to ensure that every study that recorded costs and was relevant to the inclusion criteria was covered. The search approach was developed in consultation with leading researchers who have investigated costs in education, and the final results provide a rich background of materials with which to explore the issues associated with the research question.

There are three limitations to the process used in this literature review. As only English language papers were searched, relevant foreign language papers could have been excluded, in addition to any exclusion caused by the publication bias favouring health science papers, to ensure positive results; additionally, the industry literature was not explicitly searched. Second, the inconsistency among the methods used to capture costs and the lack of standardization in cost reporting means that no meta-analysis for quantifying costs is possible because of the lack of standard pre-defined costing models for eLearning, the significant variance in the way costs are recorded, variances among experimental methods and their outcome conclusions, and variances in implementation between different eLearning types. Third, each study is treated equally in terms of its comparison of the costs of eLearning even though the costs for a team that is new to eLearning production will be higher than those of an experienced team that has produced many courses. Additionally, reported costs could have been for segments of the production process, resulting in inconsistency in reporting. Further research could explore specific aspects of

design, development, and delivery to allow for more refined comparison and analysis, including quantitative cost analysis and an analysis of fixed versus variable costs. Further work could also explore the relationship between learning impact and the associated effort attributable to cost.

While the review could be strengthened by taking further measures to either refine the research question to narrow its scope or attempt cost modelling with the accepted deficiencies, the review provides a comprehensive scoping of the evidence and highlights a gap in the literature that indicates a need for a protocol that can capture the costs of eLearning intervention in order to allow a basis for comparison with similar educational subjects or across variant curriculum implementations. Such a protocol would provide a systematic mechanism for calculating online learning costs, provide the basis for various forms of economic evaluation, would help course designers understand the total costs of eLearning delivery, and address the standardization issues revealed by this review.

2.5. Conclusions and implications for this investigation

While cost is a recognized factor in studies exploring eLearning design and implementation, cost is captured inconsistently, in relation to a wide variety of factors, and through various study-related foci. Although there is a perception that eLearning is more cost-effective than face-to-face instruction, there is insufficient evidence to assert this conclusively. Among the many factors to consider in the implementation of eLearning is the potential long-term cost-effectiveness of its delivery model in comparison to other education delivery formats. A rigorous, repeatable data-capture method is needed, in addition to a means of leveraging existing economic evaluation methods that could test whether eLearning is cost-effective and determine how to implement it with cost benefits and advantages over traditional instruction. If it is proven more cost-effective, it could assist in addressing the high cost of delivering of health professions education. On the other hand, should evidence point the other way, having discrete data points will allow those involved in health education to identify ways of optimising costs in eLearning delivery to create cost-efficiency. To evaluate and optimize the costs of education delivery, there must be a rigorous standard through which to score and assess cost-effectiveness and analyse whether investments are justified.

To identify how cost impacts the deployment of eLearning in comparison to face-to-face instruction, a body of evidence that uses economic evaluation must be developed to allow for systematic analysis of how these results demonstrate the strengths and weaknesses of comparative cost delivery modes. This review has found that economic evaluations have been rarely used to achieve this aim and that even those studies that use cost summaries lack the rigor required to provide insight into how these costs impact education delivery or to allow comparisons to other forms of learning. This thesis focuses on addressing this gap,

by developing processes and methods for an accurate reporting of eLearning costs, thus addressing the key knowledge gap identified in this review.

3. Methods

At the time of the thesis submission, aspects of Chapter Three have been drawn from a peer-reviewed research paper, two protocols in a peer-reviewed journal, and a blind peer-reviewed conference paper:

Alturkistani A., Osama T., Brindley D., Car J., Majeed A., Wells G. & Meinert E. (2018) Determining the effectiveness of a Massive Open Online Course in Data Science for Health. *International Association for Development of the Information Society, Paper presented at the International Association for Development of the Information Society (IADIS) International Conference on e-Learning (Madrid, Spain, July 17-19, 2018)*

Alturkistani A., Majeed A., Car J., Brindley D., Wells G. & Meinert E. (2019) Data collection approaches to enable evaluation of a Massive Open Online Course about data science for continuing education in health care: Case study. *JMIR Medical Education.* 5(1), e10982.

Meinert E., Alturkistani A., Car J., Carter A., Wells G. & Brindley D. (2018) Real-world evidence for postgraduate students and professionals in healthcare: protocol for the design of a blended massive open online course. *BMJ Open.* 8(9), e025196.

Meinert E., Alturkistani A., Brindley D., Carter A., Wells G. & Car J. (2018) Protocol for a mixed-methods evaluation of a massive open online course on real world evidence. *BMJ Open*. 8(8), e025188.

3.1. Introduction

Chapter Two of this thesis established the inconsistency concerning cost calculation in eLearning in the research literature. Due to this knowledge gap, this leads to a lack of data concerning the way to execute budgeting in the production and deployment of eLearning; there is not a strong basis of pre-existing data and standards for course implementers to use. Within Chapter Three the methods used in this research to capture, interpret eLearning course budgets are explained; this method provides a novel contribution to knowledge through the implementation of a repeatable means to analyse budget variance and interpret the factors which impact their composition. This thesis employs a case study research design because the investigation was centred on decisions not subject to experimental variables implemented by the research or by the participants taking part in the courses; the research strictly focused on the financial decisions of the course designers. This 'real-world' analysis of cost accounting provides primary evidence on issues and implications in budgeting in course production and delivery. The rationale for this focus is that it is necessary to bridge the gap in the literature on the means to record and budget costs in developing eLearning. Case studies were selected to examine the cost ingredients and differences between the initial budget and the actual budget post-course implementation and categorise the reasons for the variances. This research subsequently uses cross-case synthesis to identify the themes of these cases.

3.2. Methodological approach and analytic framework

A mixed-methods case study design was selected to support a systematic means of observing the subject of investigation (Yin, 2018) and the ability to combine quantitative and qualitative approaches (Creswell et al., 2007). Each case study was structured in a rigorous study design (see Section 3.3) to allow for a portable, extensible, and systematic examination of distinct eLearning cases, examining multiple data sources (see Section 3.3.2.B) to define cost in the development and production of eLearning. Case studies were selected based on their relevance and the opportunity they gave the author to capture, record, and analyse data from each case.

Mixed methods research presents an opportunity to combine the strengths of quantitative and qualitative research to overcome the limitations inherent if each method were used in isolation (Creswell et al., 2007). In this research, for example, the limitations of quantitatively isolating cost differences in three cases are overcome by the repeatable and generalizable nature of the qualitative approach used to interpret the results. Case studies were selected based on their relevance to the topic and the extent to which they made it possible to capture, record, and analyse data from them. Each study was structured through a study protocol governing the case execution.

The analytical framework for this research makes use of quantitative cost calculation and qualitative deductive–inductive analysis. The cost calculation approach is based on the cost identification methods underpinning education economic evaluation developed by Levin and McEwan (2001) and Levin et al. (2018), which extend the standard costing and variance calculation principles of activity-based costing and horizontal analysis of budget variance

(Kaplan, 1994; Mak & Roush, 1996). The 'ingredients method' (Levin & McEwan, 2001; Levin et al., 2018) is used to capture cost production against cost categories. The ingredients method examines the core composition of costs in the delivery of an educational intervention and, as indicated by this thesis's literature review, is cited extensively as a means of basic cost capture. This research applies this method to specific eLearning implementation cases and extends it by defining an interpretative framework used to analyse discrepancies between forecasted and actual costs using Total Quality Management (TQM) criteria (Sallis, 2014). Here, budget variance is the critical variable of interest, and the interpretative analysis enables an understanding of the factors that could be portable to other eLearning cases.

3.3. Research design

A case study research design was used to examine costs in eLearning development and delivery in each case. Each study was structured via a study protocol, which structured the study execution and elaborated the links between the questions, propositions, data, results, and conclusions.

3.3.1. Research ethics

Ethical approval for each study was obtained through the Imperial College Education Ethics Research Committee (Case 1: EERP1516-005; Case 2 & 3: EERP1617-030).

3.3.2. Study protocol

Study protocol summary

A. Overview of the Case Study

The objective of each case study is to understand the budgeting of future costs in the development of eLearning. Each study forms part of the broader investigation into the costs associated with the production of online learning; the focus of each case was to collect primary evidence in the construction of costs to allow for further research comparing the results to those for other online learning implementation types.

- Study question: How are the total costs for the production and delivery of an eLearning course (dependent on type) calculated?
- Proposition: Actual costs and budgeted costs will vary in the production/delivery of this course type.

As discussed in Chapter Two, the state of the literature indicates that it is challenging to capture total costs for the production of online learning, despite the standard methods used for cost calculation (Reeves et al., 2013). This variance likely occurs because

different skills are required to create an instructional learning design and to capture costs, and educators are not trained in cost-accounting methods.

A case study protocol was developed at the commencement of each case to demonstrate how costs were captured and analysed. This protocol, in addition to the protocol for qualitative and quantitative analyses of learning impact, was drafted and submitted for peer review to the Imperial College Education Ethics Committee. The role of this protocol was to memorialise the intended methods, subject them to peer review to validate the research design, and serve as the investigation's framework. Any deviations were documented and submitted for review and approval.

B. Data Collection Procedures

Evidence to be expected

Costs are incurred in the production of an online course. To validate the costs reported in the actual budget (which was an actual cost report), at least two separate sources confirming the final reported amount were sought (e.g. for a reported incurred cost for staff, timesheets were reviewed to match hours to costs and task completion and assignment in a project plan).

Events to be observed

While the course implementation was observed and additional studies completed to investigate the education effect, this study focused on cost decision making and the way production affected cost delivery. Therefore, the observation scope for this study was focused on reported costs and the way these correlate data to time actuals.

Documentation to be reviewed

Each case reviewed the project budget, actual costs, and timesheets. While the completed course and the course uptake completion will be reviewed, these were excluded from this research. A traceability log was maintained in Microsoft Excel linking the research questions to the data sources and the research findings.

C. Protocol questions

Study question: How are the total costs for the production and delivery of an eLearning (type dependent on implementation type) course calculated?

- The costs will be measured and ingredients captured and analysed to understand the factors affecting course production
- Data will be collected to support the cost analysis categories
- The corresponding evidence will be used to summarize the ways that cost-capture practices could be improved

The appendix provides complete details on the study protocols.

3.3.3. Study framework

3.3.3.1. Plan

Each case study followed a six-stage investigation process (see Table 7; Yin, 2018). The research question focused on identifying the total costs of production and delivery in these eLearning implementation cases and the effects of various factors on the variance from the anticipated budgets. This focus was selected because the literature indicates that the determination of costs for the delivery of online courses has been inconsistent (Reeves et al., 2013). This is significant because the lack of consistent cost-capture mechanisms for online learning compromises any further evaluation. Despite the availability of methods that could avoid this outcome, studies claim that online learning is more ‘cost effective’ than

face-to-face learning. This research provides a structured means of generating evidence with which to evaluate such claims by collecting base data on course production for further evaluation.

Table 7: Case study framework

	Stage	Outcome
1	Plan	Case description and linking of case approach to investigation outcomes
2	Design	Construction of research design and linkage of research questions, data, and criteria for evaluation and synthesis
3	Prepare	Draft, execution, and approval of study protocols
4	Collect	Data-collection strategy executed from a *realist* perspective to capture the decision making of the course designers centred on cost attributes.
5	Analyse	Data extracted into categories for review and analysed for variance calculation. Data analysis centres on three cost categories in the design of the pre-production budget submitted to the funder for each case. Category A: Concept and measurement of costs The pre-production budget was analysed for the following ingredient categories: 1) personnel, 2) estate charges, 3) equipment and materials, 4) indirect costs, and 5) stakeholder costs. Category B: Placing values on ingredients With the full cost of production defined, values were associated with each ingredient sub-category to reflect the chargeable cost. Category C: Calculating costs To enable a variance calculation, the budget was compared to the incurred costs on a quarterly basis. Variance = Actual spending – Budgeted spending
6	Share	The findings of the variance calculation and a synthesis of the analysis of the causes of variation were presented in a report intended for publication in a peer-reviewed journal (this manuscript).

3.3.3.2. Design

The research design (see Table 8) was structured based on four components (the proposition, the case [definition], the logic linking the data to the proposition, and the criteria for interpreting the findings) to explore the following research question: How are

the total costs for the production and delivery of eLearning calculated (with the eLearning implementation type variant depending on the case study)? Given the inconsistency in the presentation of costs indicated in the literature and recognising that using budgets to determine educational delivery costs is insufficient (Levin et al., 2018), the governing proposition of the investigation was that variances would be observed between the budgeted costs and the actual costs of producing the courses. This proposition was explored through cases conducted to examine the costs and their measurement and to place values on the key ingredients. Levin developed this 'ingredients method' to capture and analyse the costs of the delivery of an educational programme. To link the case to the proposition, the cost calculation was conducted and was then interpreted via a variance calculation of actual to budgeted costs, and a rationale was developed to explain the variations.

Table 8: Case study research design – definitions

Case	Year	Study question	Proposition	The case (definition)	Logic linking data to the proposition	Criteria for interpreting findings
Case 1: Educating administrative staff to engage with young patients [22]	2016	How are the total costs for the production and delivery of this eLearning course calculated?	Actual and budgeted costs will vary in the production/delivery of this course type	Determination and measurement of costs	Cost analysis of project, actual and underreported costs	Variance calculation from the project budget
Case 2: The impact of climate change on public health [23]	2017					
Case 3: Data science in healthcare using real world evidence [24]	2018					

Examining these cases provides data that can be used to analyse the relationship between course production and budgeting in the delivery of eLearning and provides evidence for constructing accurate budget models.

Each case was tested for construct validity (verifying that the data sources come from multiple sources), external validity (demonstrating how the principal findings could be extensible), and reliability (showing how the activities of the study could be replicated) to ensure data triangulation, study replicability, and standardisation for project data collection (Yin, 2018).

3.3.3.3. Prepare

The investigation was focused on cost measurement and analysis, structured based on three cost categories and further sub-divided using a seven-step process to analyse the pre-production and post-production budgets (Levin et al., 2018). Levin's model uses an activity-based standard costing accountancy approach, which assigns costs as they are consumed per implementation area (Kaplan, 1994; Mak & Roush, 1996).

Table 9: Course production ingredients cost analysis

Cost Categories	Objectives – adapted from Levin and McEwan (2001 and Levin et al. (2018)
A. Concept and measurement of costs	1. Describe the concept of 'costs' 2. Show the inadequacy of budgets for cost analysis 3. Present a methodology for measuring costs 4. Identify categories of cost ingredients 5. Describe sources of cost information
B. Placing values on ingredients	6. Describe the purpose of and principles for determining the values of ingredients 7. Present methods for placing values on specific types of ingredients

3.3.3.4. Collect

Data collection

Evidence from the course was retrieved from project documents and records of finance activities. The data-collection strategy was executed from a realist perspective to capture the decisions made by the course designers; however, it did not incorporate a relativist perspective with regard to stakeholders, through further qualitative investigation. This decision was made to avoid interference in course delivery. To avoid biased selectivity and reporting bias, the data were sourced through multiple sources, including finance logs (and notes), data submitted to the employer, the funder, and timesheets. A traceability log was maintained linking the study questions to the relevant data sources and the study findings.

3.3.3.5. Analyse

Data analysis was based on the three cost categories and followed the seven-step process for cost definition.

Category A: Concept and measurement of costs

The pre-production budget was analysed for the following ingredient categories: 1) personnel, 2) estate charges, 3) equipment and materials, 4) indirect costs, and 5) stakeholder costs. The initial budgets did not reflect the time for stakeholder costs (i.e. effort from third-party lecturers); therefore, this was captured as the additional time that was monitored in the study (and added for budget variance calculation), as there was no value for this in the data submitted to the funder.

Category B: Placing values on ingredients

After the full cost of production was defined, values were associated with each ingredient sub-category to reflect the total chargeable cost (including direct and indirect costs).

Category C: Calculating costs

As each course was implemented over one year and was delivered online, there were no multi-year costs to calculate; the one-time cost of the project and the variance of the projected budget from the actual budget were the only variables considered. The calculation of the budget's variance from the incurred costs was undertaken at the completion of the project. The variance calculation compared the actual spend to the adjusted standard conditions based on occurrence (Drury, 2017).

Equation 1: Variance calculation formula

Variance = Actual spending – Budgeted spending

Analysing costs of observed budget variance calculations

To determine the reasons for the favourable or negative budget variance, the course designers were interviewed in order to determine the factors contributing to budget variance. This qualitative work was planned via the consolidated criteria for reporting qualitative research (COREQ) to ensure that the interviews were conducted by the appropriate trained staff (see Table 10), that the study design (including the purposeful sampling of the course designers and in the interview sessions) could be validated, and that the resultant analysis and findings would be repeatable (Tong, Sainsbury & Craig, 2017). The sessions were conducted as semi-structured interviews, and were transcribed and coded through thematic analysis (Braun, Clarke & Terry 2014) using Total Quality Management (TQM) as coding criteria. TQM (Lobo, Samaranayake & Subramanian 2019) is a quality appraisal method used to analyse factors impacting operational efficiency (Manzoor, 2018). TQM provides a means of categorising issues relating to people, processes, or technology by

applying a systems approach to management. For each cost variance area, the course designers were asked to review budget reports to identify stages in the project lifecycle showing variances from forecasts and to describe the causal factors. Post-interview, these were coded independently by two researchers to create a novel means of interpreting the cost-calculation variance.

Table 10: COREQ checklist

Topic	Item No.	Description
Domain 1: Research team and reflexivity		
Personal characteristics		
Interviewer	1	EUR ING Edward Meinert
Credentials	2	MA, MSc, MBA, MPA, CEng FBCS
Occupation	3	Research postgraduate
Gender	4	Male
Experience and training	5	Qualitative methods training as part of PhD training at Imperial College London. Completed as part of three-year course preparation completed via Imperial College London professional development programme.
Relationship with participants		
Relationship established	6	The interviewer had a professional relationship with the course designers prior to implementation; all are members of the Global eHealth Unit (Global Digital Health Unit) in the

		Department of Primary Care and Public Health. In order to control bias, terms of reference were established to ensure course designers knew that their responses would have no impact on professional interactions, and responses were treated confidentially.
Participant knowledge of the interviewer	7	The participants were made aware of the research aims via a participant information sheet summarising the research objectives.
Interviewer characteristics	8	The participants were made aware of the research aims via a participant information sheet summarising the research objectives.
Domain 2: Study design		
Theoretical framework		
Methodological orientation and theory	9	Content analysis – thematic coding of interview data.
Participant selection		
Sampling	10	Purposive sampling of course designers building eLearning courses.
Method of approach	11	Face-to-face interview
Sample size	12	4
Non-participation	13	0
Setting		

Setting of data collection	14	Workplace
Presence of non-participants	15	N/A
Description of sample	16	The course designers who built each course and made decisions regarding planning were the sample selected.
Data collection		
Interview guide	17	The questions were guided by variances noted within the project budget; semi-structured questions were designed to identify issues causing the variance.
Repeat interviews	18	Repeat interviews were not conducted.
Audio/visual recording	19	N/A
Field notes	20	Field notes were made during each interview.
Duration	21	Each interview took 60 to 90 minutes.
Data saturation	22	Data saturation was achieved through correlation of variance to reasons evidenced through project materials.
Transcripts returned	23	Field notes were given to participants for validation.
Domain 3: analysis and findings		
Data analysis		
Number of data coders	24	Two

Description of the coding tree	25	Total quality management – identification of factors applying systems management for people, processes, and technology.
Derivation of themes	26	Themes were derived from the data, but a coding classification (TQM) was devised in advance.
Software	27	Microsoft Excel
Participant checking	28	Participants provided feedback on the findings.
Reporting		
Questions presented	29	Participant quotations were used to illustrate themes, with quotations identified by participant number.
Data and findings consistent	30	Data and findings were linked via the selected case approach.
Clarity of major themes	31	Major themes were presented in findings.
Clarity of minor themes	32	Minor themes were not weighted.

For example, if a cost variance was attributed to stakeholder costs, the researchers would examine the reported quarterly budgets (or at the project time interval) and determine where the variance began. If the variance commenced during the build stage of the project, the project plan was analysed, and questions were asked of the course designers regarding

project activities to determine the root cause of the variance.

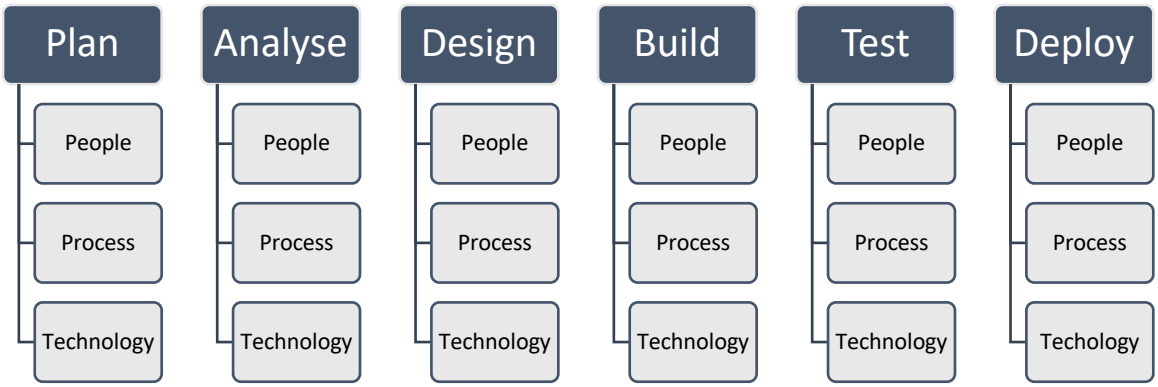

Figure 3: Isolating variance during project stage to TQM criteria during qualitative data analysis

The key themes of the TQM analysis are presented in each case, indicating the summary perspective of areas for improvement or increased efficiency in eLearning budget creation.

3.3.3.6. Share

The findings of the variance calculation and the deductive-inductive interpretation of the causes of variation were presented in a case report to the course design and production team. Feedback was gathered on the analysis and results. The key findings of each report were prepared for publication in a peer-reviewed journal.

3.3.4. Cross-case study design

To derive results from a composite analysis of the cases, this study uses the cross-case study synthesis (Yin, 2018), as illustrated in Figure 4. The standard variables in the cases are based on key ingredients and the variance of their incurred costs from the budget.

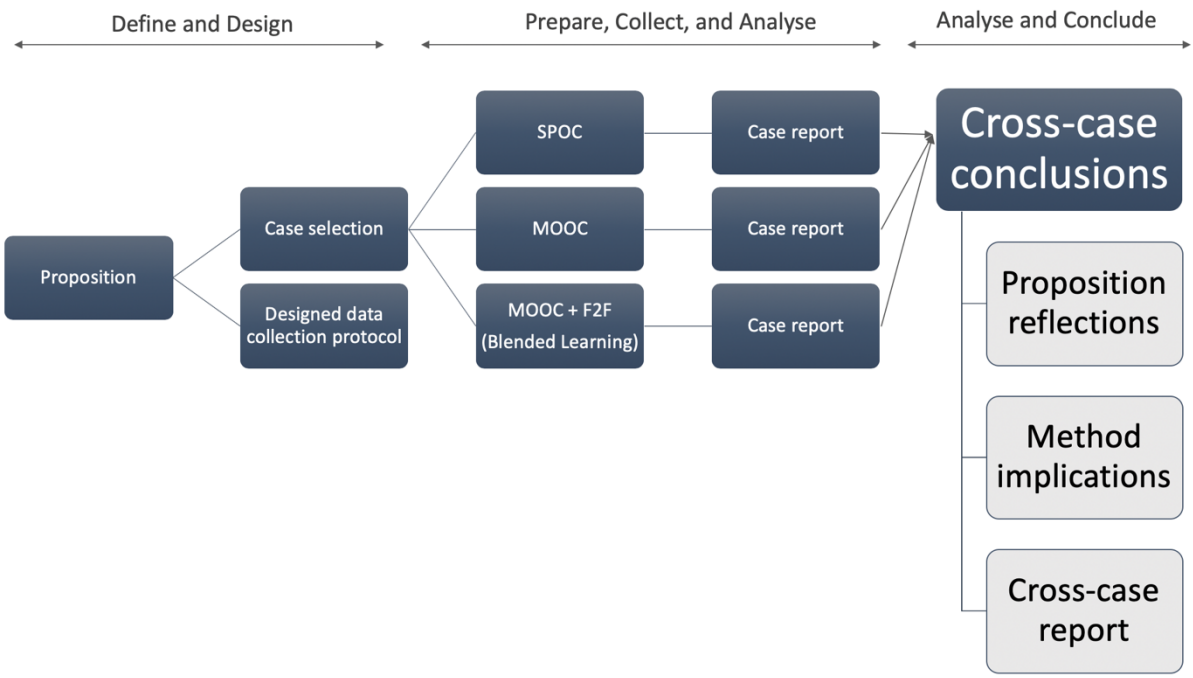

Figure 4: Cross-case synthesis study design

4. Determining costs in applied health sciences eLearning

4.1. Introduction

Chapter Three presented the methodological and quantitative approach of the study's cost calculation of budget variance and the qualitative approach of the identification of factors causing the variances and the application of TQM criteria to interpret them. This methodological approach represents a novel application of quantitative cost calculation, using TQM in a deductive-inductive qualitative cross-case study of eLearning development and production costs, employing budget variance as the main variable of interest. Chapter Four describes the application of this method to three case studies and presents the principal findings of each case, including a synthesis of all three.

4.2. Research study one: Cost measurements in production and delivery of a Small Private Online Course (SPOC)

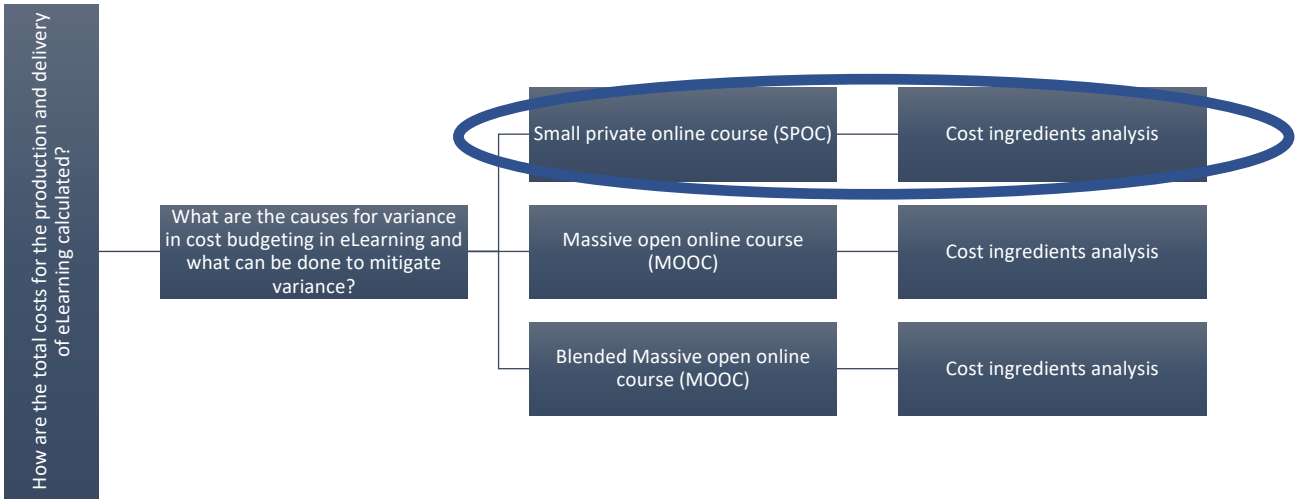

Figure 5: Research study one: setting among research questions and other case studies

4.2.1. Introduction

Small private online courses (SPOCs) are a form of eLearning derived from Massive Open Online Courses (MOOCs), which target specific learner groups (Downer et al., 2018). They can be distributed at scale. Unlike MOOCs, however, which are intended for a large and unstructured aggregate audience, SPOCs focus on specific learners for review and learning content.

The purpose of this study was to determine how the total costs for the production and delivery of a SPOC are calculated in the context of the delivery of an applied health-training course.

4.2.2. Case description

The Child and Young People's Health Partnership (CYPHP) was formed as a large-scale initiative to improve the quality of care and the physical and mental wellbeing of children and young individuals in the diverse London boroughs of Lambeth and Southwark. Following the development of a needs assessment and youth panel report on the health of young individuals, the project identified barriers to young individuals seeking health services from their GP, including mental health, owing to fears over confidentiality and services not being 'young friendly'. This investigation recommended workforce training for both clinical and non-clinical staff to respond to the health needs of adolescents effectively. This study identified a need to educate general practice office staff on handling adolescents and their issues at the surgeries. The purpose of this project was to implement a small private online course that receptionists and administrative staff (n = 187) would use to learn these critical skills. The course was implemented by an eLearning production team at the Imperial College London Global Digital Unit.

The course taught receptionists and administrative staff about the legal and medical confidentiality status of adolescents at different ages and presented use-case studies to increase their knowledge and confidence in handling different situations. It is hoped that, by addressing this gap in knowledge and experience, this course will improve the experience of young individuals when using general practice, and therefore improve their attendance, which is crucial during adolescence. The course was developed from November 2015 through August 2016 and delivered to participants from September 2016 to December 2016.

4.2.3. Results

4.2.4. Course production costs

4.2.4.1. Concept and measurement of costs

Table 11: Ingredient categories for an SPOC

Ingredient categories	Cost components
Personnel	University staff
Estate charges	IT services charges
Equipment and materials	Recording equipment, video editing software, course design software
Indirect costs	University overheads
Stakeholder costs	NHS nurses and doctors serving as lecture Subject Matter Experts

4.2.4.2. Placing values on ingredients

The initial budget was created and submitted to the funder after calculating the ingredients of course production.

Table 12: Ingredient costs for an SPOC

		Cost in 2016
Personnel		£71,119
Estate charges		£8,949
Equipment and materials		£16,773
Indirect costs		£22,717
Stakeholder costs		£9,823
		£129,382

4.2.4.3. Calculating costs

Budget variance calculation

Following the identification of budget variance and the collection of data resulting from an analysis of the data sources, the course designers were interviewed to ascertain the factors impacting the course budget.

The actual spend had a significantly negative variance from the budgeted spend (i.e. the production cost exceeded the budgeted amount) in personnel, equipment and materials, and stakeholder costs. This variance was captured only because of the comparison made with the timesheet hours and the planned spend; if this information had not been recorded, these data would have been lost, as the only information reported to the project funder was the initial budget (as this was the amount they were seeking to have reimbursed).

The greatest negative variance was in equipment and materials (135%). It was caused primarily by the costs of application development in the creation of a custom online course. As the production team had not done this before, there was a significant underestimation of the time required to build and configure the system (which was developed using the Open edX platform) and to conduct course editing. Additionally, specialist recording equipment had to be procured, which was not understood during budget completion.

The next most substantial negative variance (76%) was the time required by third-party stakeholders to produce the learning materials. This included the course lecturers from the CYPHP programme. The time allocated for recording the lecturers was underestimated

because, once the initial recordings were completed, they required several re-runs to address content changes.

The last negative cost variance (31%) was in the personnel costs required to deliver the course. While this variance was the smallest of the three categories, it was significant because the course production team did not receive any additional compensation for their additional work; although captured in the project timesheets, this extra work was not submitted to the funder for reimbursement.

Table 13: Ingredient costs variance calculation of an SPOC

	Budget	Actual	Variance	Var %
Personnel	£71,119	£93,455	£22,336	31%
Estate charges	£8,949	£8,949	£0	0%
Equipment and materials	£16,773	£39,455	£22,682	135%
Indirect costs	£22,717	£22,717	£0	0%
Stakeholder costs	£9,823	£17,333	£7,510	76%
	£129,382	£181,910	£52,527	41%

4.2.4.4. Quality testing

The construction of the cost ingredients and subsequent cost calculation underwent three validation tests:

A. Construct validity test: The case study had multiple sources of cost data with which to validate the reported costs: 1) the project budget submitted to the project funder, 2) the actual costs submitted to the funder at the completion of the project, and 3)

the timesheet log of hours captured by the course implementers. The final case report was reviewed, and feedback was gathered from the course designers (BS, MT); any inconsistencies or inaccuracies were corrected.

B. External validity test: Using the ingredients method for cost identification, the case followed an established costing procedure, which is used as the basis for analytic frameworks for economic evaluation in education. This process, based on a common analytic framework using TQM, allows the study findings to be generalised to similar use cases.

C. Reliability test: A study protocol was created at the commencement of the case; the protocol details the structure of the study and describes how data were collected to ensure the reliability of the results.

4.2.5.Project management

The CYPHP and the Digital Education Research Team at Imperial College's Global Digital Health Unit built the course. The course designers completed timesheets recording course construction; this was structured as a detailed list of activities derived from a task-based project plan. The course was divided into four modules, consisting of video recordings, worksheets, and quizzes on the learning content.

Table 14: Summary of actions and schedule for an SPOC

Activity and Schedule Recording/ Design/ Development / Production Team	2015		2016							
	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug
Content Provider (1-day work for four lessons (x7 minutes video lecture per lesson 28 minutes in total)										
Quiz and questionnaire preparation										
Exercise (1 day to create exercises, one per module)										
Instructional design (per 7 minutes of content)										
Text rework/story creation (per 7m video)										
Slide rework (number of slides from the original presentation)										
Intro (video of prof introducing his course)										
Video production (per 7m of content)										
Review by the lecturer (QA & review: per 7m of content)										
Creation of supporting text per 7m of video										
Creation of a glossary and reference for 7m video										
Video transcriptions (per 7m of video)										
Publication of video, text, quizzes, and exercises										
Creation of texts sent to the learners										
Creation of ‘About the Course’ (FAQ, course surveys, instructors’ and tutors’ text)										
Development of custom-built online learning platform										

4.2.6.Participant information

In all, 187 learners enrolled in the SPOC from September to December 2016. Of these, 84% completed the course and received a post-course certificate. The course uptake and completion, however, did not influence the production costs post-course implementation, as the course was designed as a self-managed SPOC that did not require further administration post-deployment.

4.2.7. Discussion: Principal findings

4.2.7.1. Principal findings

The implementation costs of the course were significantly underestimated at commencement, making the total cost untenable when base-lined against the budget. The course was delivered despite this budget overrun, owing to the obligation of the university and the course team to deliver within the anticipated budget; had they failed, they would not have received compensation from the funder. This dynamic creates a disincentive to report the actual costs of projects and indicates that, in this type of course delivery, the effort is not as defined at onset as it would be in face-to-face implementation (where delivery costs are predicated on preparation and one-time delivery). This outcome would seem to indicate that the costs for the production of an online course tend to be underreported. The implication of this underreporting is that the literature detailing eLearning implementation costs should be treated sceptically, especially when it lacks data on how the costs were calculated or fails to describe the factors leading to the cost overruns or underruns. These principal findings are in line with the findings of the literature review, which provided insight into both the costs involved in the deployment of eLearning to a high standard and the lack of understanding of the total costs required for the development of eLearning courses.

The case results indicate that two principal factors influenced the budget's adherence to plan.

A. Inadequacy of project budgets at the commencement of online learning for new teams (TQM Theme: Process, Technology)

The results reinforce the prior research observation that initial project budgets are insufficient for identifying the real costs of the delivery of an educational course (Levin & McEwan, 2001; Schaffer, 2010; Walsh, 2014; Wooldridge, 2000; Yeh, 2010). It is necessary to recognize that budgets are often calculated without a full consideration of the real costs of the underlying variables that make up cost categories. Therefore, an education ingredient-driven approach will lead to more accurate costing. However, the critical challenge is that even a budget constructed using the ingredients method proved insufficient, because the real cost of the course varied significantly from the ingredients-structured budget. The actual-to-incurred spend variance, primarily for costs that are not reimbursed, is a critical factor determining the true nature of spending for this type of learning.

B. Underreporting of personnel costs (TQM Theme: People, Process)

There is a disincentive to recording the actual time spent in course delivery within the implementation context of a funded education grant, as the additional cost will not be compensated. This additional effort made by educators is not unique to eLearning production but results in the underreporting of the real value of the cost associated with delivery. Software configuration, editing, online course construction, and delivery via a digital platform require a logistical setup that is difficult to plan for, especially if the delivery team is working with new course content, which is often the case in the production of new materials.

4.2.7.2. Strengths and limitations

This study provided a rigorous case examination of the implementation of eLearning via a small private online course. The implementation context of teaching administrative health policy and patient considerations is an educational model that is topical and well-suited for

online learning. The study was based on a systematic research design and implemented management accountancy methods purpose-built for the cost evaluation of learning. Its data were validated to ensure accuracy, and the method design is repeatable and reproducible in the context examined by this study and in others.

This study has one significant limitation. Its financial data might have caused a bias. Although this study triangulated data from multiple sources, the course designers might not have reported all the costs. Therefore, data could have been manipulated since there was no direct observation of all activities as they occurred. One study-design solution to this issue could be to embed researchers within the project team to capture cost data, instead of relying on data submitted by the course designers or university systems for time tracking.

4.3. Research study two: Cost measurements in production and delivery of a Massive Open Online Course (MOOC)

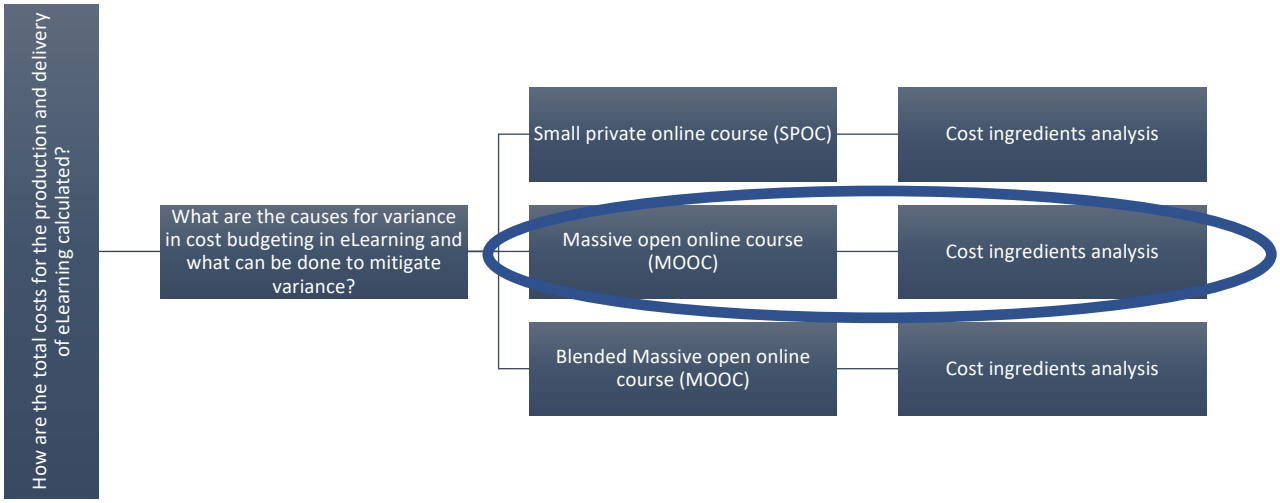

Figure 6: Research study two: setting among research questions and other case studies

4.3.1. Introduction

Climate change is already negatively affecting human health both directly and indirectly and is considered one of the most significant public health challenges for the 21st century (Watts et al., 2018; Wuebbles, Fahey & Hibbard, 2017). While the 21st Conference of the Parties (COP21) and the subsequent Paris Agreement represent critical international progress towards tackling this global threat, the world remains off-target in terms of reducing emissions to the extent required to limit warming to 'well below 2 °C' and implementing adaptation plans to meet the challenges of present and future effects. Thus, there is a growing need for active citizen engagement and education to facilitate the technological and social transitions required across sectors if global targets to limit warming and manage impacts are to be achieved (Glanz, Rimer & Viswanath, 2008).

A Massive Open Online Course (MOOC) is a form of online education that makes learning available to a large number of individuals at no charge (Veletsianos & Shepherdson, 2016). Since their inception in 2008, MOOCs have proliferated to become a major feature of the online education field. A variety of MOOCs are available, from those that attract tens of thousands of participants worldwide to courses built to train a specific cohort. While some individuals undertake MOOCs out of personal interest, others seek to enhance their employability by gaining certification for completed courses. The impact of climate change on public health has been introduced via MOOCs in various forms, such as by examining the impact of natural disasters, investigating how the increase in temperatures is affecting work productivity, and studying the monitoring and evaluation of health adaptation to climate change and its implications for policy (Milligan, Littlejohn & Margaryan, 2013). However, despite this work to advance understanding in both online and postgraduate education,

more effort is required to provide the tools and capabilities required to analyse evidence and present findings that demonstrate its impact on target outcomes, including health and wellbeing.

One principal aim of an MOOC focusing on the relationship between climate change and public health is to increase critical awareness of key issues. It also aims to inspire a new generation of actors, such as climate scientists who could help address the challenges by developing skills in integrating public health and data science, and health professionals who could catalyse the incorporation of climate change impacts into public health policies. Although these courses are publicly available, understanding the costs associated with their production and delivery will enable the development of sustainable models by which to deploy this form of citizen engagement education (Joshi & Perin, 2012).

4.3.2. Case description

The MOOC instructional design focused on connectivist learning theory, which proposes that networking and skill acquisition can be enhanced through the development of sustainable peer learning and engagement in peer-to-peer concepts (Banks & Meinert, 2016; Milligan, Littlejohn & Margaryan, 2013). By enhancing information flow and exchange, the MOOC instructional design builds online social networks to promote collaboration and discussion between learners and various stakeholders. Stakeholders were engaged in the learning process while developing digital skills. Through their challenge-based learning, learners were informed on national and regional health-climate related issues. As a way to increase the awareness and participation of local communities, the educational platform was designed to empower citizens and applied health professionals with informed decision-making skills, thus fostering (inter alia) European economic prosperity. In addition to expanding awareness of the MOOC through social media, the establishment of networks was designed to enable a deeper understanding of the target population. Additionally, a post-course collaboration between stakeholders was conducted to improve sustainability, promote the favourable impacts of the course, and maintain citizen engagement.

The course was developed from July 2017 to October 2017 and was delivered to participants from November 2017 to December 2017. The course was produced by a consortium that included Imperial College London, University Grenoble Alpes, and The European Institute of Innovation and Technology's Climate Knowledge Innovation Community Video Production Team.

4.3.3. Results

4.3.4.Course production costs

4.3.4.1. Concept and measurement of costs

Table 15: Ingredient categories for an MOOC

Ingredient categories	Cost components
Personnel	University staff
Estate charges	IT services charges
Equipment and materials	Course editing software
Indirect costs	University overheads
Stakeholder costs	Third-party subject matter experts, software designers

4.3.4.2. Placing values on ingredients

After the analysis of the course production ingredients, the initial budget was created and submitted to the funder.

Table 16: Ingredient costs for an MOOC

		Cost in 2017
Personnel		£43,646
Estate charges		£2,345
Equipment and materials		£3,255
Indirect costs		£11,725
Stakeholder costs		£25,999
		£86,970

4.3.4.3. Calculating costs

Budget variance calculation

Following the identification of a budget variance and the gathering of data resulting from an analysis of the data sources, the course designers were interviewed to ascertain the factors impacting the course budget.

The actual spend had a negative variance from the budgeted spend for personnel, equipment and materials, and stakeholder costs, with the cost of production totalling 113% of the budgeted amount. The most significant negative variance was in stakeholder costs: The total time required for external lecturers and subject matter experts (as subcontracted third parties) to deliver their work was significantly under-budgeted, by 190%. This underestimation occurred because videos had to be reshot twice, and the time allocated to retrieve stakeholders and complete associated course updates dramatically impacted the budget. The second largest negative variance was in personnel; this cost variance was directly related to the additional production time required for the video reshoots, in addition to the iteration of the platform. Changes in relevant facts during course delivery also required a reshoot; owing to the nature of this course, it requires a constant updating of materials to keep it timely and relevant. Additionally, the course's online learning provider also switched from edX to FutureLearn (edX and FutureLearn are both Massive Open Online Course learning management systems) during the project, requiring the rework of previously completed tasks. Finally, equipment and materials were underestimated with a 133% negative variance because additional software was required for video editing and additional workstations were needed to deal with further editing in course development.

Table 17: Ingredient costs variance calculation for an MOOC

	Budget	Actual	Variance	Var %
Personnel	£43,646	£88,456	£44,810	103%
Estate charges	£2,345	£2,345	£0	0%
Equipment and materials	£3,255	£7,599	£4,344	133%
Indirect costs	£11,725	£11,725	£0	0%
Stakeholder costs	£25,999	£75,332	£49,333	190%
	£86,970	£185,457	£98,487	113%

4.3.4.4. Quality testing

The construction of the cost ingredients and subsequent cost analysis underwent three validation tests:

A. Construct validity test: Multiple sources of cost data and reporting data were used to verify that the data sources offered an accurate record of what had occurred: 1) the project budget created at the project commencement, 2) the actual cost report submitted at the completion of the project, 3) the timesheet log of hours captured by each team resource, 4) a third-party work-log for course production and monitoring of billable hours recorded charged to the program, 5) external audit reports on course construction, and 6) a review of notes from monthly reviews of the budget spend. The final case report was reviewed, and feedback was gathered from the course designers (BS, MT); feedback was provided and reviewed by the research team to ensure implementation accuracy.

B. External validity test: The repetition of a model used in prior research, the application of the ingredients method for education intervention analysis, and the use of standard costing and variance calculation activity-based costing methods constituted a common analytic framework, which is adaptable to other studies.

C. Reliability test: For this test, a study protocol was used and formed the governing basis for the study.

4.3.5.Project management

The Imperial College London Global Digital Health Unit's Digital Education Research Team led a cross-university consortium in building the course. The course used the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model and conducted course planning structured along each of these design stages. The project team relied on strong project governance, including a detailed project charter and project plan, adhering to the ADDIE model. One deficiency of the project plan was the lack of a time estimation for the effort required for each task; the plan was used as a long list of tasks with no time estimation provided.

Table 18: Project task deliverables for an MOOC

ANALYSIS	
No.	**Task Description**
1	Agree on the project plan
2	Agree on a high-level course structure based on Discovery workshops
3	Agree on core concepts to be covered in each unit; add to Action Plan (AP)
4	Agree Responsible, Accountable, Contributing, Informed (RACI); add to AP
DESIGN	
5	Define course structure in detail (components per unit); add to AP
6	Create a social media/marketing strategy and advertise (add to Instructional Design Document [IDD])
7	Study ethics preparation: • Complete ethics application Ethics form • Information Sheet • Informed Consent Form • Project Gantt Chart • Sample Interview Questions • Sample Recruitment Email • Pre-and-Post course Questionnaires
8	Submit ethics application
DEVELOP	
9	Develop course content per Action Plan
10	Record videos

11	Edit videos
12	Add content and videos to LMS
13	Test pre-live version
14	Create a registry of learners and send a pre-course questionnaire
IMPLEMENT	
15	Go live with course
16	Facilitate course: post questions and encourage engagement
17	Troubleshoot and collect ad-hoc feedback
EVALUATE	
18	Sent post-course questionnaires and invitations to interview
19	Schedule and interview learners
20	Manage transcription service
21	Collect data
22	Analyse data for the report on insights and recommendations Thematic coding of transcripts and questionnaires

4.3.6.Participant information

A total of 968 learners participated in the MOOC, and 17% completed the course from November to December 2017. The course completion ratio was in line with general completion rates for MOOCs (Li & Wan, 2016); despite a high intake of initial learners, course completion rates range from 8% to 12%.

4.3.7. Discussion: Principal findings

4.3.7.1. Principal findings

While the funder had the course delivered on budget, the actual delivery cost overran by 113%, the same outcome observed in the previous study. This result reinforces the general hypothesis that costs will tend to be underreported and that actuals will tend to exceed budgeted costs. Despite developing an extremely rigorous project management methodology to avoid time and cost overruns, the production team faced several challenges that forced them to expend far more effort than they had planned or received compensation for, although this was most likely due to a lack of task time-tracking. The project benefited from in-kind work done by university staff with permanent positions. The team was not able to let timelines slip to allow for a reduction of effort over a more extended period, leading to additional effort towards the end of each delivery of the project plan. The negative variance in the project budget provides critical lessons in the implementation of this eLearning type. In reviewing these case results, four principal findings were derived concerning the production budget and adherence to plan.

A. Resource task estimation and management (TQM Theme: Process)

While the project employed a rigorous project management approach, this activity was based on overall milestones and did not link sub-activities to the time estimate required per task. The absence of tracking at this level made it difficult for the project manager to know when tasks were going significantly over budget and altering subsequent tasks to compensate for these changes. A key lesson learned from the implementation in retrospective task analysis was the importance of tracking tasks at this level to allow for better adherence to the overall schedule.

B. Contingency planning (TQM Theme: Process)

The project had three events that significantly impacted the planned delivery schedule: the change in learning platform from edX to FutureLearn, the need to redo a series of video shoots because of lighting issues, and the loss of a principal staff member during course production. The original budget did not account for any contingency scenarios in the course planning; therefore, these events created automatic overages in the time allocated for course delivery, ultimately affecting the effort required for project delivery.

C. Third-party resource management (TQM Theme: People, Process)

The project used several subcontractors to accelerate course delivery. These projects were billed on a time and materials basis. When the project overran, the associated costs of project delivery affected the budget. An alternative model for third parties could be fixed-price outcome-based projects, whereby the core project does not need to incur overruns for delivery in executing tasks. Of course, this shifts the basis of charges from the project to the third party; however, a different commercial management of these resource costs will control spending in the primary project.

D. Need for an update of course materials (TQM Theme: Process, Technology)

The course's public health and environmental contents needed continual updating to keep the course relevant. The budgeted production costs did not capture these incremental updates, and this costing is necessary to capture the total costs of this deployment type.

4.3.7.2. Strengths and limitations

This study provided a rigorous examination of the implementation of eLearning via an MOOC. The use of MOOCs to disseminate information designed to encourage behavioural changes concerning a global issue such as climate change has broad applicability and reuse.

The study leveraged an investigation into previous eLearning cost variance calculations performed by the core research team and implemented management accountancy methods purpose-built for the cost evaluation of learning projects. The study design was reinforced through a detailed review of real-time project decisions and activities through regular checkpoints of financial data conducted with the core stakeholders, leading to additional data sources that could be referenced in a cost review of the data analysed during project implementation.

The study had one significant limitation. There was no costing of the updates required to implement the course. This multi-year costing is essential for capturing the total costs of course delivery, as regular updating is necessary for the eLearning of rapidly changing health content.

4.4. Research study three: Cost measurements in production and delivery of a blended Massive Open Online Course (MOOC)

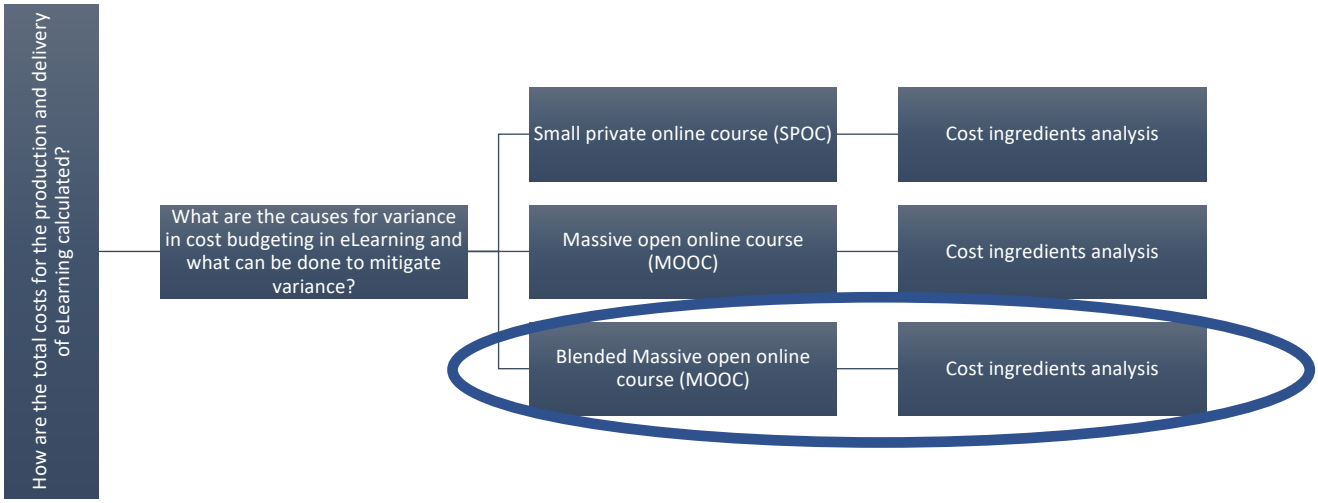

Figure 7: Research study three: setting among research questions and other case studies

4.4.1. Introduction

There is a significant demand for trained data scientists who can provide insight into and analyse health-related data (Ransbotham, Kiron & Prentice, 2015). Health issues present immense challenges. Data science can resolve key problems and improve the delivery of patient outcomes by increasing efficiency and effectiveness. For example, using computational methods on the vast quantity of real world data (RWD; data derived from everyday medical practices rather than clinical studies) could enable researchers to create predictive models, such as to identify those at risk of diabetes, and to develop preventive and personalised care for patients through mobile phone applications. An MOOC provides a flexible means of course provision for learners, who can learn at a time and location of their choice, and allows face-to-face collaboration among many learners (Margaryan, Bianco & Littlejohn, 2015). Use of MOOCs in a blended capacity is limited but increasing. This type of instructional design leverages a combination of broad access to a course while using face-to-face instruction to enable a reinforcement of learning outcomes (Israel, 2015; Phan, McNeil & Robin, 2016). This course type could enable cost-efficiency in the production of health-related skills. Further, an understanding of the total costs required to deliver these courses could induce further investment in the development of these courses, to replace costly and limited one-time-use course implementation (Sousa et al., 2013).

This study examines a course that developed data management skills, including frameworks for analysing and evaluating content (data) and encouraging the uptake of data projects, innovations, and entrepreneurship. Learners were divided into teams, and developed and implemented a data science project. These initiatives were RWD projects that addressed current healthcare problems. The projects put learning into practice and established the

foundations for further commercial activity or research. The blended format gave future (postgraduate students) and current healthcare professionals the skills and knowledge required to participate in real world evidence (RWE) projects and to help satisfy the growing need for data analysis skills in healthcare.

4.4.2. Case description

The purpose of the course was to deliver an education programme via a blended format for postgraduate students and professionals in health interested in the application of RWE data analysis and in furthering their knowledge of and skills in RWD analysis. A key objective of the programme was to establish a global network of people who could continue the dialogue on data science in healthcare. The success of the format was evaluated in terms of its education impact and its contribution to research in digital education in health, although the latter issue was subject to a separate investigation (Alturkistani et al., 2019).

The course content develops skills in the context of RWE, including frameworks for analysing and evaluating content (data). In addition to the digital component, an SPOC was offered to enable learners to complete their case study assignments over a two-day residential programme. Learners were divided into teams and developed and implemented data science projects centred on two case studies – the first examining a Herpes Simplex Patient Registry and the second examining telemedicine in secondary and tertiary care.

The course was developed and built from January 2018 to August 2018 and was delivered to participants from September 2018 to December 2018. This course built on previous online courses developed in 2017 as part of a funded project on experiential education. The course was produced by a consortium that included HealthIQ, a specialist RWE data supplier, Imperial College London, University Grenoble Alpes, the University of Oxford, and Karolinska Institute.

4.4.3. Results

4.4.4.Course production costs

4.4.4.1. Concept and measurement of costs

Table 19: Ingredient categories in a blended MOOC

Ingredient categories	Cost components
Personnel	University staff
Estate charges	IT services charges
Equipment and materials	Course production equipment, application development costs for the creation of software to support the MOOC
Indirect costs	University overhead
Stakeholder costs	Staff for third-party subject matter consultancy

4.4.4.2. Placing values on ingredients

After the course production ingredients were recorded, the initial budget was created and submitted to the funder.

Table 20: Ingredient costs of a blended MOOC

		Cost in 2018
Personnel		€ 102,041
Estate charges		€ 12,625
Equipment and materials		€ 244,517
Indirect costs		€ 88,317
Stakeholder costs		€ 50,000
		€ 497,500

4.4.4.3. Calculating costs

Budget variance calculation

Following an identification of budget variance and the gathering of data resulting from an analysis of the data sources, the course designers were interviewed to ascertain the factors impacting the course budget.

Budget variance was tracked weekly throughout the project. The research team monitored the budget regularly with the course team. The initiative had a negative variance until its final three months. In contrast to the two preceding case studies, this case demonstrates a favourable variance from the initial budget of 16% (i.e. the cost of the project was below the planned budget). Stakeholder costs for subject-matter-expert lecturers were slightly overestimated but were close to the budget. Equipment and materials had a significantly favourable variance of 37%; this occurred because not all the equipment planned for the course development was found to be necessary due to efficiencies derived in course production and through the streamlining of data science modules that were thought to require custom application development. Personnel had a negative variance of 13% due to the additional video editing effort required. Additionally, the course was completed ahead of schedule.

Table 21: Ingredient costs variance calculation in a blended MOOC

	Budget	Actual	Variance	Var %
Personnel	€ 102,040.75	€ 115,432.00	€ 13,391.25	13%
Estate charges	€ 12,625.00	€ 12,625.00	€ 0.00	0%
Equipment and materials	€ 244,517.19	€ 153,432.00	-€ 91,085.19	-37%
Indirect costs	€ 88,317.06	€ 88,317.00	-€ 0.06	0%
Stakeholder costs	€ 50,000.00	€ 48,342.00	-€ 1,658.00	-3%
	€ 497,500.00	€ 418,148.00	-€ 79,352.00	-16%

4.4.4.4. Quality testing

The construction of the cost ingredients and subsequent cost analysis underwent three validation tests:

A. Construct validity test: The data sources for each ingredient category were sourced from 1) the initial project budget, 2) reported submitted costs, 3) a time log of worked, and 4) a third-party work-log of the activities of subcontracted courses. The final case report was reviewed to ensure accuracy (YE, HC).
B. External validity test: The same process used in the two previous cases was replicated; applying the ingredients method for education intervention analysis demonstrated a common analytic framework transportable to other eLearning studies.
C. Reliability test: A minor variation of the previous study protocols was used and stored as the governance framework for the study.

4.4.5.Project management

Among the university consortium members, the Digital Education Research Team at Imperial College's Global Digital Health Unit was responsible for course production. Subject matter experts, including an RWE consultant, a clinical data analyst, and a healthcare regulator were among the other vital stakeholders who contributed to the educational videos. The RWE consultant was a Chief Commercial Officer at an organisation dedicated to the commercial use of RWD in the industry; he had been serving in his post for at least two years at the time of course development. The clinical data analyst had been leading clinical trials since 2007, and the healthcare regulator had more than five years' experience in developing policy solutions for healthcare systems. It is important to note that this course team had previously worked together on the delivery of courses in health data science. The project management accounted for contingencies in the course development and used iterations with principal stakeholders to ensure that the course was developing in line with the learning objectives.

The instructional design for the course used the ADDIE model, with the project divided into seven key delivery phases to complement this structure:

1. Marketing, whereby the course is advertised to the target audience;
2. Design, whereby the instructional design will be finalised and storyboards created for online learning;
3. Production, whereby course content is produced, and the course built on the FutureLearn Learning Management System MOOC platform;
4. Beta Trial, whereby the course is trialled/tested by a sample of users to test it and implement fixes;

5. MOOC Go-Live Round 1, whereby the course is run for the first cohort and fixed as required;
6. MOOC Go-Live Round 2, whereby the course is run for the second cohort and the blended face-to-face course is run;
7. Evaluation, whereby both MOOCs are evaluated for their impact on learners.

Table 22: Project delivery phases in a blended MOOC

	Activity
1	**DESIGN PHASE**
1.1	Instructional Design Document
1.2	ADDIE Framework Checklist
1.3	Finalise Instructional Design Strategy
1.4	Create storyboard to include guidelines and scripts
2	**PRODUCTION PHASE**
2.1	Record all videos
2.2	Edit all videos and create transcripts
2.3	Build course on LMS
3	**BETA TRIAL PHASE**
3.1	Test each component of each page
3.2	Fix and test any defects
3.3	Make any mandatory changes
4	**COURSE MARKETING PHASE**
4.1	Create content for emails, tweets, posts, websites, etc.
4.2	Distribute adverts periodically
4.2	Update course register
5	**MOOC GO-LIVE ROUND 1**
5.1	Release Module 1 content and manage issues and queries
5.2	Release Module 2 content and manage issues and queries

5.3	Release Module 3 content and manage issues and queries
5.4	Release Module 4 content and manage issues and queries
5.5	Release Module 5 content and manage issues and queries
5.6	Evaluate and fix any issues
6	**MOOC GO-LIVE ROUND 2**
6.1	Release Module 1 content and manage issues and queries
6.2	Release Module 2 content and manage issues and queries
6.3	Release Module 3 content and manage issues and queries
6.4	Release Module 4 content and manage issues and queries
6.5	Release Module 5 content and manage issues and queries
6.6	Evaluate any issues and create a fix list
7	**EVALUATION PHASE**
7.1	Complete literature review
7.2	Complete ethics application
7.3	Conduct interviews and review transcripts
7.5	Collect all data for analysis
7.6	Analyse data
7.7	Produce findings

4.4.6.Participant information

From September to December 2018, 5,036 learners participated in the MOOC, and 12% of these completed the course. The course completion ratio was in line with general completion rates for MOOCs (Li & Wan, 2016), as explained above. One blended residential course was held in November 2018 and was taken by 14 learners.

4.4.7. Discussion: Principal findings

4.4.7.1. Principal findings

The research examined in this thesis suggested that the total cost to deliver the course would show a negative variance from the budget. Throughout the project lifecycle, the project was on track for a negative variance until the final three months. It is important to note that the principal reason for the favourable variance was that less work was required to use the technology, which was achieved through the teamwork of the project participants. The negative variance in personnel costs demonstrates that more upfront work and effort were needed for communication and course building; this additional work caused inefficiency in the materials categories. The case results offer three principal findings concerning the production budget composition and adherence to plan.

A. Cost-efficiencies in the delivery of a course piloted in previous years (TQM Theme: Process)

This programme began in 2017 as a pilot initiative that implemented a limited SPOC on the edX platform. The learning content was changed entirely in 2018 and was re-platformed onto FutureLearn and made more complex, but the programme team benefited through the refactoring of the existing course material. If the course had been built from scratch, the development of the initiative would have incurred increased costs for third-party stakeholders and personnel.

B. Experience and relationship of the course learning team (TQM Theme: People)

In a related point, the course team had extensive experience working with each other. This experience of working together and delivering other eLearning initiatives resulted in

efficiency in course production and expectations surrounding content and delivery timescales.

C. Project and budget management (TQM Theme: Process)

Project management accounted for contingencies in the course development and was built with repetitive checkpoints, resulting in two-week 'sprints', whereby the course material was regularly reviewed by principal stakeholders to ensure the course was developing in line with the learning objectives. This use of iteration and review with reference to the project time, in addition to the constant reprioritising of activities using agile methods, led to efficiencies in the project budget, which had already accounted for contingencies in its schedule. The high level of interaction between stakeholders also meant that application development costs were reduced through the use of alternative solutions for addressing learning objectives that had not been anticipated at project commencement.

4.4.7.2. Strengths and limitations

This study provided a rigorous examination of a novel implementation of eLearning via a blended MOOC. The case method was tested in the two previous research studies and was refined in this case to ensure the accuracy of reported costs, thus fostering greater sophistication in eLearning.

This study has two significant limitations. The first is that it did not consider the impact of the previous pilot implementation or a planned subsequent course delivery run. A multi-year cost analysis could have demonstrated that the overall programme costs showed a favourable variance. The earlier information was excluded because the data required for cost analysis were unavailable for the pilot years; moreover, significant changes were

planned to the course implementation before any subsequent course deployment, and data on these were unavailable when this report was drafted. Second, because the core team comprised members with extensive previous experience, the impacts their relationships had on the course could be a significant variable that does not apply to the previous cases. Furthermore, noting the reduction in equipment costs may be overstating the favourable variance, as there was also a favourable variance in the time required to deliver the course.

4.5. Cross-case synthesis

This section is drawn from a research paper that has been accepted for publication:

Meinert E., Alturkistani A., Foley K., Brindley D. & Car J. (2019) Examining cost measurements in production and delivery of three case studies using eLearning for Applied Health Sciences: A cross-case synthesis. *Journal of Medical Internet Research (forthcoming/in press)*

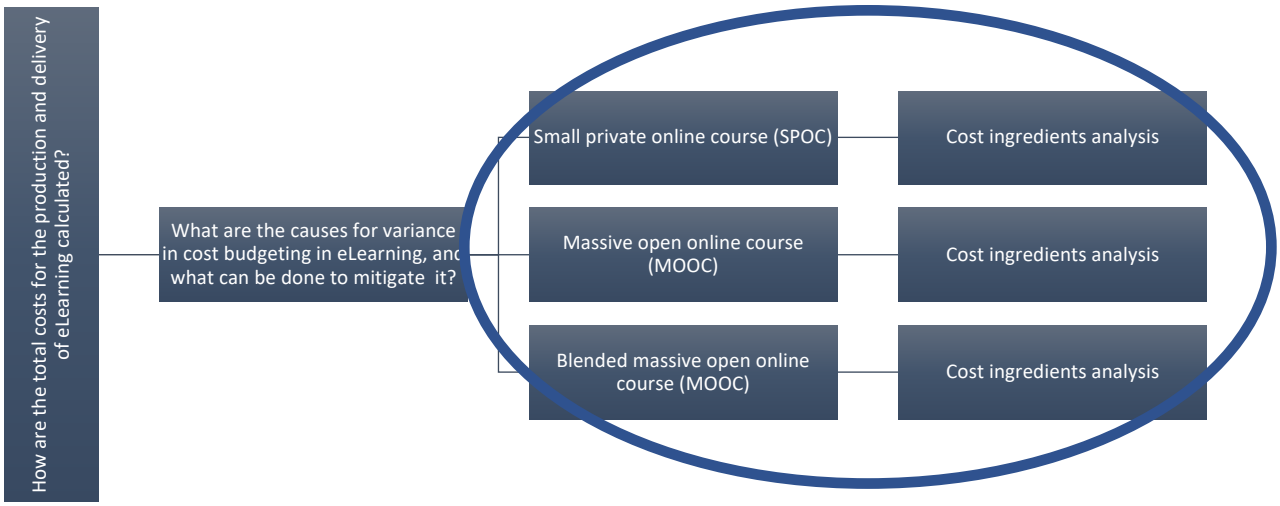

Figure 8: Cross-case synthesis: setting among research questions and other case studies

4.5.1. Introduction

This section analyses the three previous case studies to produce a synthesis through a composite of the data gleaned from each research study. Each study executed the same research questions and methods, but involved different contents and forms of eLearning.

Research study one: Educating Administrative Staff to Engage with Young Patients

The course created a **SPOC** designed to prepare general practice administrative staff for issues in the management of adolescents. The course used case studies to provide training intended to help general practice staff members who use their surgeries to improve the patient experience feel confident in helping adolescents.

Research study two: The Impact of Climate Change on Public Health

This course was created as an **MOOC** designed to educate citizens on the relationship between climate change and public health, using a multidisciplinary academic framework in data science to analyse, interpret, and present the evidence. Core case studies focused on climate change and its health and economic impacts on local, regional, and national health systems.

Research study three: Data Science in Healthcare using Real World Evidence (RWE)

This course created a **blended MOOC** to make learners aware of the impact of data science on medicine and inspire the application of these methods across various undergraduate curriculum disciplines, NHS commissioning support organisations, healthcare regulation organisations, and life sciences industries (i.e. pharmaceuticals, biotechnology, and medical devices). The target audience of the MOOC consisted of allied health professionals looking

to transition or enhance their data science skills in healthcare-related industries, such as the pharmaceutical industry or biotech organisations. A key objective of the MOOC was to establish a global network of people who could continue the dialogue on data science in healthcare. Course outcomes include the use and application of RWE data collection and analysis techniques in healthcare settings.

4.5.2. Results of synthesis

4.5.3. Course production costs

4.5.3.1. Category A: Concept and measurement of costs

The costs in each case were summarised into components and separated into ingredient cost categories (see Table 23). These categories contrasted due to the different cost compositions in course production.

Table 23: Ingredient categories

Ingredient categories
Personnel
Estate charges
Equipment and materials
Indirect costs
Stakeholder costs

4.5.3.2. Placing values on ingredients

After the course production ingredients were recorded, the initial budgets for each case were created and submitted to the funder, as is detailed in the subsequent section.

4.5.3.3. Calculating costs

Budget variance calculation (see Table 24)

Following the identification of budget variance and after gathering the data resulting from an analysis of the data sources, the course designers were interviewed to ascertain the factors impacting the course budget.

Case 1: The project implementation costs had a negative variance of 41%. The most significant negative variance (135%) was in equipment and materials, primarily from the costs of application development for creating the online course. As the production team had

not created an online course before, the time required to build and configure the system (developed using the Open edX learning management system platform) and complete course editing was significantly underestimated. Additionally, specialist recording equipment had to be procured, which was not understood at the time of budget completion. The next largest negative variance (76%) was the time required by third-party stakeholders to produce learning materials. The time allocated for recording the lecturers was underestimated; several re-runs of the recordings were necessary to address content changes. The lowest negative cost variance (31%) was in personnel costs. While this variance was the smallest of the three categories, it was still significant because the course production team received no additional compensation for their additional work; this extra work was captured in the project timesheets but was not submitted to the funder for reimbursement.

Case 2: The actual spend varied from the budgeted spend in personnel, equipment and materials, and stakeholder costs, with the total cost of production showing a negative variance of 113% from the budgeted amount. The most significant variance was in stakeholder costs; the total time required for external lecturers and subject matter experts to deliver their work was significantly under-budgeted, with a negative variance of 190%. This underestimation occurred because videos had to be reshot twice, and the time allocated to retrieve stakeholders and complete associated course updates dramatically impacted the budget. The second largest variance was in personnel; this cost variance was directly related to the additional production time required for the video reshoots, in addition to the need for content iteration during course production. The online learning provider also switched learning management systems from edX to FutureLearn during the

project, requiring the reworking of previously completed tasks. As the team was not experienced with the FutureLearn platform, this required additional effort and accounted for the unfavourable budget variance; a team with experience of and training in course material design would likely have obtained different results. Finally, equipment and materials were underestimated, with a negative variance of 133%, as additional software was required for video editing and additional workstations were needed for editing.

Case 3: In contrast to the two previous case studies, this case showed a favourable variance from the initial budget of 16%. Stakeholder costs for subject-matter-expert lecturers were slightly overestimated but were close to the budget. The third-party stakeholder team had significant previous experience working together producing related coursework, and this could have allowed precision in effort estimation. Equipment and materials had a significantly favourable variance of 37%. This occurred because not all the planned equipment was necessary for course development, as efficiency was derived in course production and through a streamlining of data science modules that had been thought to require custom application development. Personnel had a negative variance of 13%, due to the additional video editing effort required. The course was also completed ahead of schedule.

Table 24: Cross-case synthesis: Ingredient costs variance calculation

	Case 1				Case 2				Case 3			
	Budget	Actual	Variance	Var %	Budget	Actual	Variance	Var %	Budget	Actual	Variance	Var %
Personnel	£71,119	£93,455	£22,336	31%	£43,646	£88,456	£44,810	103%	€102,040.75	€115,432.00	€13,391	13%
Estate charges	£8,949	£8,949	£0	0%	£2,345	£2,345	£0	0%	€12,625.00	€12,625.00	€0	0%
Equipment and materials	£16,773	£39,455	£22,682	135%	£3,255	£7,599	£4,344	133%	€244,517.19	€153,432.00	(€91,085)	-37%
Indirect costs	£22,717	£22,717	£0	0%	£11,725	£11,725	£0	0%	€88,317.06	€88,317.00	(€0)	0%
Stakeholder costs	£9,823	£17,333	£7,510	76%	£25,999	£75,332	£49,333	190%	€50,000.00	€48,342.00	(€1,658)	-3%
	£129,382	£181,910	£52,527	41%	£86,970	£185,457	£98,487	113%	€497,500.00	€418,148.00	(€79,352)	-16%

4.5.3.4. Total Quality Management (TQM) synthesis of issues impacting budget

The issues affecting budget variance were classified using TQM (see Table 25). Although the courses were implemented with varying forms of eLearning, the issues affecting each case were similar and are cross-applicable. The critical budgeting consideration is less the eLearning type involved and more the planning done by the project management team during the creation of the course.

Table 25: Cross-case synthesis: TQM category of issues impacting budget adherence to the model

Case	Issue	People	Process	Technology
1	The inadequacy of project budgets at the commencement of online learning for new teams		X	X
1	Underreporting of personnel costs	X	X	
2	Resource task estimation and management		X	
2	Contingency planning		X	
2	Third-party resource management	X	X	
2	Need for an update of course materials		X	X
3	Cost-efficiencies in the delivery of a course piloted in previous years		X	
3	Experience of and relationships within the course learning team	X		
3	Agile project management methods and iterative budget management		X	

4.5.3.5. Quality testing

The construction of the cost ingredients and subsequent cost analysis underwent three validation tests (see Table 25):

Table 26: Cross-case syntheses: Quality tests

Case	Construct validity	External validity	Reliability
1	To validate reported costs, the case study had multiple sources of cost data: 1) the project budget submitted to the project funder, 2) the actual costs submitted to the funder at project completion, and 3) the timesheet log of hours captured by the course implementers. The final case report was reviewed and feedback was gathered from the course designers (BS, MT); any inconsistencies or inaccuracies were corrected.	Using Levin's ingredients method for cost identification, the case followed an established costing procedure, which is used as the basis for analytic frameworks for economic evaluation in education. This process, based on a common analytic framework, allows for the generalisation of the study findings to similar use cases.	A study protocol was created at the commencement of the case; the protocol details the structure of the study and data collection to ensure the reliability of the results.
2	Multiple sources of cost data and reporting data were used to validate that the data sources offered an accurate record of what occurred: 1) The project budget created at project commencement; 2) an actual cost report submitted at project completion; 3) a timesheet log of hours captured by each team resource; 4) a third-party work-log for course production and monitoring of billable hours charged to the program; 5) external audit reports on course construction; and 6) a review of notes from monthly reviews of the budget spend. The final	The repetition of a model used in prior research, application of Levin's ingredients method for education intervention analysis, and the use of standard costing and variance calculation activity-based costing methods represented a common analytic framework, which is transportable to other studies.	A study protocol was used for this test and formed the governance basis of the study.

	case report was reviewed and feedback was gathered from the course designers (BS, MT); feedback was provided and reviewed by the research team to ensure implementation accuracy		
3	The data for each ingredient category were sourced from 1) the initial project budget, 2) reported submitted costs, 3) a time log of work, and 4) a third-party work-log of the activities of subcontracted courses. The final case report was reviewed to ensure accuracy.	The same process used in two previous cases was replicated (and the application of the ingredients method for education intervention analysis represented a common analytic framework, transportable to other eLearning studies.	A minor variation of the previous study protocols executed was used and stored as the governance framework for the study.

4.5.4.Project management

Each case used project management methods to organise crucial deliverables and tasks in their design and integrated learning design methodology in different ways. Case 1 employed project-related task-centred actions performed to match each learning outcome. Case 2 integrated the ADDIE model and course planning structured along each of these design stages, while Case 3 implemented an agile project management model (with iterations) using the ADDIE model in course construction.

4.5.5.Participant information

Case 1: From September to December 2016, 124 learners enrolled in the SPOC, and 84% of these completed the course and received a post-course certificate. However, the course uptake and completion did not influence the production costs post-implementation, as the

course was designed as a self-managed SPOC that did not require further administration post-deployment.

Case 2: From November to December 2017, 968 learners participated in the MOOC, and 17% of these completed the course. The course completion ratio was in line with general completion rates for MOOCs (Li & Wan, 2016), as explained above.

Case 3: From September to December 2018, 5,036 learners participated in the MOOC, and 12% of these completed the course. The course completion ratio was also in line with completion rates for MOOCs (Li & Wan, 2016). One blended residential course was held in November 2018, in which 14 learners participated. In this residential course, the participants completed the MOOC as a pre-learning phase and then undertook case studies to put the course learning into practice.

Table 27: Cross-case synthesis: eLearning implementation participation summary

Case	Year	Number of learners	Completion %
1: Educating Administrative Staff to Engage with Young Patients	2016	187	84
2: The Impact of Climate Change on Public Health	2017	968	17
3: Data Science in Healthcare using Real World Evidence	2018	5050	12

4.5.6. Discussion: Principal findings

This research aims to establish an approach for identifying the costs in the design, development, and deployment of applied health sciences eLearning courses. The standard components for the construction of an eLearning course were determined by the methods used in this study, which combined existing approaches to cost budgeting with qualitative methods of interpreting results. While Levin's ingredients method provides a mechanism for categorizing cost design and implementation costs for budgeting, TQM provides a qualitative framework for examining how design and production decisions affect the budget. Process issues were the key issues affecting the ability of the budget to deliver consistent with expectations at the close of the project. Familiarization with technology was also a key issue in Cases 1 and 2, where familiarity with production methods and learning technology had an effect on the course effort required.

The key recommendations that flow from an examination of these cases concern three areas of process-related enhancement – one related to project management and the other two related to budget management. Both involve course production and instructional design:

1. **Project management: Linking the instructional design method to stages in the project lifecycle with time tracking**

   Project management allows for planning; activity prioritising; and the managing of risk, issues, and actions to ensure quality. In the cases studied, the use of robust project management methods and the development of iterative methods of validating learning materials tended to create favourable results. Additionally, linking an instructional design approach to project stages and tracking tasks by time to each

component created an awareness of associated effort and linked the financial impacts of delivery to course building.

2. **Budget planning: Use of 'confidence factors' in budget time estimation**

   A vital issue in all cases was an overestimation of the amount of effort required to build tasks. To manage time tracking better, we suggest tracking tasks by time linked to the learning design. As an additional measure, building confidence factors into budgets would allow a degree of error and contingency when developing initial budgets. A confidence factor is a percentage of variance added to an initial cost forecast as a contingency. When applying confidence factors based on the course requirements, the project team's familiarity with the approach being used and other factors can lead to higher estimation precision.

3. **Budget planning: Modelling budget forecasts for similar implementation cases**

   Research study three examined the most successful delivery. The course team had worked together to deliver similar content and was therefore able to gain efficiency through pre-existing relationships, using an evidence base to build their cost models. The starting point of eLearning implementation planning should be to consider previous projects or data from the literature about factors influencing costs, to avoid the need to create budgets from scratch. Part of the budget variance observed in research studies one and two occurred because cost estimates were not built on prior evidence; this can be controlled by beginning with an experience-driven starting point.

5. Discussion, strengths and limitations, implications, and conclusions

5.1. Introduction

The research objectives of this thesis were to identify the costs associated with the production and delivery of eLearning and to determine the factors that impact cost calculation. This was achieved by using mixed methods to analyse and interpret costs in the production of eLearning, including a research design intended to obtain data from three case studies of eLearning implementation in different forms as well as a quantitative analysis via an ingredients-method cost summary and a variance calculation using horizontal analysis.

Each research study and cross-case synthesis was concluded by discussing the principal findings of the investigation. The cross-case synthesis presented in the previous chapter represents the interpretive component of this thesis and explores the implications of the study's results, which are expected to form an evidence base that can be used to advance the research field. This final chapter discusses the study's key findings, reviews the strengths and limitations of the thesis, and makes recommendations for future research. It closes with a summary of the key conclusions regarding the primary and secondary research questions.

5.2. Summary of principal findings across literature and case studies

There is a gap in the literature concerning the cost measurement of eLearning, while the case studies present an approach for capturing costs for budget management. This outcome is important because achieving such gains could help address issues in the delivery of health professions education. While the literature suggests that there are ongoing attempts to analyse and capture costs within studies, it is often done inconsistently and with associated findings concerning impact that are not substantiated with financial accounting rigour. The case studies indicate that by using a structured approach for the design, development, and deployment of eLearning, it is possible to produce more accurate budgets and predict costs; however, to take this information and apply it to cost-effectiveness analysis of face-to-face learning requires more development, and the lack of their understanding can lead to underreporting of costs in eLearning implementations. These observations demonstrate the necessity for standardisation of approach.

The literature review of this thesis collected data capturing trends concerning reported eLearning costs per learner and a perspective, arguing that these costs are generally lower than face-to-face implementation costs when applied at scale. However, the conclusiveness of these perceptions is questionable due to a lack of standard mechanisms for cost data collection and a lack of primary studies focusing on cost analysis as a critical research objective. These review findings were consistent with previous research that suggests that the relationship between cost and eLearning is not well-developed (Atun et al., 2015; Car et al., 2019; George et al., 2014). A critical limitation of the literature is the lack of consistency among the use of cost analysis methodologies. With each study taking different approaches, comparison among studies is challenging due to methodological inconsistency.

The case studies in this thesis aimed to establish an approach for identifying the costs in the design, development, and deployment of applied health sciences eLearning courses. The components of the course design and implementation were determined using Levin's ingredients method. A qualitative method for interpreting budget variance was developed using TQM to examine how design and production decisions affected delivery. Process issues were the key issues affecting the ability of budgets to be delivered consistent with expectations in two of the three cases, with the last case accomplishing cost optimisation through rigorous process management and familiarisation with production methods. The principal findings from the case studies centre on the need to link project management to instructional design methods throughout the project lifecycle with time tracking of activity in units, the importance of the use of confidence factors in budget estimation to allow for a range for effort variances, and finally, the need to structure budgets on models stemming from similar implementation use cases. To implement further economic evaluation demonstrating the value of eLearning in contrast to other learning types, standardisation of means to calculate costs is essential, and considering the principal findings from the case studies, such an approach could be made possible.

5.3. Strengths and limitations of the study

This thesis has several strengths and limitations which should be considered when interpreting its findings. While these considerations have been included in each case study, this section defines broader perspectives and their impact on the overall research approach.

5.3.1. Validity, reliability, and transferability

The reliability and validity of the data collected for the case studies were tested using quality tests, described in each case study section. The application of TQM was derived from processes that pre-dated this thesis, which could be seen as a limitation. For example, developing a bespoke interpretative method for this study may have generated different results. However, given that TQM is a long-standing quality analysis approach and that defining a new method for quality analysis was not an aim of this thesis, the approach used was deemed appropriate. The use of standard costing quantitative methods, the COREQ checklist for qualitative interpretation, and the case study protocols address the transferability of this investigation and potential reuse by other researchers.

5.3.2. Terminology and definitions issues

eLearning is referred to in the literature as 'web-based' learning, 'online learning', 'digital learning', and by other permutations. This thesis focused on Sangra's definition, which is broad and encompasses learning across a vast medium of electronic devices (Sangra, Vlachopoulos & Cabrera, 2012). However, the critical terminology issue here underpinning the investigation is that, depending on the type of eLearning, such implementation differences could have a dramatic impact on the costs associated with their delivery. Because this thesis focused on variations of distributed learning courses via the internet, these implementation differences did not receive significant attention in the analysis;

however, for examining eLearning variants and comparing them with the forms introduced in this thesis, further analysis and comparison would be required. Additionally, although the learning mediums were similar in this thesis, the variant delivery methods also have different considerations but were treated equally for this investigation. Although the difference in the eLearning implementation type can be abstracted for cost capture—the underlying primary objective of the thesis—for qualitative analysis of reasons for cost variance, further consideration of the difference between implementation types is required.

While the cost definitions and associated methods described in this thesis are based on pre-existing methods, the categorisation of costs within ingredients could also be subject to debate by researchers undertaking cost investigation studies. This issue provides further support for one of the principal findings of this investigation, that is, there is a need for standardisation of the components of cost derivation within studies to address this issue. In practice, without such standards, how researchers report costs can be too diverse, making comparison between subsequent case studies challenging.

5.3.3. Learning technology considerations

Similar to the terminology issues identified with variant eLearning types, different learning technologies have various implementation variances which can impact design, development, and delivery and their associated costs. The combination of these issues and pedagogical considerations are factors which are not explored in this thesis but merit further investigation. For example, there may be instances in which a more expensive form of learning is justified even within an eLearning context, and these design considerations merit analysis given the overall question of cost capture and possible cost-efficiency.

5.3.4. Other methodological issues

Limitations of mixed methods design

Combining research approaches taken from different disciplines has an inherent limitation because of the different theories and traditions employed by each approach. Each method's contrasting purpose was acknowledged throughout this thesis to mitigate this limitation, and this deficiency was offset by the strength produced by combining the methods.

Limitations of quantitative approach

The quantitative approach calculated costs and budget variances using horizontal budget analysis but did not analyse the offsetting or magnifying of variances, deal with forecasting, conduct a sensitivity analysis, or perform other financial planning and analysis methods. The design decision was made to concentrate on the qualitative interpretation of the cost variance, which could have been strengthened by further cost analysis. The study specifically and narrowly focused on cost calculation and variance because of the evidence gaps identified in the literature review (i.e. the lack of data on significant costs and associated factors impacting their definition).

Limitations of qualitative approach

All cases explored in this thesis involved variants of MOOC technologies. Their similarities (despite the different implementation contexts) may reduce the generalizability of the results. However, as each course followed the core principles of eLearning delivery, it could be argued that the system-specific implementation context is trivial and, in fact, represents eLearning accurately because of its significant impact on learners.

5.3.5. The value of case study research

Case study research can provide only a snapshot of activities observed in each case, and these cases may have limited applicability in other contexts. This weakness was mitigated through the use of construct validity, external validity, and reliability tests in each case. However, case study research has an inherent design limitation in the observation of the events under consideration; experimental methods deliver more rigorous test results (Yin, 2018). Additionally, the cases were opportunistic, as they involved eLearning projects available for investigation by the author's research unit.

5.3.6. Contextual factors

The author had a prior professional relationship with the course designers, which may bias the results. However, an examination of the findings and the suggested improvement points suggests that this possibility was well mitigated. The reliance on primary evidence for points of inquiry also helped mitigate potential bias.

5.3.7. Perspective of different stakeholders

There is a natural tension between the aims of educators, course designers, administrators, policy makers, and learners in the development of a course. This tension is first centred on identifying appropriate learning aims and objectives, with a view on who should ultimately drive that agenda and subsequently judge the way it is implemented. This perspective is further complicated in terms of the question of cost, as decisions of value can have a subsequent impact on learning delivery. This investigation did not explore these considerations, but future research could consider the needs of the different stakeholders and examine how their different perspectives impact the overall cost of course construction and delivery.

5.3.8. Learners' preferences

Learner preferences impact optimal considerations for their learning, and these variances are essential factors when designing and building learning interventions. These aspects of learner preferences were not considered in this investigation, and their associated impact on optimal cost delivery was not analysed. For example, some learners may prefer a blended learning structure, while some others may prefer a completely online course implementation, with the latter obtaining more significant potential cost savings over time. When considering a large learning population, the need to consider learner preferences will be vital, as one learning implementation solution will not address the variances in learning styles, and the associated need to have various options will need to be considered from a cost perspective.

5.4. Main practice and policy implications

5.4.1. Increasing transparency of costs involved in development and running of eLearning

eLearning in the form of distributed online courses provides an opportunity to engage a large audience and disseminate information, which could be critical in promoting awareness of crucial topics. The ability to reach vast audiences and engage them in course content enables the leveraging of content delivery efficiencies. The key challenges in the development of this learning are the associated planning required and the need to deal with course content delivery issues—significant upfront effort is required in the delivery of this course type. Potential project issues can have a dramatic impact on course implementation, thus altering the planned budget during course delivery and encouraging underreporting of actual costs. Factors accounting for the project management and associated cost tracking of this type of eLearning are necessary to accurately capture the costs associated with this learning content, and administrators should also work to encourage practices to ensure costs for eLearning are fully reported, even if these costs exceed allocations of resources, to ensure long-term sustainability of courses and accurate resource budgeting.

5.4.2. Better anticipation of costs incurred in delivery

eLearning presents an opportunity to create a scaled-up, multi-implementation construction of learning content, which can then be offered to a broad distribution of learners. The promise of this application within health professions education and the popularity of learning via mobile devices and browsers have led to a significant expansion of such course deployments. A common perception is that eLearning is more cost-effective than face-to-face instruction. This thesis' literature review on eLearning implementation found frequent

references to its cost-effectiveness or cost benefits. However, the lack of a standardised approach to capturing costs creates a need to further explore the relationship between costs and eLearning production (Atun et al., 2015). Research studies one and two demonstrated that the real costs of implementation exceeded the initial budget, leading to an underreporting of costs; this is a consistent feature of projects due to the challenges of creating an online course, which requires upfront effort and moderation before course delivery. Despite the development of costing capture models for the components and ingredients of educational interventions, the driver for these models has been the development of frameworks allowing for further economic evaluation of learning types. Further work is required on the foundational aspects of cost capture in the production of eLearning, to ensure that total costs are recorded and to thus capture the real costs of delivery.

5.4.3. Developing new paradigms of life-long learning requires investment

To achieve a course that will be relevant and reusable over time—especially within a context of continuous learning or 'life-long' learning where the learner is using variations of a course building on prior knowledge and skill to augment existing knowledge—executing a project within the allocated cost parameters requires a combination of skills that enable the team, process, and technology to deliver the project's requirements within a predicated framework. Research study three demonstrated that this is possible, despite a large programme implementation with a significant undertaking in resources and scope, combining a digital programme with a face-to-face residential course. The project achieved its planned cost schedule by optimising its project management, leveraging the strong relationships among its principals, and building on successful smaller-scale learning implementations developed in previous years. Such iterative and incremental course

planning could achieve similar results in the development of other eLearning programmes, by proceeding along these lines and combining the implications derived from the other cases studied in this research.

5.4.4. Combining research and education efforts: Learning analytics

Research in this investigation was primarily centred on the post-implementation analysis of eLearning to understand the relationship between course implementation and costs. As this study was presenting new methods for investigation, this could not be avoided, but further work could centre on real-time analysis of course development to impact the way the course is being developed. Real-time feedback to course designers on variance and adherence to budget could lead to better cost efficiency in course implementation.

The use of analytics to track learner activity, such as the Experience API (xAPI), could be employed to provide real-time feedback to course organisers on how learners are responding to the course. Feedback could allow for in-course adjustments and continuous improvement of further iterations of course implementations. The combination of pedagogical engagement to the course in the application and costing data could yield new data for consideration of course constructions.

5.4.5. A need for establishing an evidence base for different modalities, purposes, and implementation of eLearning

Once there is better evidence on the associated costs of developing eLearning and further foundation for comparison on ongoing implementations, the field will need to evolve to create evidence which is specific to different modalities, purposes, and implementation considerations of eLearning. Such evidence will be vital because these variables will lead to

differences in decision-making in planning and design and it will be necessary to treat each eLearning construct distinctively as opposed to providing an overarching principle to subsequent evaluation.

5.4.6. Unanswered questions and future research considerations

While this thesis has established the basis for future standards for costing of eLearning, there are still unanswered questions on the definition of an ongoing economic evaluation model, the best way to structure project management methods with eLearning design, and how to manage various stakeholder perceptions of cost. The outputs of this research, in addition to its strengths and limitations, suggest three possible areas for future research:

1. **Standards for costing in economic evaluations of eLearning**

   As revealed by the literature review, few economic evaluations of eLearning have been conducted, likely because educators focus on content delivery and educational impact rather than on creating cost data. This research has extended existing costing methods and demonstrated how its method can be applied to eLearning. Future researchers can use this approach to create consistent costing data, which could be subsequently benchmarked. Given the growing evidence base composed of eLearning cost data, this could also promote further research into various forms of economic evaluation and help create business cases for future investment in eLearning, should value be demonstrated. This would go a long way towards addressing the need to reduce training costs in health professions education.

2. **Integration of project management, instructional design methods, and costing**

   This research found that there are benefits to combining project management and instructional design methods. Further research on ways of combining existing

instructional design methods with project management methodologies and linking these methods with cost management approaches could help address the high investment costs of eLearning. While this research was centred on SPOCs, MOOCs, and a blended implementation of these courses, its findings are applicable to alternative instructional designs—including online master's degrees, small local eLearning implementation, and microlearning—because they encounter similar design issues. Further research into the specific implementation impacts of each instructional method and their relationships to course costs would refine our understanding of the issues involved in course development.

3. **Cost and value perceptions of students and educators**

   Future research could use the improved cost data gleaned from this thesis to examine perceptions concerning cost and value by comparing perspectives between students and educators.

5.5. Conclusion of the thesis

The eLearning literature frequently refers to the promise and opportunity of its cost-effectiveness in contrast to face-to-face instruction; however, the underlying data regarding the costs necessary for its delivery are not well understood. Determining the economic value of eLearning in contrast to that of other learning types requires standard means of calculating the costs of delivering these types of projects. Through a consistent management of the factors impacting the costs of course production, further research can be undertaken using standard economic evaluation methods to evaluate the advantages of using eLearning. This thesis analyses three distinct cases of eLearning, covering 6,128 applied health learners over three years, and provides a comprehensive summary of the issues affecting course production and development. The results provide researchers and course designers with methods for planning and evaluating eLearning implementation and offers lessons regarding budget planning to ensure that projects meet their objectives. The thesis presents an approach to capturing and structuring eLearning costing that addresses gaps in the relevant research. It extends existing cost calculation methods and provides a means of planning and subsequently analysing the cost performance of eLearning implementation. Moreover, it also provides a means of interpreting budget variances. Applying this approach in eLearning studies focused on cost and value can enable higher-quality forecasting and analyses of course delivery.

This work set out to investigate the costs associated with the production of eLearning and the factors influencing its production and deployment. The ingredients method for standard costing served as the mechanism for examining budgeting for eLearning implementation costs, while horizontal budget analysis highlighted issues that were qualitatively analysed

using TQM themes. This approach addressed the primary research question by creating a cost capture mechanism for eLearning implementation costs. The secondary research question was subsequently addressed through a qualitative investigation of budget variance. This work serves as a framework for future research due to the further applicability of the case study method used here to identify the costs and factors affecting adherence to the planning and execution of work plans and budgets. Further, it enables an understanding of the issues impacting cost planning in the design, development, and deployment of eLearning, and provides recommendations for controlling cost variance in eLearning projects.

The literature establishes that cost is a critical factor in the design and implementation of eLearning, which presents opportunities for scalability and cost-effectiveness relative to face-to-face instruction. While the importance of cost is understood, the literature also indicates that there is insufficient evidence to justify eLearning's reputation as the most cost-efficient learning type. The research community's views on the challenges of understanding eLearning costs were substantiated by this research, which identified the factors that contribute to cost underreporting in the development of eLearning. This research sought ways to identify these costs in order to create the basis for a repeatable cost capture method. By contrast, the more common research approach is to offer overall observations on eLearning courses without specifically exploring the issue of cost data capture; the issue of cost is broader than many of the other factors that are typically examined. This thesis proposes a need for sustained research focusing on the issue of cost calculation to enable further economic evaluation and provide further evidence to justify the use of eLearning in health professions education.

This thesis sought to provide researchers with methodological insights into cost management in eLearning evaluation and to help course designers and education policy makers establish frameworks for the economic evaluation of eLearning. Most course implementers limit costing to budgeting, disregarding the impact that costing has on the further allocation of resources or on sustainability. Education is often seen as a sunk cost of implementation, without consideration of the rate of resource consumption. Increasing eLearning adoption and use will require a stronger emphasis on costing methods to justify investments in these implementation types. This research provides such an emphasis. Integrating project management, instructional design, and budget management in a unified approach will enhance precision in the design and development of eLearning costing, while anchoring additional data points for future cost analysis between practitioners. Using the principles described in course development will enhance budget adherence and could have positive correlative effects on course quality.

This research hypothesised that costs in the development of eLearning are likely underreported and explored this proposition through research into practical eLearning implementation to understand the factors influencing resource use. This approach used existing cost capture methods, while extending them in the context of eLearning course design by providing common themes for the classification of eLearning costs that were applied to three eLearning cases. In doing so, this research created a repeatable data capture method that could enable further work seeking to standardise how costs are captured in eLearning development. In addition, it offers a systematic approach to costing in eLearning, which course designers and researchers could use to design and calculate the

costs of course production and deployment. The thesis thus addresses a knowledge gap by providing a standard means of cost data collection and interpretation.

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Appendices

Literature review: Full search strategy

Electronic database searches for peer-reviewed literature

1. PubMed

(((‘Costs and Cost Analysis’[Mesh] OR (‘cost-benefit analysis’[MeSH Terms] OR (‘cost-benefit’[All Fields] AND ‘analysis’[All Fields]) OR ‘cost-benefit analysis’[All Fields] OR (‘cost’[All Fields] AND ‘effectiveness’[All Fields]) OR ‘cost effectiveness’[All Fields])) OR (‘cost-benefit analysis’[MeSH Terms] OR (‘cost-benefit’[All Fields] AND ‘analysis’[All Fields]) OR ‘cost-benefit analysis’[All Fields] OR (‘economic’[All Fields] AND ‘evaluation’[All Fields]) OR ‘economic evaluation’[All Fields])) OR ((‘cost-benefit analysis’[MeSH Terms] OR (‘cost-benefit’[All Fields] AND ‘analysis’[All Fields]) OR ‘cost-benefit analysis’[All Fields] OR (‘cost’[All Fields] AND ‘benefit’[All Fields]) OR ‘cost benefit’[All Fields]) OR (economic evaluation[All Fields] OR economic evaluation,[All Fields] OR economic evaluations[All Fields] OR economic evaluations,[All Fields]) OR cost-utility[All Fields] OR (marginal analyses[All Fields] OR marginal analysis[All Fields]) OR ((‘economics’[Subheading] OR ‘economics’[All Fields] OR ‘cost’[All Fields] OR ‘costs and cost analysis’[MeSH Terms] OR (‘costs’[All Fields] AND ‘cost’[All Fields] AND ‘analysis’[All Fields]) OR ‘costs and cost analysis’[All Fields]) AND benefit$[All Fields]) OR ((‘costs and cost analysis’[MeSH Terms] OR (‘costs’[All Fields] AND ‘cost’[All Fields] AND ‘analysis’[All Fields]) OR ‘costs and cost analysis’[All Fields] OR ‘costs’[All Fields]) AND benefit$[All Fields]) OR (‘cost-benefit analysis’[MeSH Terms] OR (‘cost-benefit’[All Fields] AND ‘analysis’[All Fields]) OR ‘cost-benefit analysis’[All Fields] OR (‘cost’[All Fields] AND ‘effectiveness’[All Fields]) OR ‘cost

effectiveness'[All Fields]) OR ('costs and cost analysis'[MeSH Terms] OR ('costs'[All Fields] AND 'cost'[All Fields] AND 'analysis'[All Fields]) OR 'costs and cost analysis'[All Fields] OR ('cost'[All Fields] AND 'comparison'[All Fields]) OR 'cost comparison'[All Fields]) OR (cost analyses[All Fields] OR cost analysis[All Fields] OR cost analysis,[All Fields]) OR (costs analyses[All Fields] OR costs analysis[All Fields]) OR (action analyses[All Fields] OR action analysis[All Fields]) OR (action analyses[All Fields] OR action analysis[All Fields]) OR (('costs and cost analysis'[MeSH Terms] OR ('costs'[All Fields] AND 'cost'[All Fields] AND 'analysis'[All Fields]) OR 'costs and cost analysis'[All Fields] OR 'costs'[All Fields]) AND value[All Fields]) OR (('economics'[Subheading] OR 'economics'[All Fields] OR 'cost'[All Fields] OR 'costs and cost analysis'[MeSH Terms] OR ('costs'[All Fields] AND 'cost'[All Fields] AND 'analysis'[All Fields]) OR 'costs and cost analysis'[All Fields]) AND value[All Fields]) OR cost-feasibility[All Fields] OR cost-acceptability[All Fields] OR (willingness[All Fields] AND pay[All Fields]) OR breakeven[All Fields])) AND ((((web-based[All Fields] AND ('teaching'[MeSH Terms] OR 'teaching'[All Fields] OR 'instruction'[All Fields])) OR (online[All Fields] AND ('learning'[MeSH Terms] OR 'learning'[All Fields]))) OR (mobile[All Fields] AND ('learning'[MeSH Terms] OR 'learning'[All Fields]))) OR 'blended learning'[All Fields])

2. Scopus

((TITLE-ABS-KEY (cost-benefit)) OR (TITLE-ABS-KEY (Cost-utility)) OR (TITLE-ABS-KEY (marginal analys*)) OR (TITLE-ABS-KEY (cost and benefit$)) OR (TITLE-ABS-KEY (costs and benefit$)) OR (TITLE-ABS-KEY (cost-comparison$)) OR (TITLE-ABS-KEY (cost-analys*)) OR (TITLE-ABS-KEY (costs-analys*)) OR (TITLE-ABS-KEY (cost-minimi$ation analys*)) OR (TITLE-ABS-KEY (Costs and value)) OR (TITLE-ABS-KEY (Cost and value)) OR (TITLE-ABS-KEY (Cost-feasibility)) OR (TITLE-ABS-KEY (Cost-acceptability)) OR (TITLE-ABS-KEY (

Willingness to pay)) OR (TITLE-ABS-KEY (Breakeven)) OR (TITLE-ABS-KEY (economic evaluation)) OR (TITLE-ABS-KEY (cost-effectiveness))) AND ((TITLE-ABS-KEY ('blended learning')) OR (TITLE-ABS-KEY (elearning)) OR (TITLE-ABS-KEY ('mobile learning')) OR (TITLE-ABS-KEY ('online learning'))) AND ((TITLE-ABS-KEY (Health Profession$)) OR (TITLE-ABS-KEY (Physical Therap*)) OR (TITLE-ABS-KEY (Physiotherapy)) OR (TITLE-ABS-KEY (General Practitioner$)) OR (TITLE-ABS-KEY (Family practitioner$)) OR (TITLE-ABS-KEY (General Physician$)) OR (TITLE-ABS-KEY (General Physician$)) OR (TITLE-ABS-KEY (Hospitalist)) OR (TITLE-ABS-KEY (Surgeon$)) OR (TITLE-ABS-KEY (Occupational health)) OR (TITLE-ABS-KEY (Occupational therap*)) OR (TITLE-ABS-KEY (Physician$)) OR (TITLE-ABS-KEY (Chiropractic)) OR (TITLE-ABS-KEY (Dentist$)) OR (TITLE-ABS-KEY (Optometr*)) OR (TITLE-ABS-KEY (Orthopt*)) OR (TITLE-ABS-KEY (Pharma*)) OR (TITLE-ABS-KEY (Podiat*)) OR (TITLE-ABS-KEY (Psycholog*)) OR (TITLE-ABS-KEY (Serolog*)) OR (TITLE-ABS-KEY (dietitian)) OR (TITLE-ABS-KEY (Nutrition*)) OR (TITLE-ABS-KEY (Paramedic*)) OR (TITLE-ABS-KEY (Community health work$)))

3. ERIC

elearning or 'blended learning' or 'online learning' AND Health Profession$ OR Physical Therap* OR Physiotherapy OR General Practitioner$ OR Family practitioner$ OR General Physician$ OR Family Physician$ OR Hospitalist OR Surgeon$ OR Occupational health OR Occupational therap* OR Physician$ OR Chiropractic OR Dentist$ OR Optometr* OR Orthopt* OR Pharma* OR Podiat* OR Psycholog* OR Serolog* OR dietitian OR Nutrition* OR Paramedic* OR Community health work$ and cost

4. Web of Science

TOPIC: (Health Profession$) OR TOPIC: (Physical Therap*) OR TOPIC: (Physiotherapy) OR TOPIC: (General Practitioner$) OR TOPIC: (Family practitioner$) OR TOPIC: (General Physician$) OR TOPIC: (Family Physician$) OR TOPIC: (Hospitalist) OR TOPIC: (Surgeon$) OR TOPIC: (Occupational health) OR TOPIC: (Occupational therap*) OR TOPIC: (Physician$) OR TOPIC: (Chiropractic) OR TOPIC: (Dentist$) OR TOPIC: (Optometr*) OR TOPIC: (Orthopt*) OR TOPIC: (Pharma*) OR TOPIC: (Podiat*) OR TOPIC: (Psycholog*) OR TOPIC: (Serolog*) OR TOPIC: (dietitian) OR TOPIC: (Nutrition*) OR TOPIC: (Paramedic*) OR TOPIC: (Community health work$) Search language=English AND TOPIC: (cost-benefit) OR TOPIC: (Economic evaluation*) OR TOPIC: (Cost-utility) OR TOPIC: (marginal analys*) OR TOPIC: (cost and benefit$) OR TOPIC: (costs and benefit$) OR TOPIC: (Cost-effectiveness) OR TOPIC: (cost-comparison$) OR TOPIC: (cost-analys*) OR TOPIC: (costs-analys*) OR TOPIC: (cost-minimi$ation analys*) OR TOPIC: (cost-minimi$ation analys*) OR TOPIC: (Costs and value) OR TOPIC: (Cost and value) OR TOPIC: (Cost-feasibility) OR TOPIC: (Cost-acceptability) OR TOPIC: (Willingness to pay) OR Search language=English AND TOPIC: (blended learning) OR TOPIC: (online learning) OR TOPIC: (elearning) Search language=English

5. EMBASE, OVID, GLOBAL HEALTH, HMIC

(Health Profession$ or Physical Therap* or Physiotherapy or General Practitioner$ or Family practitioner$ or General Physician$ or Family Physician$ or Hospitalist or Surgeon$ or Occupational health or Occupational therap* or Physician$ or Chiropractic or Dentist$ or Optometr* or Orthopt*OR Pharma* or Podiat* or Psycholog* or Serolog* or dietitian or Nutrition* or Paramedic* or Community health work$).mp. [mp=tx, bt, ti, ab, ct, sh, hw, tn, ot, dm, mf, dv, kw, id, cc, nm, kf, px, rx, an, ui] and (((((((((cost-benefit or Economic

evaluation* or Cost-utility or marginal analys* or cost) and benefit$) or costs) and benefit$) or Cost-effectiveness or cost-comparison$ or cost-analys* or costs-analys* or cost-minimi$ation analys* or cost-minimi$ation analys* or Costs) and value) or Cost) and value) or Cost-feasibility or Cost-acceptability or Willingness to pay or Breakeven).mp. [mp=tx, bt, ti, ab, ct, sh, hw, tn, ot, dm, mf, dv, kw, id, cc, nm, kf, px, rx, an, ui] AND ('blended learning' or 'online learning' or elearning).mp. [mp=tx, bt, ti, ab, ct, sh, hw, tn, ot, dm, mf, dv, kw, id, cc, nm, kf, px, rx, an, ui]

6. PROSPERO

Limited advanced search capability on database. Used following terms: eLearning OR blended learning OR online learning AND cost* OR economic*

7. eLefant

Abstract contains cost* or Abstract contains economic* or Abstract contains marginal* or Abstract contains willingness* or Abstract contains break*

8. Results Screening

Abstract Contains trial OR Abstract Contains systematic* AND Abstract Contains online OR Abstract Contains blended OR Abstract Contains web AND Keywords contains education AND Any Field Contains cost*

Literature Review: Eligibility Stage Search Exclusions

Prefix	No	First Author	Year	Reason for Exclusion	Additional Comments
EXC	1	A Bussieres	2014	Not eLearning	
EXC	2	A Gardner	2018	Not eLearning	
EXC	3	A Greech	2018	No cost data	
EXC	4	A Huhn	2018	Not eLearning	
EXC	5	A Malfliet	2018	No cost data	Suggests analysing cost-effectiveness in further research
EXC	6	A Pourmand	2018	Not eLearning	
EXC	7	A Srivastava	2014	Not eLearning	
EXC	8	A Woolley	2013	Not eLearning	
EXC	9	Aggarwal	2009	No cost data	
EXC	10	Ashurst	2012	No cost data	Suggests that online methods may be more cost-effective but that this requires further study
EXC	11	B Fuehrlein	2016	Not eLearning	
EXC	12	B Naresh	2015	No cost data	
EXC	13	B Naresh	2015	No cost data	Indicates that cost is a driver but with no specific data points
EXC	14	B Yorkgitis	2017	Not eLearning	
EXC	15	Banks	2014	No cost data	Concluded that it was cost-effective, but with no associated results
EXC	16	Bateman	2012	No cost data	
EXC	17	Bellido	2011	No cost data	
EXC	18	Bitton	2014	No cost data	Cost stated as a driver, but with no associated results
EXC	19	Boling	2013	No cost data	

EXC	20	Bowie	2013	No cost data	Concluded that examination of cost–benefit requires further study
EXC	21	Buxton	2013	No cost data	
EXC	22	C Chan	2017	Not eLearning	
EXC	23	C Cunningham	2017	Not eLearning	
EXC	24	C Gay	2016	Not eLearning	
EXC	25	C Ho	2018	No cost data	Concluded that it could lead to lower cost implementation; however, included no data.
EXC	26	C Lehna	2014	No cost data	
EXC	27	C Tian	2014	No cost data	
EXC	28	C Tochel	2009	Not eLearning	
EXC	29	Chaiyachati	2014	Not eLearning	
EXC	30	Charman	2011	No cost data	
EXC	31	Chhabra	2013	No cost data	Concluded that eLearning is more cost-effective via reference and not experimental data
EXC	32	Claxton	2011	No cost data	Stated that cost-effective means are desirable
EXC	33	Colman-Brochu	2009	No cost data	Cost stated as a driver, but with no associated results
EXC	34	Cothran	2009	No cost data	Concluded that it could lead to lower cost implementation
EXC	35	D Andrew	2008	No cost data	Concluded that cost was a barrier to eLearning uptake
EXC	36	D Ettlin	2016	No cost data	Concluded that it could lead to lower cost implementation
EXC	37	D McLeod	2014	No cost data	
EXC	38	D Munafo	2016	Not eLearning	
EXC	39	D Peterson	2008	No cost data	
EXC	40	D Smith	2011	No cost data	
EXC	41	D White	2008	Not eLearning	
EXC	42	Danielson	2014	Not eLearning	

EXC	43	Davis	2014	No cost data	Cost stated as a driver, but with no associated results
EXC	44	Dinleyici	2013	Not eLearning	
EXC	45	Donald	2013	No cost data	
EXC	46	Dragovic	2014	No cost data	
EXC	47	E Dinleyici	2013	Not eLearning	
EXC	48	E Meinert	2018	No cost data	
EXC	49	E Murray	2015	Not eLearning	
EXC	50	E Schneider	2017	Not eLearning	
EXC	51	E Williamson	2018	Not eLearning	
EXC	52	E Willignendael	2005	Not eLearning	
EXC	53	Eng	2013	No cost data	
EXC	54	Eryilmaz	2013	No cost data	
EXC	55	F Bishop	2014	Not eLearning	
EXC	56	F Lobban	2017	No cost data	
EXC	57	F Pickard	2014	No cost data	
EXC	58	F Pradel	2008	Not eLearning	
EXC	59	Fontelo	2012	No cost data	Concluded that it could lead to lower cost implementation
EXC	60	G Currie	2014	Not eLearning	
EXC	61	G Perryer	2000	No cost data	
EXC	62	Graafland	2013	No cost data	
EXC	63	Grieff	2014	No cost data	
EXC	64	Grieff	2013	No cost data	
EXC	65	Guise	2012	No cost data	
EXC	66	Hibbert	2013	No cost data	Concluded that it could lead to lower cost implementation
EXC	67	Hu	2009	No cost data	Concluded that it was cost-effective, but with no associated results

EXC	68	Ilic	2015	No cost data	Concluded that further research on the cost-effectiveness of EBM teaching modalities is required
EXC	69	J Cote	2012	Not eLearning	
EXC	70	J Curtis	2007	Not eLearning	
EXC	71	J Eriksen	2018	Not eLearning	
EXC	72	J Fortney	2012	Not eLearning	
EXC	73	J Kibble	2011	No cost data	
EXC	74	J Mersereau	2013	Not eLearning	
EXC	75	J Pechacek	2015	Not eLearning	
EXC	76	J Place	2019	Limited cost data	
EXC	77	J Ruiz	2006	No cost data	Could be more cost-effective, but with no corresponding data
EXC	78	J Starren	2002	No cost data	
EXC	79	J Whiteman	2013	No cost data	
EXC	80	J Yang	2017	Not eLearning	
EXC	81	K Belogianni	2018	No cost data	Intended purpose of study was to introduce cost-effective learning, yet there is no cost analysis
EXC	82	K Calzone	2018	Not eLearning	
EXC	83	K Harrington	2012	Not eLearning	
EXC	84	K Hauer	2004	Not eLearning	
EXC	85	K Klein	2012	No cost data	
EXC	86	K long	2007	No cost data	
EXC	87	K Ly	2012	No cost data	
EXC	88	K Pfeiffer	2018	Not eLearning	
EXC	89	K Shen	2012	Not eLearning	
EXC	90	K Stuber	2005	Not eLearning	
EXC	91	Kaufmann	2013	No cost data	

EXC	92	Klein	2012	No cost data	Cost stated as a driver, but with no associated results
EXC	93	Klien	2012	No cost data	Cost stated as a driver, but with no associated results
EXC	94	L Leishman	2013	No cost data	
EXC	95	L Marsh	2015	No cost data	Could be more cost-effective, but with no corresponding data
EXC	96	L Moore	2017	No cost data	
EXC	97	L Yardley	2010	No cost data	
EXC	98	Lehna	2014	No cost data	
EXC	99	M Blumenschine	2018	Not eLearning	
EXC	100	M Brunette	2015	Not eLearning	
EXC	101	M Hertz	2008	No cost data	Could lead to lower cost implementation; however, no data included
EXC	102	M Li	2016	No cost data	
EXC	103	M Morgan	2014	No cost data	
EXC	104	M Price	2009	Not eLearning	
EXC	105	M Rasura	2014	Limited cost data	
EXC	106	M Tchou	2017	Not eLearning	
EXC	107	M Willis	2016	No cost data	
EXC	108	Manners	2013	No cost data	
EXC	109	Martin	2014	No cost data	
EXC	110	McLeod	2012	No cost data	
EXC	111	McVey	2013	No cost data	
EXC	112	Mittelman	2014	No cost data	Concluded that it could lead to low-cost implementation
EXC	113	Mobley	2011	No cost data	
EXC	114	Myers	2009	No cost data	Cost stated as a driver, but with no associated results
EXC	115	N Henrikson	2014	Not eLearning	

EXC	116	N Kohle	2015	No cost data	
EXC	117	N Milic	2016	No cost data	
EXC	118	N Rocha-Pereira	2015	No cost data	
EXC	119	O Simmons	2018	Not eLearning	
EXC	120	Okrainec	2010	No cost data	Concluded that it was cost-effective, but with no associated results
EXC	121	P Bowie	2013	Not eLearning	Concluded that the examination of cost–benefit requires further study
EXC	122	P Butow	2018	Not eLearning	
EXC	123	P Garcia	2009	No cost data	
EXC	124	P McDonald	2017	No cost data	
EXC	125	P Nambisan	2010	No cost data	
EXC	126	P Reynolds	2008	No cost data	
EXC	127	Parker	2010	No cost data	Cost stated as a driver, but with no associated results
EXC	128	Parker	2010	No cost data	Cost stated as a driver, but with no associated results
EXC	129	Patterson	2011	No cost data	
EXC	130	Phillippi	2010	No cost data	
EXC	131	Pinto	2008	No cost data	Could lead to lower cost implementation
EXC	132	Piorkowski	2013	No cost data	
EXC	133	Platz	2010	No cost data	Could lead to lower cost implementation
EXC	134	Pletcher	2011	No cost data	
EXC	135	R Carrick	2017	No cost data	Cost stated as a driver, but with no associated results
EXC	136	R Enserick	2014	Not eLearning	
EXC	137	R Hughes	2018	Not eLearning	
EXC	138	R Pettit	2017	Not eLearning	
EXC	139	R Tamler	2012	No cost data	
EXC	140	Rogers	2011	No cost data	

EXC	141	S Claudel	2018	Not eLearning	
EXC	142	S Cooper	2016	Not eLearning	
EXC	143	S Glegg	2016	No cost data	
EXC	144	S Jennings	2014	Not eLearning	
EXC	145	S Nobis	2018	Not eLearning	
EXC	146	S Shah	2012	Not eLearning	
EXC	147	S Sheridan	2013	Not eLearning	
EXC	148	Saker	2010	No cost data	
EXC	149	Scott	2013	No cost data	Cost stated as a driver, but with no associated results
EXC	150	Shaikh	2012	Limited cost data	Incomplete costing details
EXC	151	Stevenson	2011	No cost data	
EXC	152	Stewart	2010	No cost data	
EXC	153	Sung	2008	No cost data	Could lead to lower cost implementation
EXC	154	T Coughlan	2015	No cost data	Cost stated as a driver, but with no associated results
EXC	155	T Deliens	2016	Not eLearning	
EXC	156	T Hartranft	2017	Not eLearning	
EXC	157	T Krebs	1999	Limited cost data	Provided cost per learner but no details on how it was calculated. Indicated that online costs were lower than costs for face-to-face learning
EXC	158	T Luckett	2018	No cost data	Protocol with education secondary area of analysis without explicit details of cost analysis
EXC	159	T Pascual	2013	No cost data	
EXC	160	Trocky	2011	No cost data	Cost stated as a driver, but with no associated results
EXC	161	Walsh	2014	No cost data	
EXC	162	Wisner	2008	No cost data	Concluded that it was cost-effective, but with no associated results
EXC	163	Y AlJamal	2018	Not eLearning	

EXC	164	Y Erard	2018	Not eLearning	
EXC	165	Y Ramallo-Farina	2015	Not eLearning	
EXC	166	Y Sung	2008	No cost data	
EXC	167	Z Ma	2008	No cost data	
EXC	168	Z Pruitt	2017	Not eLearning	

Research study one: Case study protocol

Structure adopted from Yin (2018)

Section A. Overview of the Case Study

1. Mission and goals reflecting the interest of the case study's sponsor (if any) and audience
    a. The objective of the case study is to inform the way future costs would be budgeted in the development of online learning courses. The research forms a part of a broader investigation into the costs associated with the production of online learning courses; the main focus of this report was to collect primary evidence in the construction of these costs to allow for further research by comparing the results with other types of online learning implementation.
2. Case study questions and propositions
    a. Study question: How are the total costs for the production and delivery of a small private online course calculated? (See Table A below)
    b. Proposition: Actual and budgeted costs will vary in the production/delivery of this course type.

    The state of the literature indicates challenges in the capture of total costs to produce online learning, despite standard methods for cost calculation [8]. The reason for this variance is likely because the skills required to create instructional learning design and to capture costs are different and educators are not trained in cost accounting methods.
3. A theoretical framework for the case study; essential readings:
    a. The analytical framework for this investigation is based on cost analysis methods underpinning the education economic evaluation developed by Levin [15], which extends standard costing and variance analysis principles of activity-based costing [16–18]. Defining core costs is critical to performing further economic evaluations,

though it is important to note that the scope of this research is limited to cost identification (Table A) and not further economic analysis (e.g. cost-benefit analysis, cost-effectiveness analysis, cost-utility analysis, cost-feasibility analysis)

Table A Cost Categories and their Objectives

Cost Categories	Objectives
A. Concept and measurement of costs	1. Describe the concept of costs 2. Show the inadequacy of budgets for cost analysis 3. Present a methodology for measuring costs 4. Identify categories of cost ingredients 5. Describe sources of cost information
B. Placing values on ingredients	6. Describe the purpose and principles for determining the values of ingredients 7. Present methods for placing values on specific types of ingredients
C. Analysing costs	8. Summarise the application of the cost methodology with the use of a cost worksheet

	9. Show how to analyse the distribution of cost burdens among different stakeholders 10. Address cost estimation for multiyear projects 11. Illustrate the estimation of costs under uncertainty 12. Present different ways of using costs for decisions

4. Role of protocol in guiding the case study research
    a. The protocol was developed at the beginning of the study to demonstrate how costs would be captured and analysed in the study. This protocol, in addition to a protocol for qualitative and quantitative analysis of the learning effect [19], were drafted and submitted to peer review by the Imperial College Education Ethics Committee. The role of this protocol is to memorialise the intended methods, submit them to peer review to validate the research design, and serve as the framework for the investigation. Any deviations must be documented and submitted for review.

Section B. Data Collection Procedures

5. Key stakeholders
    - Research team: Team responsible for field work
        i. EM – Lead researcher
        ii. JE – Research assistant
        iii. CB – Research assistant
    - Course team: Team observed in the case study
        i. BS – Learning technologist

ii. MT – Business analyst

6. Data collection plan (covers the type of evidence to be expected including the roles of people to be interviewed, the events to be observed, and any documentation to be reviewed in the field)

    - Evidence to be expected

      Costs incurred in the production of the online course. This will be calculated using three different sources of data for the triangulation of results

    - Events to be observed

      While the course implementation will be observed and additional studies completed investigating the education effect, the scope of this study is centred on cost decision making, and the way production affected cost delivery. Therefore, the observation scope for this study will be focused on reported costs and the way these correlate data to time actuals.

    - Documentation to be reviewed

      The project budget, actual costs, and timesheets will be reviewed for this study. While there will be a review of the completed course and observation of the way the course uptake is completed, the latter shall be excluded from this study. A traceability log will be maintained in Excel linking the research questions to data sources and the study findings.

7. Expected preparation before fieldwork (identified specific information to be reviewed and issues to be covered before fieldwork)

    (1) Confirmation of the initial budget from the funder

    (2) Confirmation of appointment of course delivery team

    (3) Ethical approval

Section C. Protocol Questions

8. Study question: How are the total costs for the production and delivery of a small private online course calculated?
    - The costs shall be measured, ingredients captured and analysed to understand the factors affecting course production
    - Data shall be collected to support the cost analysis categories
    - The corresponding evidence will be used to summarise how cost capture practices can be improved

Section D. Tentative Outline for the Case Study Report

9. The audience for the report and stylistic preferences for communicating with the audience(s)
    - The case report will be presented as a manuscript for publication in a peer-reviewed journal. The audience will comprise academics with the intent to inform future practice for the development of online learning
10. Case Report Format
    - The case report will be structured as a standard research report, covering an Introduction/rationale, Methods, Results, Discussion, and Key Findings against the research question

Research study two: Case study protocol

Structure adopted from Yin (2018)

Section A. Overview of the Case Study

1. Mission and goals reflecting the interest of the sponsor of the case study (if any) and audience
    a. The objective of the case study is to inform how future costs would be budgeted in the development of online learning courses. The research forms part of a broader investigation into the costs associated with the production of online learning; the main focus of this report was to collect primary evidence in the construction of these costs to allow for further research comparing results with other online learning implementation types.
2. Case study questions and propositions
    a. Study question: How are the total costs for the production and delivery of a massive online course calculated? (See Table B below)
    b. Proposition: Actual and budgeted costs will vary in the production/delivery of this course type.

    The state of the literature indicates challenges in the capture of total costs to produce online learning, despite standard methods for cost calculation [8]. The reason for this variance is likely because the skills required to create robust instructional learning design and to capture costs are different, and educators are not trained in cost accounting methods.
3. A theoretical framework for the case study; essential readings
    a. The analytical framework for this investigation is based on cost analysis methods underpinning the education economic evaluation developed by Levin [15], which extends standard costing and variance analysis principles of activity-based costing

[16–18]. Defining core costs is critical to performing further economic evaluations (see table B below), though it is important to note that the scope of this research is limited to cost identification and not further economic analysis (e.g. cost-benefit analysis, cost-effectiveness analysis, cost-utility analysis, cost-feasibility analysis)

Table B Cost Categories and their Objectives

Cost Categories	Objectives
D. Concept and measurement of costs	4. Describe the concept of costs 5. Show the inadequacy of budgets for cost analysis 6. Present a methodology for measuring costs 7. Identify categories of cost ingredients 8. Describe sources of cost information
E. Placing values on ingredients	9. Describe the purpose and principles for determining the values of ingredients 10. Present methods for placing values on specific types of ingredients
F. Analysing costs	11. Summarise the application of cost methodology with the use of a cost worksheet

	12. Show how to analyse the distribution of cost burdens among different stakeholders 13. Address cost estimation for multiyear projects 14. Illustrate the estimation of costs under uncertainty 15. Present different ways of using costs for decisions

4. Role of protocol in guiding the case study research
    a. The protocol was developed at study commencement to demonstrate the way costs would be captured and analysed in the study. This protocol, in addition to a protocol for qualitative and quantitative analysis of learning effect [19], were drafted and submitted to peer review by the Imperial College Education Ethics Committee. The role of this protocol is to memorialise the intend methods, submit them to peer review to validate the research design, and serve as the framework for the investigation. Any deviations are to be documented and submitted for review.

Section B. Data Collection Procedures

5. Key stakeholders
    a. Research team: Team responsible for field work
        i. EM – Lead researcher
        ii. AA – Research assistant
    b. Course team: Team observed in the case study
        i. BS – Learning technologist
        ii. MT – Business analyst

6. Data collection plan (covers the type of evidence to be expected, including the roles of people to be interviewed, the events to be observed, and any documentation to be reviewed in the field)
    a. Evidence to be expected

       Costs incurred in the production of the online course. This will be calculated using three different data sources to provide triangulation of results
    b. Events to be observed

       While the course implementation will be observed and additional studies completed investigating the education effect, the scope of this study is centred on the cost decision making, and the way production affected cost delivery. Therefore, the observation scope for this study will focus on reported costs and the way these correlate data to time actuals.
    c. Documentation to be reviewed

       The project budget, actual costs, and timesheets will be reviewed for this study. While there will be a review of the completed course and observation of the way the course uptake is completed, the latter shall be excluded from this study. A traceability log will be maintained in Excel linking the research questions to data sources and the study findings.
7. Expected preparation before fieldwork (identified specific information to be reviewed and issues to be covered before fieldwork)
    (1) Confirmation of the initial budget from the funder
    (2) Confirmation of the appointment of the course delivery team
    (3) Ethical approval

Section C. Protocol Questions

8. Study question: How are the total costs for the production and delivery of a small private online course calculated?

a. The costs shall be measured and ingredients captured and analysed to understand the factors affecting course production
b. Data shall be collected to support the cost analysis categories
c. The corresponding evidence will be used to summarise ways cost capture practices could be improved

Section D. Tentative Outline for the Case Study Report

9. The audience for the report and stylistic preferences for communicating with the audience(s)
    a. The case report will be presented as a manuscript for publication in a peer-reviewed journal. The audience will comprise academics with the intent to inform future practice for the development of online learning
10. Case Report Format
    a. The case report will be structured as a standard research report, covering an Introduction/rationale, Methods, Results, Discussion, and Key Findings against a research question.

Research study three: Case study protocol

Structure adopted from Yin (2018)

Section A. Overview of the Case Study

1. Mission and goals reflecting the interest of the case study's sponsor (if any) and audience
    a. The objective of the case study is to inform the way future costs would be budgeted in the development of online learning. The research forms part of a broader investigation into the costs associated with the production of online learning; the main focus of this report was to collect primary evidence in the construction of these costs to allow for further research comparing results with other online learning implementation types.
2. Case study questions and propositions
    a. Study question: How are the total costs for the production and delivery of a massive online course calculated? (See Table C below)
    b. Proposition: Actual costs and budgeted costs will vary in the production/delivery of this course type.

    The state of the literature indicates challenges in the capture of total costs to produce online learning, despite standard methods for cost calculation [8]. The reason for this variance is likely because the skills required to create robust instructional learning design and to capture costs are different, and educators are not trained in cost accounting methods.
3. A theoretical framework for the case study essential readings
    a. The analytical framework for this investigation is based on cost analysis methods underpinning education economic evaluation developed by Levin [15], which extends standard costing and variance analysis principles of activity-based costing [16–18]. Defining core costs is critical to performing further economic evaluations,

though it is important to note that the scope of this research is limited to cost identification and not further economic analysis (e.g. cost-benefit analysis, cost-effectiveness analysis, cost-utility analysis, cost-feasibility analysis)

Table C Cost Categories and their Objectives

Cost Categories	Objectives
G. Concept and measurement of costs	4. Describe the concept of costs 5. Show the inadequacy of budgets for cost analysis 6. Present a methodology for measuring costs 7. Identify categories of cost ingredients 8. Describe sources of cost information
H. Placing values on ingredients	9. Describe the purpose and principles for determining the values of ingredients 10. Present methods for placing values on specific types of ingredients
I. Analysing costs	11. Summarise the application of cost methodology with the use of a cost worksheet

	12. Show how to analyse the distribution of cost burdens among different stakeholders 13. Address cost estimation for multiyear projects 14. Illustrate the estimation of costs under uncertainty 15. Present different ways of using costs for decisions

4. Role of protocol in guiding the case study research
    a. The protocol was developed at study commencement to demonstrate the way costs would be captured and analysed in the study. This protocol, in addition to a protocol for qualitative and quantitative analysis of learning effect [19], were drafted and submitted to peer review by the Imperial College Education Ethics Committee. The role of this protocol is to memorialise the intended methods, submit them to peer review to validate the research design, and serve as the framework for the investigation. Any deviations are to be documented and submitted for review.

Section B. Data Collection Procedures

5. Key stakeholders
    a. Research team: Team responsible for field work
        i. EM – Lead researcher
        ii. PS – Co-investigator
        iii. TS – Co-investigator
    b. Course team: Team observed in the case study
        i. KF – Research associate

ii. AA – Research assistant

iii. HC – Subject Matter Expert

iv. YE – Subject Matter Expert

v. MT – Business analyst

6. Data collection plan (covers the type of evidence to be expected, including the roles of people to be interviewed, the events to be observed, and any documentation to be reviewed in the field)

    a. Evidence to be expected

        Costs incurred in the production of the online course. This will be calculated using three different data sources to provide triangulation of results

    b. Events to be observed

        While the course implementation will be observed and additional studies completed investigating the education effect, the scope of this study is centred on the cost decision making, and the way production affected cost delivery. Therefore, the observation scope for this study will be focused on reported costs and the way these correlate data to time actuals.

    c. Documentation to be reviewed

        The project budget, actual costs, and timesheets will be reviewed for this study. While there will be a review of the completed course and observation of the way the course uptake is completed, the latter shall be excluded from this study. A traceability log will be maintained in Excel linking the research questions to data sources and the study findings.

7. Expected preparation before fieldwork (identified specific information to be reviewed and issues to be covered before fieldwork)

    (1) Confirmation of the initial budget from the funder

    (2) Confirmation of the appointment of the course delivery team

(3) Ethical approval

Section C. Protocol Questions

8. Study question: How are the total costs for the production and delivery of a small private online course calculated? (Table C above)
    a. The costs shall be measured and ingredients captured and analysed to understand the factors affecting course production
    b. Data shall be collected to support the cost analysis categories
    c. The corresponding evidence will be used to summarise ways cost capture practices could be improved

Section D. Tentative Outline for the Case Study Report

9. The audience for the report and stylistic preferences for communicating with the audience(s)
    a. The case report will be presented as a manuscript for publication in a peer-reviewed journal. The audience will be an academic audience with the intent to inform future practice for the development of online learning
10. Case Report Format
    a. The case report will be structured as a standard research report, covering an Introduction/rationale, Methods, Results, Discussion, and Key Findings against a research question.

Real-world evidence for postgraduate students and professionals in healthcare: Protocol for the design of a blended Massive Open Online Course

This protocol is included as an appendix because the course structure for the MOOC was used in case study three. The protocol describes the course's instructional design and the methods used in the analysis of the course impact. However, the evaluation aspects of the study focused on knowledge and skills assessment, which (though related) were outside the scope of this research.

BMJ Open

Real-world evidence for postgraduate students and professionals in healthcare: protocol for the design of a blended massive open online course

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To cite: Meinert E, Alturkistani A, Car J, *et al*. Real-world evidence for postgraduate students and professionals in healthcare: protocol for the design of a blended massive open online course. *BMJ Open* 2018;**8**:e025196. doi:10.1136/bmjopen-2018-025196

► Prepublication history for this paper is available online. To view these files please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2018-025196).

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Received 3 July 2018
Revised 10 July 2018
Accepted 12 July 2018

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ABSTRACT

Introduction There is an increased need for improving data science skills of healthcare professionals. Massive open online courses (MOOCs) provide the opportunity to train professionals in a sustainable and cost-effective way. We present a protocol for the design and development of a blended MOOC on real-world evidence (RWE) aimed at improving RWE data science skills. The primary objective is to provide the opportunity to understand the fundamentals of RWE data science and to implement methods for analysing RWD. The blended format of MOOC will combine the expertise of healthcare professionals joining the course online with the on-campus students. We expect learners to take skills taught in MOOC and use them to seek new employment or to explore entpreneurship activities in these domains.

Methods and analysis The proposed MOOC will be developed through a blended format using the Analysis, Design, Development, Implementation and Evaluation instructional design model and following the connectivist–heutagogical learning theories (as a hybrid MOOC). The target learners will include postgraduate students and professionals working in the health-related roles with interest in data science. An evaluation of MOOC will be performed to assess MOOCs success in meeting its intended outcomes and to improve future iterations of the course.

Ethics and dissemination The education course design protocol was approved by EIT Health (grant 18654) as part of the EIT Health CAMPUS Deferred Call for Innovative Education 2018. Results will be published in a peer-reviewed journal.

Strengths and limitations of this study

- ► The strengths of the blended massive open online course design is the use of pedagogical design based on the connectivist and heutagogical learning theories.
- ► Another strength is that the evaluation study of the course is embedded in the course design increasing the likelihood of a timely evaluation.
- ► Successful implementation and evaluation of the course will depend on learner recruitment and retention.

INTRODUCTION

Healthcare is becoming increasingly dependent on data analytics for improvement of care, efficiency and quality, and getting more value from resources.[1] However, the fast-growing data analysis field requires constant and up-to-date training in new skills.[2] There is a high demand for trained data scientists in healthcare,[1] as health is associated with challenges that can be solved by advanced data science methods with the potential to improve delivery of patient outcomes by increasing efficiency and effectiveness. For example, using big data methods on the vast quantity of real-world data (RWD) enables providers the ability to create predictive models which can help accurately identify risk of disease and improved and personalised preventive care for patients.[3] RWD includes the vast quantity of data that falls outside the boundaries of controlled clinical trials which can be used for: measuring healthcare resource-use and the burden of disease, evaluating prescribing patterns or clinical outcomes of a new medicine, describing current treatment patterns for a patient group for baseline information.[4] Real-world evidence (RWE), which is derived as a result of RWD, is starting to play a significant role in decision-making, and it is expected to grow in the future.[3]

Mentoring, team-based training and self-study are recognised as effective measures to train professionals in data analytical skills.[2] Massive open online courses (MOOCs), a form of web-based online learning, provide skills adoption opportunities through the provision of learning in an open, publicly available platform that is often free of charge on specialised topics.[5] MOOCs can increase the knowledge of professionals in a new topic[6]

and can help them gain new skills.[7] MOOCs have gained large popularity in different fields in the last 10 years,[8] but despite the availability of numerous MOOCs on data science, currently, there are very limited courses focusing on the topic of RWE. Also, there has been limited, but increasing use of MOOCs in a blended capacity and use of this project's proposed instructional design shall create the opportunity to observe how a MOOC can be managed in this capacity, considering the logic and structural issues incumbent in this format.[9]

Dealing with RWD can be daunting and challenging due to its volume, scale and the requirement to understand the source data and its collection in context. Researchers and healthcare professionals who want to use RWD need to learn new methodologies and frameworks which deviate from standard research methods. Although MOOCs provide an opportunity to train healthcare professional in data science skills, very limited number of MOOCs have touched on the topic of RWE. This MOOC will therefore create an educational programme that focuses on RWD data analysis methods and skills to improve healthcare delivery.

The proposed blended-MOOC will prepare future (postgraduate students) and current healthcare professionals with the required skills and knowledge to conduct and be part of RWE projects. Through the course, we aim to impact the learners' knowledge, skills and attitudes on the use of RWE data science in healthcare, as well as their communication and participation in networks of data science in healthcare. We also aim to inspire the use of RWE methods across various postgraduate curriculum disciplines, National Health Service (NHS) commissioning support organisations, healthcare regulation organisations and life sciences industries (ie, pharmaceuticals, biotechnology and medical devices). RWE MOOC was funded in April 2018. Planning preparation and planning for the course will begin in June 2018 with the identification of key themes and concepts to be translated into content. Course production will commence in June 2018, and the course will go live in December 2018. The course will be deployed on the Innoenergy X-KIC FutureLearn Platform. The impact and efficacy of this delivery model will be evaluated as a mixed-methods study; further details of the evaluation protocol are defined in a separate publication.[10]

We aim to bring the online learning component (MOOC) together with a face-to-face university level course, to enhance the learning experience and to challenge and enrich postgraduate-level course taught with traditional methods. This will allow diversifying knowledge delivery mediums and will enable university students to be exposed to a global community of learners. MOOC will allow learners the flexibility of amending the learning from any location, the advantage of meeting a large number of students outside their regular university classrooms and will meet EIT Health's call for 'massive dissemination' of innovative education ideas. A blended course will allow knowledge integration between the university students and the global learners joining MOOC from all over the world which can add richness and enhance the learning experience for all learners. The limited availability of courses on RWE, a topic that is gaining popularity in healthcare and the use of the latest advances in online education (blended MOOC), is what makes our proposed programme unique regarding the topic and educational strategies used.

METHODS AND ANALYSIS

MOOC overview

The project will deliver an education programme via a MOOC and a face-to-face course, to create a blended format for postgraduate students and professionals interested in the application of RWE data analysis and in furthering their knowledge base and skill-set to include conducting and commissioning RWD analysis. To help meet this goal, a key objective of MOOC is to establish a global network of people to continue and advance the dialogue on data science in healthcare. It is expected that MOOC will provide the opportunity to understand the fundamentals of RWE data science and to implement methods for analysing RWD.

MOOC development

The course will be organised from Imperial College's Global eHealth Unit, and course material will be filmed on Imperial College premises. The face-to-face component of the course will be offered at the University of Oxford. The course will be delivered in 5 weeks (five modules). However, the fifth module will only be offered to learners who sign up for certification. The course will be offered on specific dates and will be run for 5 weeks, and each module will be released on a weekly basis. Pilot implementation of the course will occur in 2018; partners will construct the core course programme, developing the face-to-face course and the complementary digital learning. Two face-to-face workshops will be held in the UK to pilot the blended course design. Scale-out will occur in 2019, face-to-face workshops will be held in France, Sweden, Spain and the UK, one per quarter. This will expand the reach of the programme and facilitate project development which will be done in conjunction with industry partners in each European Union region. Workshops will include industry partners focused on the design, development and implementation of RWE methods.

MOOC pedagogical design

Course design will be based on the hybrid connectivist–heutagogical learning theories. The connectivism theory emphasises the use of networking and communication to deliver the learning material, where interactions and discussions between learners can also contribute to the introduction of new knowledge.[11] Heutagogy principles emphasises creating competent learners through touching on 'learner autonomy and self-directedness'.[12]

To enhance the connectivist characteristics of course, the digital platform will be created in a way that can enable learners to create social networks and communicate with like-minded individuals. One of the objectives of the course is to establish a global network to continue and advance the dialogue on data science in healthcare. Attendance in a course with healthcare professionals from around the world will give the postgraduate students the opportunity to appreciate the role of data in real-life clinical settings and introduce them to methods and challenges faced in practical healthcare settings. At the same time, healthcare professionals joining the course will be able to communicate and engage with other professionals who will be possibly using data in a different healthcare setting; clinical or non-clinical. The heutagogical characteristics of the course will be enhanced, by allowing learners the flexibility to go through the course material in their own time and to move through the material according to their preference. This learning principle will also be enhanced by incorporating social media into the discussions,[12] and creating a course hashtag that can be accessed by learners for further discussion.

Teaching strategies

The course plan will be prepared following the Analysis, Design, Development, Implementation and Evaluation (ADDIE) model (instructional design model).[13] The ADDIE model provides a systematic, step-by-step framework to ensure the course is developed in a structured and comprehensive way.[14] To teach innovation, learners will be structured into teams to develop and implement a data science project. These initiatives will be RWE projects that will address current health problems. Our assessment strategies will include both formative (polls and peer-assessment) and summative assessments (multiple choice questions/module). We will offer an optional fee-based certificate for completion of MOOC and a separate project. The project will involve the proposal of an RWE data analysis methodology (using techniques learnt in the course) to solving a current healthcare problem. Learners will be engaged in collaborative exercises and reflective discussions with other learners where the 'teacher' will act as a facilitator and a contributor to the discussions. Each module will provide a list of required reading, recommended reading and RWE-related datasets and tools to allow learners to individualise their learning and explore other sources of knowledge.[15]

Target learners

The course will cater to two types of learners: current university-level students (postgraduate) and professionals in the healthcare field (eg, professionals working in healthcare, commissioners, policy-makers, healthcare regulators and those working in the life sciences) (1) who have some background knowledge of statistics in healthcare and/or (2) who carry out hands-on data analysis in their work or studies. The target audience will include postgraduate students in health-related fields with an interest in the use of RWD and RWE data science in healthcare and professionals working in NHS commissioning, healthcare regulation and life sciences. Selection parameters will be based on participant's occupation and statistical knowledge. Participants who are postgraduate students or professionals in healthcare fields, who have completed a basic university-level statistics course or who have professional experience in data analysis and research will be eligible to join MOOC. The required prerequisite is knowledge in basic statistics and understanding of statistical measures used in healthcare which is met if the learner completed a university-level basic statistics course or professionally works on data analysis.

Learning outcomes

The content from the course develops skills in the context of RWE, including frameworks for analysing and evaluating content (data) and subsequently, will encourage them to embark on healthcare RWE-related projects, innovation and entrepreneurship. To complete the course, learners will be structured into teams to develop and implement a data science project. These initiatives will be RWD projects that will address current healthcare problems. Completion of projects will be a form of learning into practice and will establish a foundation for further commercial activity or research. The proposed blended format will prepare future (postgraduate students) and current healthcare professionals with the required skills and knowledge to conduct and be part of RWE projects and will help develop them to the growing need of data-analysis skills in the healthcare field. Topics and key concepts will include principles of RWE in health, information governance for RWE, design, methodology and framework for RWE, and RWE exploratory analysis and evaluation.

One of the primary learning outcomes of the course will be the ability to apply an established RWE framework that ensures transparency and integrity around the collection, analysis and use of RWD. Other learning outcomes include: (1) to provide learners with formal knowledge of RWE, (2) to provide learners with experiences that expand on their existing knowledge of RWE, (3) to have learners determine how to learn about the evolving topic, (4) to have learners self-organise into social networks to develop knowledge and address situated problems, (5) to have learners collaborate to master the competencies required to solve RWD challenges. Each learning outcome will be delivered on a module basis.

Production

A pan-European collaboration has been established including Université Grenoble Alpes, Karolinska Institutet, Imperial College London and the University of Oxford. Video presentations will be made with partners and recorded and edited by the production team. Written pieces such as articles, case studies PowerPoint presentations, quizzes and assessment will be developed by the production team and partners prior to integration onto

the delivery platform. The face-to-face on-campus course will be developed and offered at the Medical Sciences Division at the University of Oxford. To evaluate the content before it is released, we will run a beta trial of MOOC with a sample of target learners.

Learner recruitment

We will develop a marketing campaign focused on social media and online advertising in order to recruit learners; also coordinating with the marketing of other courses. We will also cross-market to our database of 1000+ learners. Specifically, course promotion will involve a variety of methods to include (1) the institution's own website; (2) social media (eg, Facebook, Twitter, Google+, LinkedIn); (3) posting of articles via distance learning portals; (4) materials such as flyers, brochures, roll-ups and posters; (5) emails; (6) regular course newsletters. Providing the recruiting process on public platforms will ensure the process is clear, open and transparent. As a key element of the course will be connectivity between participants, learners will be encouraged to share knowledge, experience and ideas throughout the course by discussion forums and via social media. We will continue the same promotional activities during the course delivery and to actively encourage partition, newsletter and course social media hashtag will be available during and 1 year is the course.

Problems anticipated

To create a feasible work plan, potential risks and contingencies were identified in the following areas:

Instructional design:

Key risks: On-boarding of new staff.

Contingency: Imperial College is contributing existing staff familiar with this form of course design.

Learning management system design:

Key risks: Requesting functionality not possible from the learning management system.

Contingency: Will mitigate risk through early engagement with faculty and planning in advance.

The beta trial of course:

Key risks: Non-availability of test students.

Contingency: Will incentivise beta participant learners.

Live implementation of course:

Key risks: Student recruitment and marketing.

Contingency: Will market the course from the beginning of the year to ensure high student enrolment numbers.

Evaluation:

Key risks: Ethical considerations in the evaluation.

Contingency: Will seek ethical approval of the evaluation process.

MOOC outcomes

Success for this course will be maintaining an active cohort of learners who will engage in continued discussion on these topics (eg, via social media), where we also establish a basis for possible collaborations on future initiatives. The short-term impact of the course includes enabling participants to join networks of data science in healthcare and engaging and educating participants on the basic skills needed to conduct RWE projects in their work or studies. The long-term impact includes enabling participants to maintain their presence in networks of data science in healthcare and enabling participants to conduct RWE projects in their work and contribute to the improvement of healthcare through the use of data and evidence-based approaches.

We expect learners to take skills taught in MOOC and use them to seek new employment or start to initiatives in these domains. Learners will be able to start new RWE initiatives as a result of the practical RWE projects they will complete in MOOC. Learners will submit a project using an RWE framework taught in MOOC that will be peer assessed. To make sure that projects are assessed properly, a rubric with clearly defined guidelines and reviewing criteria will be provided. The course coordinator will also facilitate these exercises. The successful completion of the RWE project (both submitting a project and peer assessing the project) will give learners the basic skills to carry out an RWE project.

Evaluation

MOOC evaluation is a significant practice to assess its value and effectiveness.[16] To evaluate the course's impact, we will complete an evaluation on a participant level to measure the MOOC training effects over me. We plan to prepare the evaluation findings in the form of a report that can be shared with our partners.To ensure evaluation results are shared and used for the improvement of future projects, a report summarising the research findings of our MOOC evaluation will be published in a peer-reviewed journal. Findings shall also be disseminated at an international conference.

During the course launch, we will use the Experience API (xAPI) to track all learning activities taking place in the course. This software tracks and records all learning activities with the learning management system and will be used to assist to provide real-time feedback to the course organisers on how learners are responding to the course. Moreover, pre-MOOC and post-MOOC survey data will be captured to evaluate learner's satisfaction with the course, and whether it met their expectations. Course metrics such as retention on the course, number of participants in discussion posts, number of participants in the course's social media posts and the number of learners who completed the RWE projects will all be used as indicators for course impact.

Other postproject monitoring will be conducted with learners from MOOC via two interviews, the first 1 month after the course, the second, 3 months postcourse. We are aiming to recruit 16 participants for interviews and if more than 16 agree to an interview, we will include participants who represent as wide a range of data science backgrounds and levels of MOOC completion as possible. We

have targeted 16 learners because based on the literature,[17] a study size of 16 is appropriate for collection of qualitative data and for providing sufficient insight into the questions studied. However, should there be a need for further exploration of phenomena under study (and themes and findings which emerge), we will attempt to continue interviewing participants until saturation is reached on the most important themes relating primarily to the course's effectiveness.

A mixed-methods approach will be used to analyse these outcomes, incorporating precourse and postcourse survey results, semistructured interviews of a subset of the learners and social media network analysis. The evaluation's main focus will be learners' application of the practical skills gained through MOOC in their workplace using Kirkpatrick evaluation method and will be conducted on selected learners a year postimplementation.[18] The Kirkpatrick evaluation is a methodology that evaluates the success of training courses, and it is a suitable choice for evaluating the success of the proposed MOOC since MOOC's aim is to teach hands-on skills in RWE data analysis.[18] In addition, course metrics such as retention on the course, number of learners who completed the RWE projects will all be used as indicators of course outcomes achievement.

Patient and public involvement

Members of the public were informed the development of research questions and study objectives via a workshop held at the European Scientific Institute in July 2017.

Sustainability

We plan to sustain the course and course updates via internal funding following this investment round and sustaining the course through course certification fees.

ETHICS AND DISSEMINATION

Ethics approval for this study was obtained from Imperial College London through the Education Ethics Review Process (EERP) (EERP1617-030). A report summarising the research findings will be published in a peer-reviewed journal. A presentation will be given to a selected audience of health professionals and academics, to include individuals from Imperial College. Findings will also be presented at an international conference.

Acknowledgements This work was also supported by the Sir David Cooksey Fellowship in Healthcare Translation, the Oxford Academic Health Sciences Centre and the SENS Research Foundation.

Contributors EM conceived the study and drafted the manuscript. AA revised the manuscript, structured it to journal requirements and made amendments based on feedback from EM. JC contributed to the protocol design and provided feedback on the manuscript iterations. AC and GW revised iterations of the prepublication protocol and provided feedback for amendment. DB revised all versions, structured the project work-plan with EM and provided methods feedback. All authors read/edited the first and second drafts and approved the final manuscript. EM responded to all external peer review comments. EM is the guarantor. All authors read and approved the final manuscript.

Funding This work was funded by EIT Health (Grant 18654).

Competing interests None declared.

Patient consent Not required.

Ethics approval Ethics approval for this study was obtained from Imperial College London through the Education Ethics Review Process (EERP) (EERP1617-030) and the grant approved via EIT Health CAMPUS Deferred Call for Innovative Education 2018.

Provenance and peer review Not commissioned; peer reviewed for ethical and funding approval prior to submission.

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Protocol for a mixed-methods evaluation of a MOOC on real world evidence

This protocol is included as an appendix because the approach it used for qualitative data interpretation was also used in this investigation. The peer-review process enhanced the qualitative methods used in this thesis by ensuring that bias and other factors that could have influenced the results were managed.

BMJ Open

Protocol for a mixed-methods evaluation of a massive open online course on real world evidence

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To cite: Meinert E, Alturkistani A, Brindley D, *et al*. Protocol for a mixed-methods evaluation of a massive open online course on real world evidence. *BMJ Open* 2018;**8**:e025188. doi:10.1136/bmjopen-2018-025188

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2018-025188).

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Received 3 July 2018
Revised 19 July 2018
Accepted 20 July 2018

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ABSTRACT

Introduction Increasing number of Massive Open Online Courses (MOOCs) are being used to train learners at scale in various healthcare-related skills. However, many challenges in course delivery require further understanding, for example, factors exploring the reasons for high MOOC dropout rates, recorded low social interaction between learners and the lack of understanding of the impact of a course facilitators' presence in course engagement. There is a need to generate further evidence to explore these detriments to MOOC course delivery to enable enhanced course learning design. The proposed mixed-methods evaluation of the MOOC was determined based on the MOOC's aims and objectives and the methodological approaches used to evaluate this type of a course. The MOOC evaluation will help appraise the effectiveness of the MOOC in delivering its intended objectives. This protocol aims to describe the design of a study evaluating learners knowledge, skills and attitudes in a MOOCs about data science for healthcare.

Methods and analysis Study participants will be recruited from learners who have registered for the MOOC. On registration, learners will be given an opportunity to opt into the study and complete informed consent. Following completion of the course, study participants will be contacted to complete semistructured interviews. Interviews will be transcribed and coded using thematic analysis, with data analysed using two evaluation models: (1) the reach, effectiveness, adoption, implementation, maintenance framework and the (2) Kirkpatrick model drawing data from pre and post-course surveys and post-MOOC semi-structured interviews. The primary goal of the evaluation is to appraise participants' knowledge, skills and attitude after taking the MOOC.

Ethics and dissemination Ethics approval for this study was obtained from Imperial College London through the Education Ethics Review Process (EERP) (EERP1617-030). A summary of the research findings will be reported through a peer-reviewed journal and will be presented at an international conference.

Strengths and limitations of this study

- ► One strength of the study is the use of qualitative data from semistructured interviews triangulated via evidence experiences to validate reported activity.
- ► A limitation of the study is the course evaluation may be affected by factors other than the course that may be difficult to identify.
- ► The evaluation of the course is dependent on participant study recruitment via the course.

INTRODUCTION

Although research about Massive Open Online Courses (MOOCs) have been increasing with their continued and increased popularity, there remain gaps in understanding on how to achieve similar course impact as compared with face-to-face instruction.[1] There is a need for evidence on MOOCs to determine how to resolve numerous challenges that impede MOOC uptake and completion.[2] The factors impacting MOOCs delivery can be summarised as (1) low-course completion rates (less than 10%) relative to the number of learners who sign up,[3] with more recent evaluation of the literature (2017) revealing that high dropout rates remain a challenge for most MOOCs.[1] (2) Lack of social interaction between learners raises concerns about the open and diverse environments that MOOCs generally should offer.[4] (3) Not understanding how the role an educator or facilitator in a MOOC plays in promoting interaction and networking for learners.[5] Further research on how a MOOC can address these issues is needed to facilitate more effective MOOC course design in the future.

Evaluating MOOCs to test their effectiveness is essential for the effective delivery of learning and for appraising its performance. This study will use a mixed methods combining the reach, effectiveness, adoption, implementation, maintenance (RE-AIM) framework and the Kirkpatrick evaluation models to evaluate learners' acquisition of learning and skills post-MOOC and their attitudes towards the course. This evaluation will be of value to all stakeholders involved including the learning institution that

developed the course (Imperial College and the University of Oxford), other researchers and learners. The value of the outcomes of the research is understanding how successful the MOOC was to achieving impact to justify further continuing the MOOC and enhancing delivery. Gathering first-hand information on how participants valued the MOOC, their reasons for undertaking the MOOC, and the perceived impact it has had on their studies, working environment or professional practice, is key in understanding if the MOOC had an impact on participants and is justified for further investment. The value for other researchers will stem from the addition to the literature about MOOCs and MOOC evaluations. The value to students result from the evaluation being used to improve the redesign of the current MOOC and potential improvement of other MOOCs in general based on the insights from this study.

Increased use of data analytics can significantly improve quality and value of health services through increased efficiency and effectiveness.[6] For example, the use of aggregate population level data collection, as implemented in Real World Data (RWD) approaches, could contribute to advancing capabilities in personalising care, through adjustments in interventions based on real-time analysis of patient responses[7] and could develop predictive capabilities that can help identify patients at higher risk and contribute to adverse events.[8] For organisations to receive the full benefits of data analytics, there is a growing demand for training staff in data analysis and 'to equip managers and employees with relevant professional competencies.'[8] MOOCs have been successful in delivering new skills. For example, a MOOC on antimicrobial stewardship in low-income and middle-income countries reported that 49% of the participants interviewed 6 months after the MOOC (n=409) have assured that they have implemented the interventions learnt from the MOOC in their practice.[9] In addition, a randomised controlled trial found that both MOOCs and a self-paced online educational module were useful in training physiotherapists about spinal cord injuries and increasing their confidence about administering therapy to patients.[10] MOOCs are seen as a suitable method for delivering continuing education in improving their patient care.[11]

This study examines a MOOC centred on Real World Evidence (RWE). The objective of the MOOC is to introduce learners to data analysis methods and techniques of RWE. The MOOC aims to raise awareness of the potential impact RWD data science methods can have on medicine. To evaluate the success of achieving the MOOCs objectives, this study will evaluate the MOOC's 'reach' of its intended audience and social networks, 'efficacy' regarding the knowledge/skill gain and attrition, adoption and sustainability of social networks for continual learning in this emerging field; further details of the course instructional design are defined in a separate publication.[12] The evaluation is conducted not only to contribute to the current literature, but also to enable evidence to support future iterations of the course to increase its impact.

Research question

The primary research question of the evaluation is: How has the course impacted learners' knowledge, skills and attitudes on the use of data science in healthcare?

The secondary questions of the evaluation include the following:

- What evidence is there that the intended target audience was reached?
- What evidence is there that the MOOC has made a difference to participants in their work or studies
- What evidence is there of participant networks for data science in healthcare being adopted during the MOOC?
- What evidence is there that the MOOC format and materials engaged participants?
- What evidence is there of participant networks for data science in healthcare being sustained post-MOOC?

METHODS AND ANALYSIS

Study participants will be recruited from learners who have registered for the MOOC. On registration to the course, learners will be given an opportunity to opt into the study, receiving a participant information sheet (online Supplementary appendix 1). Study participants will also be recruited via email (online Supplementary appendix 2). Should learners wish to participate, they will sign an informed consent form (online Supplementary appendix 3). Following completion of the course, study participants will be contacted to schedule interviews. A researcher holding postgraduate level training in qualitative research methods (via Imperial College's Master of Public Health and/or Doctorate training programme in Clinical Medicine Research) will hold semistructured interviews with the study participant (online Supplementary appendix 4).

Study design

This study will apply two evaluation methods to investigate the impact of the MOOC. The RE-AIM framework will be used to evaluate the reach, delivery (implementation) and sustainability (maintenance) of the MOOC with efficacy and adoption examined by the Kirkpatrick model. The Kirkpatrick evaluation will follow the four levels of assessment: reaction, learning, behaviour and results,[13] where a particular focus will be given to determine if participants were able to increase their learning through the course, if they were able to apply the skills learnt in the course in their study/workplace (adoption) and if through attending the MOOC they were able to influence their broader community (efficacy). The RE-AIM framework will be used for evaluation of reach at the participant level. We will examine total recruitment on the course and compare their characteristics to eligibility criteria, demographic information and other measures. Facilitators and barriers to individual patient

recruitment and suggestions for improvement will be identified through interviews with the research team. Evaluation of the implementation will be done at participant level via a post-course survey (for graded feedback on course delivery to include materials, content, layout and format, etc) and post-course interviews to discuss perceptions of participants in greater depth. Maintenance will be evaluated at participant level to measure the continuation of MOOC effects over time. This will be conducted via a post-course interview, held 3 months post-course to identifyspecific examples and evidence to substantiate participants views/claims. To evaluate impact further, the Kirkpatrick evaluation model shall be used. For Level 1 (Reaction), the survey material completed pre-course and post-course will be captured. For learners who did not complete immediate post-course surveys, this will be noted, but reflections of the course will be captured in the interview (for recording purposes). For Level 2 (learning), the learning record from the MOOC shall be used. For Level 3 (behaviour), the semistructured interviews will investigate the impact of the MOOC on multiple factors of professional behaviour. For Level 4 (results), through aggregation and coding of the interview results, the research team will analyse the overall impact of the results on training.[13] The Kirkpatrick model was selected for evaluating the MOOC due to it being directed towards evaluating training programmes designed for professional development training,[13] and since this MOOC was designed to influence learners' skills and behaviour, this was seen as a suitable model. Also, the model is commonly used for MOOC evaluations as other studies have reported using the Kirkpatrick model in their evaluation methodologies.[14–16]

Participants

All learners who participated in the MOOC for any length of time will be recruited for the study. Participants recruited will differ due to the diversity of participants joining a MOOC in general. Possible differences will be in the level of data science knowledge and MOOC completion. We will try to reflect this diversity in the participants recruited for the study, by categorising participants and aggregating their results in their response group classification (eg, undergraduates in data science who completed the post-course survey). An additional high-level classification is all learners who (1) completed the pre-course survey, (2) completed the post course survey, and (3) completed the certificate track (further categories shall be analysed depending on respondents). The exclusion criteria shall exclude learners who are employed by Imperial College London or are known by the researchers, therefore addressing possible power issues.

Recruitment

The participants in this MOOC self-select by registering for the course and participants in this study will be drawn from this pool. All those who have participated in the course will be approached, to prevent participation bias. The learners will be contacted by the research team to participate in the interviews. To avoid conflicts, the exclusion criteria have been designed to avoid any power of coercion from the participants. All learners will be contacted via email twice for participation over a 2-week period. This method is consistent with previous contact methods during the course and was selected to be non-intrusive to learners.

Sample size

We are aiming to recruit 16 learners to the study. We predict that interviews from 16 learners will generate enough data for answering the research questions and fall within the scope of effort allocated for this investigation; additionally, the recent literature suggests that this amount of thematic data will be sufficient for qualitative analysis.[17] However, if there is a need for further investigation of further phenomena or themes, additional participantswill be interviewed until saturation is reached for all the key themes concerning the study objectives.

Data collection

Pre-course and post-course surveys

Pre-course and post-course surveys are surveys that are administered online and that are accessible to all learners who have participated in the MOOC. The surveys capture the learners' general reaction to the course. Pre-course surveys include questions about reasons for taking the course, preferred learning methods and current knowledge of the topic being taught. The post-course survey gives the learners a chance to provide graded feedback on course delivery to include feedback on the materials provided, the content of the course, and the design of the MOOC (layout and format). The delivery of the post-course survey will be segmented cross-sectionally by learner groups identified from course trends (eg, those who completed the course, those who only participated in part of the course, those who registered but did not complete a significant portion of the course). Survey results will be structured on a Likert scale, using a Kruskal-Wallis test to identify comparison of data between groups. Logistic regression analysis will determine statistically significant results among groups. Reporting structure for the surveys are described in a strengthening the reporting of observational studies (STROBE) statement,[18] which is detailed in online Supplementary appendix 5.

Semistructured interviews

Interviews are scheduled to take place between 30 and 60 min (maximum). The interviews will be executed at greater than 3 months than the course execution to allow for analysis of the impact of the course has had on behaviour. Interviews will be conducted through Skype and telephone conference calls because course participants are distributed globally, and this is the most accessible means of interviewing participants.[19] All interviews will be recorded. The reason semistructured interviewing is being used is to investigate further what factors could

impact behaviour that is not fully understood at this stage in the study. This will also allow for aggregation of responses and the ability to allow further examination of learners' perspectives on the research question categories. 16 learners will take approximately 160 hours of transcription/analysis to complete with a planned effort of 5 weeks. Interview recordings will be transcribed by an internal third party (an Imperial College staff member trained in transcription) and given to study participants for review for accuracy. Reporting structure for the interviews are reported in the consolidated criterion for reporting qualitative research (COREQ) Statement,[20] which is detailed in the online Supplementary appendix 6.

Study ethics

Anonymisation via a unique ID will be created to protect confidentiality. The primary key between unique ID and participant shall be securely held on a secured drive at Imperial College. Only the research administrators will have access to correlate information to respondents (via a primary key) which will be stored on a secured drive at Imperial College. The reason the primary key is being maintained is in the event of participant wishes to withdraw their data from the study; should a request be received all of their corresponding data and files shall be destroyed. Only the research administrators shall have access to this file. The British Educational Research Association guidelines[21] have been followed for standards in voluntary informed consent. All participants will receive an information sheet with adequate reading time, and all participants will be asked to sign a written informed consent explaining that all participants have the right to withdraw and remove their data should they decide to even after the interview has been completed. To reimburse participants for their time in participating in the interviews, three response participants will be randomly selected to receive a 40-pound voucher from amazon.co.uk . This study will not include children, vulnerable young people or vulnerable adults. If there are problems raised during the study, this will be escalated to the Head of the Department who will act following discussion with the PI.

Data analysis

Data analysis will be performed using thematic analysis methods and then evaluate the responses based on the RE-AIM framework and Kirkpatrick evaluation models. The RE-AIM framework has been utilised because of its recognition to identify adoption trends,[22] while the Kirkpatrick method will form a data set for triangulation. Coding of responses will be completed by an independent review of transcripts (by two members of staff) to ensure consistency in analysis.

Patient and public involvement

Members of the public informed the development of research questions and study objectives via a workshop held at the European Scientific Institute in July 2017. Learners participating in this study shall complete informed consent (online Supplementary appendix 3) and shall receive a copy of results and publications from this work (online Supplementary appendix 1).

ETHICS AND DISSEMINATION

Ethics approval for this study was obtained from Imperial College London through the Education Ethics Review Process (EERP) (EERP1617-030). A report summarising the research findings will be published in a peer-reviewed journal. A presentation will be given to a selected audience of health professionals and academics, to include individuals from Imperial College. Findings will also be presented at an international conference.

Contributors EM conceived the evaluation objectives and methods. AA and EM drafted the design and development of the protocol; completed the first draft of the manuscript and incorporated and addressed the feedback from the authors. DB, AC, GW and JC reviewed the second draft. EM responded to all external peer review comments. All authors read and approved the final manuscript. All authors completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf. There are no relevant conflicts of interest, financial or other types of relationships that may influence the manuscript declared by authors. Authors do not have any patents and are not associated to any conditions or circumstances that may lead to conflicts of interest.

Funding This work was funded by EIT Health (Grant 18654). This work was also supported by the Sir David Cooksey Fellowship in Healthcare Translation, the Oxford Academic Health Sciences Centre and the SENS Research Foundation.

Competing interests None declared.

Patient consent Not required.

Ethics approval Ethics approval for this study was obtained from Imperial College London through the Education Ethics Review Process (EERP) (EERP1617-030).

Provenance and peer review Not commissioned; peer reviewed for ethical and funding approval prior to submission.

Data sharing statement We shall make data available to the scientific community with as few restrictions as feasible while retaining exclusive use until the publication of major outputs. Requests for anonymised data can be made by contacting the corresponding author.

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The acceptability of MOOC certificates in the workplace

This paper is included as an appendix because it provides an overview of the use of MOOCs as a form of validation in the learning of key job-related skills, indicating the importance of this form of educational intervention in continuing professional development.

THE ACCEPTABILITY OF MOOC CERTIFICATES IN THE WORKPLACE

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ABSTRACT

Massive open online courses (MOOCs) are being undertaken by hundreds of thousands of participants globally. Reasons for taking these courses vary, such as improving employment prospects, especially in the technology sector, though the impact of these certificates has not been established. Factors identified as barriers to the acceptance of these certifications include user verification issues and a lack of familiarity of MOOC content. There are positive signs in employers recommending MOOCs for training purposes and a major MOOC platform collaborating with companies to provide a work placement scheme. The discussion regarding the value of traditional and online education also applies, as employers are seeking candidates who are technically skilled and ready for work, which is not guaranteed by a traditional degree certificate. This review provides a baseline collation of current opinion and research. Independent qualitative research and further literature review should be conducted to build an evidence base regarding the use of MOOCs and their certificates.

KEYWORDS

MOOC, Employment, Online Education, Certificate

1. INTRODUCTION

Since their inception in 2008, massive open online courses (MOOCs) have proliferated to become a major feature of the online education field. A variety of MOOCs are available, from those which attract tens of thousands of participants worldwide, to courses which are built to train a specific cohort. While some individuals undertake MOOCs out of personal interest, others intend to enhance their employability through gaining certification for completed courses. Although the completion rate of MOOCs is low (generally <10%), increasing numbers are finishing and achieving completion certificates (Jordan, 2014). This raises the question of how these courses and certificates will be received by potential employers, and how they will be viewed in comparison to education obtained through more traditional methods. It is important to compare the factors standing for and against the recognition of these courses in the employment process as part of the movement towards developing standards to be used by recruiters. To date this is a subject not comprehensively addressed in the literature, and this paper sought to review information published or posted regarding the subject thus far, and describe and discuss the points arising.

2. DISCUSSION

There are multiple discussion points concerning the use of MOOCs and their certificates for employment purposes. A central issue is that of the credibility of courses and certificates, and whether or not these can be taken seriously by employers (Krumrie, 2014, Ossiannilsson, 2014). Currently, MOOC providers are developing further methods of verification to reduce the likelihood of fraud or plagiarism by participants in both coursework and assessment, a problem which hinders trust in certificates (Boeckh, 2014). The use of webcams, keystroke analysis, valid photo identification and in-person test centres is being explored by the major MOOC providers in order to definitively verify the identity of participants and confirm that they have completed the work submitted in their name (Boeckh, 2014). At present these efforts are not infallible and

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require refinement, though employers may choose to test prospective employees on relevant material in order to show up anyone who has falsely claimed to have completed a certain course, and it may be easy to identify these individuals during standard job interviews.

If the credibility of the MOOCs is deemed acceptable then the process of verifying the educational component of the MOOC certificate is crucial if it is to be meaningful to potential employers (Krumrie, 2014). A means of quantifying the knowledge given in courses is required so that the level of education attained is clear to those reading CVs, similar to the widely known qualifications of formal education. Moves towards awarding university credit to MOOCs began in 2013, and have continued in countries across the world. Students in many universities who complete MOOCs, (in most cases) purchase the end of course certification, and have their identity verified, can add the course to their university transcript (Haynie, 2015). This move by academia sets a positive precedent for the recognition of MOOCs in other sectors.

The notion of interpreting MOOCs on CVs is still novel and there are no established standards to aid recruiters in discerning the value of these courses or their impact on the candidate (Krumrie, 2014). Therefore, receptiveness may predominantly be a case of whether the recruiter is familiar with MOOCs and their terminology. Also, due to the novelty, companies may not have had the chance to hire or monitor employees who have previously completed MOOCs, a barrier which may potentially be solved in time. In a 2014 study of North Carolina based human resource professionals, it was found that only 31% had heard of MOOCs, consistent with the general public, though this increased to 50% for respondents from educational organisations. Interviewees who had heard of MOOCs stated they had researched these because of either management enquiries about using them to save costs within the company or through other employees who were undertaking MOOCs, rather than as part of updated recruitment guidelines (Radford et al., 2014). Coursera co-founder Daphne Koller stated in an interview in 2015 that this study showed that a significant uptake of MOOCs by employers was beginning (Koller, 2015).

While increasing numbers of businesses are looking to MOOCs and online education to reinforce or build workforce knowledge and skills, this hasn't translated into them being fully acceptable for recruiting purposes (Ng, 2016). They are seen by some as being a tool to further professional development in their workforce rather than justify the hiring of an individual (Ossiannilsson, 2014). Nevertheless, the use of MOOCs by employers is a positive step, and they are being utilised by companies recommending that employees undertake a certain MOOC available freely on online platforms, or larger institutions such as the NHS which are developing courses to target a particular element which they have identified as requiring improvement (NHS Improving Quality, 2015).

The value of traditional education when hiring is being brought into question, adding another dimension to the discussion on online education (Ma, 2015, Ng, 2016). Some employers, such as Ernst and Young, are blinding recruiters to the details of candidate's university education, and more non-graduates than ever are being hired at Google for jobs which would typically require a degree elsewhere (Andersen, 2014). It is being found that graduates are not leaving university with technical skills which are directly applicable to the working environment – meaning that employees must undergo further training before they are competent to work independently anyway. A recruiter polled by the Success Communications Group noted that a person with online certification usually uses this method as they are balancing full time work alongside their studies and may therefore have more real-world job experience which is attractive to employers, as well as demonstrating their time management skills (Larson, 2013). This being said, the traditional degree and where it was achieved are still the more valued commodities among employers in general, with the element of interpersonal and leadership skills which are developed during the course of degree programmes being as important as entry technical skill level in many settings (Larson, 2013). However, looking to the future, the recruitment environment is changing and the need for any certificates at all may diminish (Winkler, 2014).

This is particularly true in the technology sector, in which a feature of growing importance in recruitment is a practical demonstration of the candidate's abilities, rather than a piece of certification (O'Connor, 2013). The use of portfolios or coursework allows recruiters to see physical evidence of what the applicant is capable of, rather than a certificate of their expertise in a general broad subject (Belleflamme and Jacqmin, 2015, Ng, 2016, Kirsner, 2013, O'Connor, 2013). It was suggested that MOOCs could play a role in this due to the continuous collection of data from students over the duration of the course in order to build a profile of participants which may be of interest to prospective employers (Belleflamme and Jacqmin, 2015). This data and the end products of practical and projects can give a clear picture of what a participant can produce and the manner in which they go about this. However, as mentioned before the reliability of this is subject to increased measures of user verification. Also, with online platforms such as GitHub and Dribble also acting

as repositories for portfolios, MOOCs must strive to offer that bit more to students (Ng, 2016). The equivalent in traditional education is the large scale final year dissertation or thesis which gives a comprehensive overview of the student's skills and standard of work; this has the additional benefit of being supervised by Professors or lecturers who can provide trusted references for job applications.

Branching out from issuing certificates to participants, an Open Education Alliance has been launched by the MOOC provider platform Udacity in cooperation with employers such as Google, AT&T, Intuit and Autodesk (Thomas, 2014). These sectors are working in partnership to equip students with the technological skills required to work for these companies, with a view to potentially hiring Udacity "graduates" (Belkin and Porter, 2013, Thomas, 2014, Ng, 2016). This is a promising avenue for MOOC providers to prove the employability of their students, and demonstrates a show of faith from industry.

It is important to consider the participant perspective on what they have gained from MOOCs in terms of employment prospects. A 2015 survey of Coursera MOOC finishers found that 72% of the 51,954 respondents reported having gained career benefits from participating, and 52% had undertaken courses with a primary aim of improving their career. Of those aiming to develop their career, a third reported a tangible benefit of partaking in MOOCs, from finding a new job or receiving a promotion as a result. An even higher percentage, 85%, stated they had received less quantifiable benefits such as enhancing their skills for a current job or improving their candidacy for a new job (Zhenghao et al., 2015). The longer time lag between tangible benefits being seen compared to more abstract benefits may mean that the number of MOOC participants achieving pay increases or new jobs could still increase over time. Although this survey was conducted by Coursera's own staff, there is a clear demonstration that many of those who complete MOOCs are able to use these qualifications or certifications to advance their career.

What is for certain is that freely choosing to partake in a MOOC demonstrates the participant's interest and passion for a subject above and beyond the norm. Courses delivered through online platforms by the likes of MIT, Harvard and Stanford are not easy to pass, and with completion rates of MOOCs generally below 10%, finishing the course and receiving the certificate shows perseverance and dedication, though this fact may not be widely known (Zheng et al., 2015). For a student to go out of their way and complete multiple courses shows them to be motivated, creative, entrepreneurial, and self-starters, traits which are key for success in the technology sector and attractive in others (Ng, 2016, Zheng et al., 2015).

3. CONCLUSION

Currently, the acceptance of MOOCs for employment purposes is warming up but is still not a mainstream phenomenon. Pushes by major MOOC providers to increase uptake of these courses by employers through work placement schemes and academic recognition are reaping benefits, and these efforts should be continued until recruiters can fully recognise their worth on a CV, though provider platforms must address issues with validity. The greater deal of flexibility in MOOC provision compared to traditional education allows providers to observe and adapt to contemporary trends. Besides the surveys published, this review relied heavily on online editorials and opinion pieces due to the lack of peer-reviewed literature. As yet, the majority of hype surrounding MOOCs is generated by those with a vested interest in the courses, so the general consensus of opinion on these courses is not immediately clear through literature and online article review and it would be useful to conduct independent interviews with companies and recruitment agencies. This paper provides a collation of current opinion and provides the baseline for future research. The long term impacts of MOOC participation on prospective employees are yet to be fully understood, however positive moves towards the acceptance and recognition of MOOC achievements are being made by industry.

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Determining the effectiveness of a Massive Open Online Course for Health

This paper is included as an appendix because it implements the qualitative thematic data analysis used in this thesis. The paper was focused on learning impacts, however, which was outside the scope of the thesis.

DETERMINING THE EFFECTIVENESS OF A MASSIVE OPEN ONLINE COURSE IN DATA SCIENCE FOR HEALTH

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ABSTRACT

Massive Open Online Courses (MOOCs) are widely used to deliver specialized education and training in different fields. Determining the effectiveness of these courses is an integral part of delivering comprehensive, high-quality learning. This study is an evaluation of a MOOC offered by Imperial College London in collaboration with Health iQ called, Data Science Essentials: Real World Evidence. The paper analyzes the reported learning outcomes, attitudes and behaviours of students after completing the MOOC. The study used mixed-methods, drawing from a Kirkpatrick evaluation-using data from semi-structured interviews transcribed and analyzed through Braun and Clark's method for thematic coding. 191 learners joined the MOOC. Two participants who completed at least 75% of the course were interviewed for the course evaluation. The findings of the analysis suggest that the course attracted target learners and learners found its application and engagement methods effective. Learners found the training provided by the MOOC to be helpful and with the potential to be applied in their work environment in the future and identified some work-related barriers that prevent knowledge application. Networking during and post-MOOC was identified as an area that needs improvement and development in the future. Findings derived from this evaluation support the fact that generally, MOOCs can improve learning and knowledge attainment in practical skills-based knowledge. One implication of this study is to inform factors that engage learners in the design and implementation of MOOC. The findings have shown that factors that affect the learners' engagement are the availability of lecture videos, self-assessment tools and high networking and communication between learners. In terms of knowledge application, support and availability of the right resources are essential because learners are not able to apply learning in their workplace if the workplace lacked the right resources and support. Developers of MOOCs for continuing professional development should take into consideration work-related barriers when designing their MOOCs.

KEYWORDS

Massive Open Online Course (MOOC), e-learning, Qualitative analysis, Continuing professional development (CPD)

1. INTRODUCTION

Evaluating Massive Open Online Courses (MOOCs) can help appraise their effectiveness and improve utilization (Chapman et al., 2016). There is a need for more evidence analyzing the impact of MOOCs on learners' knowledge, skills and attitudes (Khalil, 2014). Although some studies have found that MOOCs have the potential to foster student autonomy and create learning communities conducive to the learning process (Goldie, 2016), other research suggests significant issues in MOOC efficacy particularly due to factors including 1) Dropout rates; on average less than 10% of learners who signup actually make it to course completion (Khalil, 2014), 2) Social connections between learners not being a universal occurrence, raising questions about openness and diversity, 3) The need for the "social presence" of course facilitators to not only stimulate but maintain active learner participation (Goldie, 2016). More evidence is required to better understand how MOOCs can be used to address these factors to encourage higher rates of engagement.

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The MOOC: Data Science Essentials: Real World Evidence (RWE) was offered by Imperial College and Health IQ through the online learning platform: GOMO and was designed by Imperial College. The MOOC lasted for five weeks and was offered twice. The 4-weeks course was available for free to all learners and the fifth week of the MOOC was exclusively available to participants who signed up for certification. To investigate the success of the MOOC in reaching its aim, this evaluation was conducted to better understand what impact the course had on further use of the skills taught in the course.

- Primary research question:
  - How has the course impacted the learners' knowledge, skills and attitudes on the use of data science in healthcare?
- Primary research question:
  - What evidence is there that the intended target audience was reached?
  - What evidence is there that the MOOC has made a difference to participants in their work or studies?
  - What evidence is there of participant networks for data science in healthcare being adopted during the MOOC?
  - What evidence is there that the MOOC format and materials engaged participants?
  - What evidence is there of participant networks for data science in healthcare being sustained post MOOC?

1.1 About the MOOC

There is an increased demand for increasing healthcare professionals' training and skills in data science and use of Information and Communication Technologies (ICT) (Gallagher, 2015). MOOCs are being used to teach professionals in the healthcare field new skills (Hossain et al., 2015) and can be used for continued professional development for healthcare professionals. Despite data analysis opportunities in healthcare, which can improve its effectiveness and efficiency, this is an area that requires continuous skill development because of the rapid changes of methods and data sources available. Using population-level big data, collected through the various activities that occur in a healthcare system can make it possible to create models that can predict disease, enable better preventive measures and create more personalised care for patients (Raghupathi and Raghupathi, 2014). This MOOC aimed to introduce students the impact data science can have on medicine and inspire the application of these methods across various undergraduate curriculum disciplines, NHS commissioning support organisations, healthcare regulation organisations and life sciences industries (Imperial College London, 2017). The MOOC was offered twice, in August and in October, with each MOOC lasting for five weeks. A total of 191 learners have joined both MOOCs, 135 of them from the August cohort and 56 of them from the October cohort. 11 learning outcomes were formulated to meet the aims of the MOOC (Table 1).

Table 1. MOOC learning outcomes

Order	Learning Outcome
1	Acquire knowledge in the fundamentals of Real World Evidence (RWE) to include definition and background, current RWE trends and themes, benefits and limitations of RWE, and its place today in organisations dealing in patient care/data.
2	Acquire knowledge of information governance requirements and policy with regard to patient data as well as knowledge of key datasets that RWE can exploit across primary and secondary care (HES/CPRD).
3	Understand the difference between what Real World is and what is not.
4	Understand the essential theory of using RWE with data science, and key differences between using RWE with and without data science.

5	Understand the different data investigation tasks and the most appropriate algorithms for selecting/addressing them.
6	Identify and apply appropriate data analytic techniques to a problem using an RWE framework (decision tree) further to practical group sessions thereby demonstrating an understanding of knowledge gained.
7	Carry out exploratory analysis of Real World Data (RWD) (structured data).
8	Evaluate RWD, models or algorithms for accuracy in order to make an informed decision with regard to their use.
9	Conceptualise a [data mining solution] to a practical problem through teamwork and collaboration.
10	Critique the results of a [data mining] exercise and the pitfalls of analysing RWD.
11	Develop hypotheses based on the analysis of the results obtained and test them.

2. METHODS

The Kirkpatrick Model was used to evaluate the effectiveness of training to impact professional practice (Kirkpatrick and Kirkpatrick, 2006). The model assesses training through four levels. Level 1 Reaction; assesses participants' response to the training. Level 2 Learning; assesses participants learning from training. Level 3 Behaviour; assesses participants' use of training in their job and Level 4 Results; evaluates the impact of training on the organization. The reason that the Kirkpatrick model was selected as an evaluation model was due to its suitability for supporting professional development training and its approach to measuring behaviour following a three to six month time interval post training. As sufficient time had passed to investigate these outcomes, this model was well suited. To address the four levels of the Kirkpatrick evaluation method, data were collected from participants who joined and participated in the MOOC. All participants who were registered in the MOOC were recruited to be interviewed for the evaluation. 7 participants volunteered to be interviewed, 5 who subsequently declined or did not respond to interview invitations. The remaining two participants participated in the one-on-one semi-structured interviews. The participants interviewed for this study were employed adults, one male and one female. Only one participant was a part-time postgraduate student studying a healthcare related topic at the time of the interview. Both participants worked in the healthcare field and used data science in their work. One participant had a MOOC completion rate of 100% while the other had a completion rate of 75%. Data from the two participants were evaluated using thematic analysis and Kirkpatrick evaluation methods. Interviews were conducted through conference calls. Questions about each level of the Kirkpatrick evaluation were incorporated into the interview questions. Kirkpatrick evaluation was completed for each interview data separately, and results from both analyses were concluded in a single report and summarized in this evaluation.

2.1 Data Collection

Data for the evaluation was collected through semi-structured interviews. The interview questions included questions about learners' background, reasons for joining the MOOC, their use of the information in their workplace, participant's interaction with other learners and what participants liked or disliked about the MOOC.

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2.2 Data Analysis

Interview recordings were transcribed and anonymized. Thematic analysis was performed using Braun and Clarke's framework for thematic data analysis. Thematic analysis method allowed for aggregation of responses and provided the ability to perform an in-depth investigation of learner perspectives on the question categories and research questions. This analysis was performed through 6 steps: familiarisation with data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing a report (Clarke and Braun, 2013). After defining and naming the themes, a thematic map was formulated to review themes and show the relationships between them (Daley, 2004). The Kirkpatrick evaluation followed thematic analysis to enhance analysis reliability by using more than one method for data analysis (Patton, 1999).

3. RESULTS

3.1 Thematic Analysis Results

Thematic analysis of the interview data gave rise to three main themes 'learner background', 'MOOC learning' and 'MOOC' features (Figure 1). Themes were formulated inductively using interview excerpts. In this section, in-depth results for each theme are discussed using supporting interview quotes.

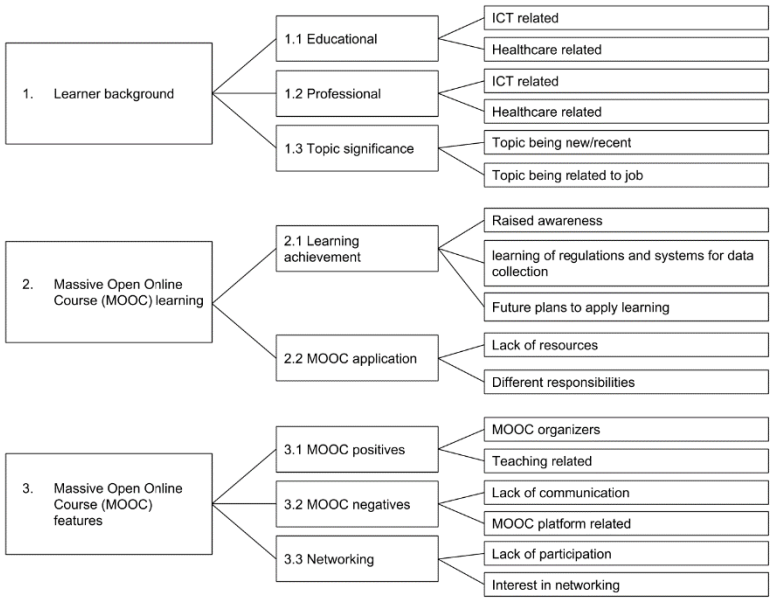

Figure 1. Figure showing themes, sub-themes and codes that resulted from the thematic analysis of the interview data

3.1.1 Theme 1: Learner Background

The learner background theme (Figure 1) represented participants' educational and professional experience showing that both participants worked in the healthcare sector and were involved with data analysis. The codes ICT related and healthcare related (Figure 1) represented learners educational and professional backgrounds that were relevant to the topic of the MOOC: data science skills for healthcare. Both participants were exposed to data analysis through their educational and professional backgrounds. For example, one participant was studying Masters in Economic Evaluation in Healthcare and the other had completed Masters in Biostatistics. Moreover, both participants were involved in healthcare-related jobs. The topic significance subtheme was created to represent participants' interest in the topic of the MOOC. It was made clear that participants joined the MOOC for its relevance to their jobs, and for improving job-related skills: "The reason I joined this course is because I anticipated that having, being equipped with this knowledge put me in a better position within my job" (Participant 1).

3.1.2 Theme 2: MOOC Learning

The MOOC learning theme (Figure 1) represented participants gained learning and application of the learning in their workplace. The raised awareness subtheme was concluded from participants' comments about having better awareness after the MOOC: "it definitely made me more conscious..." (Participant 1) and "There are many many sources of datasets I didn't know they existed" (Participant 2). In terms of knowledge application, both participants strongly believed that they would be using the knowledge in the future and both mentioned work-related barriers that prevented them from applying learning from the MOOC. For example, one participant mentioned the lack of data sources as a barrier for using the skills learned through the MOOC: "currently in my current role, we, unfortunately, don't have data source, but we are planning to discover and to develop some, but I should be, I am assigned to do this, but we did not start yet" (Participant 2). Learning of regulations and systems for data collection subtheme was created because these were key topics delivered through the course, and both participants have demonstrated that they have learned them thoroughly from the MOOC. One participant has explained this by emphasizing the importance of disseminating the data properly to be as representative of the original data as possible: "is important to maintain the, well to improve the data integrity as much as possible during the data collection, because data collection is such a laborious process and there is a high chance that if you don't implement the right systems, that you're going to get messing the data because people who are collecting the data, don't know what you need or they are not properly trained, so I do feel like it did help me" (Participant 1). The other participant has emphasized the importance of the systems explained through the course for data collection and analysis: "actually and just it puts the whole process into perspective, in a system, like now I know that there is a system existing for payroll data and pharmaceutical academic collaboration." (Participant 2). Despite not being able to apply learning from the MOOC in their workplace, both participants were confident the learning will be put to use in the future. For instance, one participant mentioned that the resources they learned about in the course will be of great use in the future: "I'm sure I will get back to them one day" (Participant 2). Also, the same participant has added about the regulations taught in the MOOC: "...I believe, they will give, they are a very good example of the existing regulations, and also different resources and sources of datasets, I believe this will be very helpful" (Participant 2).

3.1.3 Theme 3: MOOC Features

The MOOC features theme (Figure 1) represented the positives and negatives participants mentioned about the MOOC. In terms of positives, participants liked the videos and assessments provided throughout the course: "The videos were the most engaging. I like both. I like the videos and the articles, but the videos were more engaging for me. They are easier to follow maybe" (Participant 2) "I like the questions throughout the lesson because it does test you, whether you're actually concentrating or flicking through the MOOC. Yeah, I definitely appreciate that part. yeah, because you didn't have to pay for that even if, you wanted to do it, it was just like a final assessment that you didn't have to pay for. yeah, it just tested to see whether you were concentrating" (Participant 1). In terms of MOOC negatives, lack of communication and inactivity in the course's social media page was seen as a negative, because both participants were looking to communicate with other learners. Other negatives mentioned were about MOOC platform features such as pausing videos, or downloading videos for offline viewing, both features that were not available, and seen as a shortfall by participants. Networking is an important part of most MOOCs (Liyanagunawardena, Adams and Williams,

2013). Networking was an important part of this MOOC as well, for a social media page was created to increase socializing and networking among participants. Course coordinators posted questions on the social media page to encourage discussions and joining of networks of health science between learners. However, through the evaluation interviews, it was discovered that there was a lack of participation and networking through the social media page of the course. Participants attributed this to the social media page being inactive and lacking participation from other learners: " when I first started the course, I think it was like the first two weeks, so I looked at the hashtag, which encourages conversation on Twitter, but I did notice that there wasn't that much going on, I guess because there were so few people actually speaking or having a conversation about those topics, that I ended up not going forward with joining in the conversation to say and just based on looking at the weekly hashtag, well not the weekly hashtag, the hashtag in general," (Participant 1). "Unfortunately not, I tried to follow at the beginning the hashtag of the course on Twitter, but I didn't find it very active, so I didn't follow up after the first week. I just viewed what are the topics of discussion, but they were not very active. So I didn't initiate any conversations." (Participant 2). Despite not being able to actively network through the MOOC, both participants have demonstrated that they would have preferred an increased networking opportunity, which was represented in the code: interest in networking.

3.2 Kirkpatrick Evaluation Results

The evaluation levels: reaction, learning, behaviour and results were all analyzed using the data from the semi-structured interviews.

3.2.1 Level 1 Evaluation – Reaction

This level tests participants' perception of the course and answers questions such as; did participants enjoy the course, did they find it useful, and what materials did they find most engaging? Participants' reaction to the course was generally positive. There was a consensus on the course being unique, for offering learning in a brand new topic; RWE, and for being offered by Imperial College; a renowned institute according to participants. Participants found the course videos, assessment to be the most engaging, and appreciate that the course content was up-to-date with the latest research, Participants reacted negatively to the course platform's technical issues and for the lack of communication and networking during and after the course.

3.2.2 Level 2 Evaluation – Learning

This level tests participants' gained learning from the course, which can be in the form of "advancement" in skills, knowledge or attitude (Ayub, Wei and Yue, 2017). Participants demonstrated that they have gained learning from the course by discussing the key topics learned and explaining what they understood. For instance, they talked about information governance, Real World Data, data sources and frameworks for data analysis. These discussions demonstrated that participants have gained knowledge from the course evidenced by their ability to talk about and discuss the course content and topics.

3.2.3 Level 3 Evaluation – Behavior

In terms of behaviour, both participants believed that the course offered knowledge in practical skills they can use in real life. However, both explained that this was not possible yet due to lack of resources or support in their workplace.

3.2.4 Level 4 Evaluation – Results

The course description of the MOOC mentions that the aim of the course is to help students "develop new methods for data analysis" to "inform decision-making in healthcare" (Imperial College London, 2017). Therefore, the most accurate evaluation of the results would have been to evaluate whether the course has affected decision-making in participants' workplace. However, due to the short time period between the course end date and the evaluation interviews, it was not possible to report such results. Nevertheless, overall reaction to the course indicates that these results are likely to be seen in the future.

4. CONCLUSION

This study adds to the current literature on MOOCs developed for counting professional development. The findings acknowledge that in general, MOOCs can improve learning and knowledge attainment in practical skills-based knowledge. One of the implications of this study is to inform factors that engage learners in the design and implementation of MOOC. The findings have shown that factors that affect the learners' engagement are availability of lecture videos, self-assessment tools and high networking and communication between learners. In terms of knowledge application, support and availability of the right resources in the workplace are essential because learners are not able to apply learning in their workplace if lacking the right resources and support. Developers of MOOCs for continuing professional development should take into consideration work-related barriers when designing their MOOCs.

Participants reported increased learning and being introduced to new topics and resources as a result of joining the MOOC. Previous evaluations of MOOCs have reported very positive results in terms of learning. One study comparing learning outcomes from a MOOC to a traditional university classroom, reported better learning outcomes among MOOC students (Colvin et al., 2014). Positive learning outcomes as a result of joining a MOOC was also reported for teaching practical skills to healthcare professionals as a randomized trial found that a MOOC was sufficient to teach and train physical therapists about spinal cord injuries (Hossain et al., 2015).

Three features were identified as essential features that participants liked in the MOOC; availability of lecture videos, self-assessments and increased networking and communication between participants. While the former two characteristics were available in the current MOOC, the last characteristic was a feature participants criticized for not being delivered effectively. Networking as part of a MOOC is a very important feature as it can increase the number of students joining the MOOC (Liyanagunawardena, Adams and Williams, 2013), and can increase learner satisfaction (Hossain et al., 2015). Therefore, increased effort is needed to increase networking opportunities for learners in the MOOC and to encourage more participation in discussion posts, and making sure that participants return to the posts and continue to actively join discussions.

In terms of applying skills in the workplace and contributing to the continued professional development, this evaluation indicated that participants were not able to take skills from the MOOC and apply them to daily life. This may be due to the topic of the MOOC (RWE) being relatively new, and the data analysis skills taught in the MOOC requiring a complicated set of resources and support to be applied in the workplace. In fact, analyzing RWE requires the availability of multiple sources of data, competent patient protection policies, organizational support and a set of resource (Hubbard and Paradis, 2015), meaning that even if the learning was effective, the lack of these resources prevents students from applying their learning.

4.1 Strengths and Limitations

The strength of this evaluation is that it used qualitative data to evaluate learners' reaction, learning and skills gained from the MOOC. Learning from an online-course is most valuable not only when it is offered through the highest quality and latest technologies, but when the learning from the course can affect learners' day-to-day activities in a positive way (Romiszowski, 2003). For these reasons, this evaluation focused the most on evaluating participants' learning and how much of the learning they were able to or will be able to apply in their professional activities. The limitations of the study include lack of data sources in measures such as pre-course survey and post-course surveys and relying mostly on participants' self-reported data to complete the evaluation, which may be at risk of recall bias. Finally, a limitation in our use of the Kirkpatrick evaluation model was that it is intended to be applied 6 months after training, whereas in our evaluation we have used it four months after the course. However, findings from this evaluation could help future MOOC evaluations in determining which factors to study to evaluate the effectiveness of the MOOC and could help researchers consider factors other than learners' knowledge to understand how we can help improve the applicability of the learning from the MOOC in real life.

ISBN: 978-989-8533-78-4 © 2018

ACKNOWLEDGEMENT

This work was funded by the Higher Education Funding Council for England.

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Data collection approaches to enable evaluation of a Massive Open Online Course (MOOC) about data science for continuing education in healthcare

This paper is included as an appendix because its approach to qualitative data interpretation was used in this thesis. The paper was focused on learning impacts, however, which was outside the scope of the thesis.

Original Paper

Data Collection Approaches to Enable Evaluation of a Massive Open Online Course About Data Science for Continuing Education in Health Care: Case Study

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Abstract

Background: This study presents learner perceptions of a pilot massive open online course (MOOC).

Objective: The objective of this study was to explore data collection approaches to help inform future MOOC evaluations on the use of semistructured interviews and the Kirkpatrick evaluation model.

Methods: A total of 191 learners joined 2 course runs of a limited trial of the MOOC. Moreover, 7 learners volunteered to be interviewed for the study. The study design drew on semistructured interviews of 2 learners transcribed and analyzed using Braun and Clark's method for thematic coding. This limited participant set was used to identify how the Kirkpatrick evaluation model could be used to evaluate further implementations of the course at scale.

Results: The study identified several themes that could be used for further analysis. The themes and subthemes include learner background (educational, professional, and topic significance), MOOC learning (learning achievement and MOOC application), and MOOC features (MOOC positives, MOOC negatives, and networking). There were insufficient data points to perform a Kirkpatrick evaluation.

Conclusions: Semistructured interviews for MOOC evaluation can provide a valuable in-depth analysis of learners' experience of the course. However, there must be sufficient data sources to complete a Kirkpatrick evaluation to provide for data triangulation. For example, data from precourse and postcourse surveys, quizzes, and test results could be used to improve the evaluation methodology.

(JMIR Med Educ 2019;5(1):e10982) doi:10.2196/10982

KEYWORDS

education, distance; education; teaching; online learning; online education; MOOC; massive open online course

Introduction

Background

Online learning in the form of massive open online courses (MOOCs) became internationally famous in 2011 when a Stanford University MOOC attracted learners from more than 190 different countries [1]. Although these courses have become heralded for their ability to attract a significant number of learners, their overall effectiveness is not well understood, especially considering most learners who start these courses do

not finish them. MOOC evaluations can help analyze learning effectiveness and help improve their application [2]; however, there is a gap in the literature on MOOC evaluation methods [3]. Recent systematic reviews on MOOC research have concluded that there is a need for more research on methodologies used in MOOC research [4,5]. In addition, because of the diversity and heterogeneity of MOOCs, there is a need to focus on individual MOOCs and evaluate their effectiveness on a course level [6]. Current MOOC studies lack consideration of work-related skill development and organizational-level improvements [7]. A MOOC, especially one which focuses on practical skills development goals, should be assessed based on its quality of instruction, the inclusion of assessments, support of participation, instructional support, and enabling of continuous education [8]. Therefore, a MOOC evaluation should consider different aspects of the course instead of focusing on only limited aspects of learning.

Recent trends in MOOC research indicate there is an increase in using qualitative studies in MOOC research, which has been dominated by quantitative studies historically [7]. A quantitative approach tends to focus on course activity of the mass number of participants but without insight into individual activity. Qualitative methods and examination of individual learners provide contrasting data but are challenging to execute. Mixed-methods studies could enhance the methodological quality of this research by allowing for data triangulation from quantitative and qualitative data sources [4]. In addition, using more refined and sophisticated data collection and analysis methods such as interviews and focus groups and adopting thematic or social network analyses are highly recommended to improve MOOC evaluations [4]. There is a need for comprehensive and sophisticated data analyses methods to improve MOOC research.

Objectives

Health iQ created a pilot MOOC called "Data Science Essentials: Real World Evidence" with the aim to introduce learners to the concept of real-world evidence and demonstrate the application of these methods across various health care and life sciences industries [9]. As the online course was a pilot run, it had a limited trial audience. The target audience of the course was described as "undergraduate students in data science, an analyst or commercial manager working in life sciences pharmaceuticals, healthcare regulation, biotech and medical devices, especially those with an interest in the application of Information and Communication Technologies (ICT) within healthcare" [9]. In this investigation, we sought to explore the success of the course's objectives regarding "reach" about intended audience and social networks, "efficacy" about knowledge/skill gain skill and attrition, and adoption and sustainability of social networks for continual learning in this emerging field.

The objective of this study was to trial data collection methods to inform course development and to reflect on evaluation methodology for future course runs. Although an initial goal of the study was to perform an overall evaluation of the course using the Kirkpatrick evaluation method, because of time constraints and lack of data, we were only able to perform thematic analysis of the semistructured interview data. The purpose of the study was centered on the way semistructured interviewing could be used to implement the execution of a Kirkpatrick evaluation. The purpose for establishing an evaluation model that could be used in future MOOC evaluations is to be able to address research questions centered on the course's impact on learners knowledge, skills and attitudes, and its effect on learners' work and workplace.

Methods

Overview

This section will first provide an introduction about the course being studied and give an overview of the participants, data collection, and the data analysis methods used. This study employed semistructured interviews to analyze learner perspectives. The interview data were analyzed using thematic analysis methods. The Kirkpatrick evaluation model was used to organize and structure themes identified from interviews. We have reported the study methods and results according to the Consolidated Criteria for Reporting Qualitative Research (COREQ) [10]. The completed COREQ checklist can be found in Multimedia Appendix 1. The study received ethical approval from the Education Ethics Review Process (EERP) at Imperial College London (EERP1617-030).

About the Course

Data Science Essentials: Real World Evidence was run twice, during August to September and October to November 2017. In total, 191 learners joined both runs of the course, where 56 were from the October cohort [11]. The course learning outcomes and facilitation have been described previously [11].

Participants

All course participants were invited to be interviewed for the study via email through purposive sampling. A total of 7 learners had expressed interest to be interviewed, out of which only 2 chose to participate following informed consent [11]. Participants who dropped out did not provide any reasons. Interviewed participants' gender was 1 male and 1 female. Participants' age was not recorded, but only adults older than 18 years were able to participate in the study. Both participants were professionals working in health care–related fields, a medical doctor working in the pharmaceutical industry and a health care economist working in a consultancy organization.

Data Collection

The interviews were conducted in December 2017 through conference calls [11]. Only the participant and interviewer were present in the interview [11]. An interview guide with the key topics and questions was used to help focus on the topics of interest. The guide included the interview questions and possible follow-up questions. Questions were centered on the participant's background, reasons for taking the course, participant's use of the learning in the workplace, participant's interaction with other learners, and participant's opinions about the different materials and tools used to deliver the course. Each interview lasted approximately 20 to 40 min and was audio recorded. Interview transcription was performed by the

researcher as a way to start data familiarization [12]. The interviewees did not have any personal or professional relationship with anyone from the research team.

Data Analysis

Data analysis was completed by performing thematic analysis. Interview recordings were transcribed verbatim, anonymized, and analyzed [13-15]. The semistructured interview questions were grouped into 3 sections: learners' occupation and interests, learners' application of the learning, and learners' networking in the course. The participants were first asked about their background and their reasons for joining the course. The next questions were mainly focused on learners' behavior after the course. For example, learners were asked whether they were able to apply learning in their work or studies and whether the course affected their data analysis skills. Participants were also asked about their engagement with other learners and their engagement with the course, and their feedback about these aspects was collected to collect data about networking in the course. The primary author conducted the interviews and (a female research assistant with training in qualitative research) was the primary data coder. Thematic analysis of the data was carried out using Braun and Clarke's framework for thematic data analysis consisting of 6 phases: familiarization with data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and production of a report [13-15]. Revision and verification of the codes were carried out through discussions with the principal investigator in each phase of the coding.

Data management before coding included removing interview questions from the transcripts to keep the coder focused on the primary purpose of the research. Preliminary coding occurred through the transcription of the interviews, reading and rereading of the data, and systematically open coding the data [13-15]. Coding was performed manually using Microsoft Word, and preliminary codes were organized in an Excel sheet to be reviewed by the principal investigator. We have used inductive coding, meaning that the themes formulated were data-driven [16].

Thematic analysis is one of the most used methods in qualitative studies, and interpreting data by forming themes is "the most applicable" method of analysis for interview data [16]. Previous evaluations of educational and training programs have used thematic analysis for the interpretation of data such as interviews, surveys, and discussion posts [17-19].

Kirkpatrick Evaluation Model

The Kirkpatrick evaluation focuses on 4 levels of a training program: reaction, learning, behavior, and results [20]. This method could be used to evaluate participants' opinion about the course (reaction); whether the participants learned from the course (learning); whether they experienced any consequent changes in behavior (behavior); and how this impacted their studies, work, or broader community (results) [18]. Kirkpatrick evaluation provides a practical and systematic method for evaluating a training program, and it was used previously in MOOC evaluations [21-23]. The semistructured interviews can address some of the Kirkpatrick model's evaluation levels, but there is still a need for further data collection to fully validate the 4 levels of the model. In the following paragraphs, we describe the components of the model that could be covered using the semistructured interview data. Below we discuss the elements of the evaluation model that could be addressed by the semistructured interviews.

Level 1: Reaction

This level of the Kirkpatrick model evaluates participants' overall reaction to the course and their opinions about the delivery of the course. Information such as why the learners joined the course, what they liked or disliked about the course, and how much they have completed of the course could be reported in this level of the model.

Level 2: Learning

This level of the model evaluates learning gained from the course. It can evaluate how well participants acquired new information or new skills through the course.

Level 3: Behavior

This level of the model should evaluate the behavioral change that participants were able to adopt as a result of taking the course. For example, this level could evaluate whether participants were able to create change in their workplace as a result of taking the course, whether this change (if any) was sustainable, and whether they were aware of a shift in their behavior.

Level 4: Results

This level of the model assesses whether differences were made for the participants' workplace or organization as a result of the learning. This level of the model might be best evaluated after the course to allow time for the changes to occur.

Results

The thematic analysis resulted in the following themes: learner background, MOOC learning, and MOOC features [11].

Thematic Analysis Results

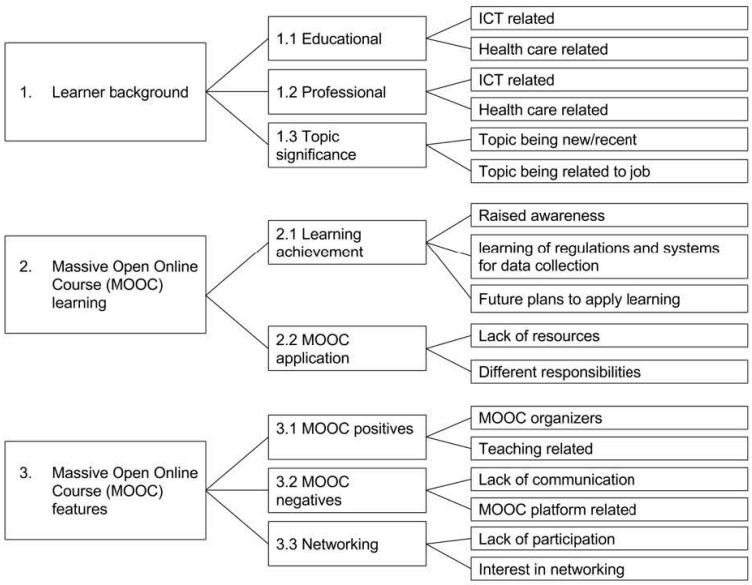
Analysis of the semistructured interview data gave rise to 3 central themes: learner background, MOOC learning, and MOOC features. Each of the themes and their subsequent codes from the thematic analysis of semistructured interview data (adapted from the study by Alturkistani et al [11]) are shown in Table 1. Figure 1 shows the themes, subthemes and codes developed through thematic analysis of interview data. Complete results of the thematic analysis can be found in Multimedia Appendix 2. The results were based on the 2 learners' responses. For that reason, it cannot be said that data saturation was reached; therefore, the study outcomes were limited to the view of the 2 learners only.

Table 1. Themes, subthemes, and codes from the thematic analysis of semistructured interview data.

Themes and subthemes	Codes
Learner background theme	
Educational	Information and communication technologies–related and health care–related
Professional	Information and communication technologies–related and health care–related
Topic significance	Topic being new/recent and topic being related to job
MOOC[a] learning theme	
Learning achievement	Raised awareness, learning of regulations and systems for data collection, and future plans to apply learning
MOOC application	Lack of resources and different responsibilities
MOOC features theme	
MOOC positive	MOOC organizers and teaching-related
MOOC negatives	Lack of communication and MOOC platform–related
Networking	Lack of participation and interest in networking

[a]MOOC: massive open online course.

Figure 1. Themes, subthemes and codes developed through thematic analysis of interview data. ICT: information and communication technologies.



Theme 1: Learner Background

Learners' educational background included undergraduate clinical medical training, a Masters in Economic Evaluation in Health Care, and Masters in Biostatistics, and their professional experience included working in the pharmaceutical industry and the health care sector and being involved with data science at work. The codes ICT–related and health care–related represent learners' educational and professional fields that were closely related to the course's field of interest, the intersection of ICT with health care.

Theme 2: Massive Open Online Course Learning

Participants expressed their learning through different methods such as expressing the different topics that they have learned through the course. They have also discussed how they were able or not able to apply learning in their work or studies.

Theme 3: Massive Open Online Course Features

Each participant had different opinions about what they liked and disliked about the MOOC and their experience in networking.

Reflection on the Kirkpatrick Evaluation Model

Level 1: Reaction

The reaction level of the model could be collected through the semistructured interviews. The participants' reaction to the course could easily be collected through the semistructured interview. Completion rates of learners could be collected through the interview but can also be recorded through the learning management system data, which can automatically report the completion rate of the different components of the course.

Level 2: Learning

Overall, it is possible to ask participants how much and how well they have learned in the course through the semistructured interviews. However, it may be useful to collect data through quiz or test scores, if possible, to triangulate and strengthen the interview findings.

Level 3: Behavior

It is possible to ask participants about the different behaviors they have changed as a result of taking a course. However, behavior change is one of the least studied outcomes in MOOC research, and it may be challenging to only record it through the semistructured interviews. When learners were asked if they have engaged in different projects as a result of taking the course, they have responded negatively. It may be useful to enhance the results of this level of the evaluation by collecting data through postcourse surveys possibly in 2 different time points, right after the course and 3 to 6 months after the course to allow some time for changes after the MOOC.

Level 4: Results

On the basis of the course description, the aim of the course was to teach learners how to "develop new methods for data analysis" and use of the data to "inform decision making in health care" [9]. Therefore, the potential impact of course would have been to demonstrate that new methods of data analysis were adopted and that the new data informed decisions in health care. The data for this level of the evaluation could be collected both through semistructured interviews and postcourse surveys.

Discussion

Principal Findings

This study gathered data to consider the use of semistructured interviews to inform a proposed evaluation method. Thematic analysis of semistructured interview data with learners of the pilot run of the course was completed to identify key themes for future development of the course. The Kirkpatrick evaluation model components were reviewed to assess whether semistructured interview data could help evaluate the course. The trial interview process revealed that the Kirkpatrick evaluation model could be used through the semistructured interview data in addition to other data sources such as surveys and quizzes. Semistructured interviews, while providing in-depth data about the learners' experience, may be a limited method to record objective data on things such as learning, behavior, and results.

A review of the recent MOOC literature (2013-2017) found that there is limited literature on studies focusing on learners' acquired practical skills from MOOCs [8]. In general, MOOC evaluations have not yet been able to measure the long-term impacts of MOOCs on learners [24]. However, the use of methods to measure course impact, including the Kirkpatrick evaluation model with its consideration of behavior change and results on the organizational level can help take learner skills and behavior change into account when evaluating the course. In a subsequent study, use of this method could be conducted by collecting pre- and postcourse surveys, quiz, and test results and possible discussion posts and triangulating this information with semistructured interviews data.

Our study's strengths are that it used qualitative data to assess the applicability of evaluating learning and skills of participants after the course. A recent systematic review (2018) of MOOC research recommended that methods such as interviews that offer an in-depth data of learner or participant experiences should be preferred to survey and "easily obtainable descriptive statistics" data [4]. It is believed that studying the success of an online learning course should focus more on the applicability of the information to the learners' day-to-day activities [25]. Our study suggests that evaluations should focus on how learning can affect that participant's behavior and work.

The limited qualitative data we collected informed us what factors need to be examined in more depth to evaluate the effectiveness of a MOOC and could help researchers consider factors beyond learners' knowledge to understand what can help improve the MOOC's applicability in real life. Future evaluations could include more data sources such as surveys, discussion posts, and quiz results when using the Kirkpatrick model [21] to increase the reliability of analysis. Furthermore, studies could use learning analytics data that are recorded through the host online course website of learners' use of the course (eg, login details and video viewing activity) to have a more comprehensive understanding of MOOC activity [26]. The main limitation of the study was the small sample size, which limits the generalizability of our study. The small sample size also meant that we were not able to fully address the study research questions. Due to the lack of data, we were unable to use any precourse measurements to compare participants' reaction before and after the course or report demographic information about the target population of the course. We also relied entirely on participants' self-reported data, which are subject to bias. However, this was a pilot study to inform our future course evaluations, and the limitations were taken into account when reporting the outcomes of the study.

Conclusions

The core themes that resulted from this study indicate that MOOCs could potentially be evaluated in terms of their impact on learners' behavior and skills acquired from the course through performing the Kirkpatrick evaluation. The study concluded that semistructured interviews can provide valuable, in-depth data about the course but should be used along with other data sources for data triangulation. Data sources such as pre- and postcourse survey data, quiz and test scores data, and possible discussion or social media thread posts could help create a

comprehensive evaluation using the Kirkpatrick evaluation method.

Acknowledgments

The authors acknowledge the professionals and academics who contributed to the delivery of the MOOC, Data Science Essentials: Real World Evidence: Hassan Chaudhury, Yusuf Ermak, Enda Ridge, and Jerrell Schivers. This work was supported by the Higher Education Funding Council (HEFCE) for England. The content is solely the responsibility of the authors and does not represent the views of HEFCE.

Authors' Contributions

The first author AA performed data collection and data analysis. Codes and themes resulting from the analysis were reviewed in discussions between AA and EM. EM provided feedback and oversight. AM, JC, DB, and GW reviewed the second and third drafts. AA incorporated and addressed the feedback from the authors. All authors approved the manuscript before submission. EM is the guarantor.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist.

[PDF File (Adobe PDF File), 335KB - mededu_v5i1e10982_app1.pdf]

Multimedia Appendix 2

Thematic analysis results.

[PDF File (Adobe PDF File), 90KB - mededu_v5i1e10982_app2.pdf]

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Abbreviations

COREQ: Consolidated Criteria for Reporting Qualitative Research
EERP: Education Ethics Review Process
HEFCE: Higher Education Funding Council
ICT: information and communication technologies
MOOC: massive open online course

Edited by G Eysenbach; submitted 06.05.18; peer-reviewed by K Goniewicz, M El Tantawi, J Richardson; comments to author 03.09.18; revised version received 14.12.18; accepted 26.01.19; published 23.03.19

Please cite as:
Alturkistani A, Majeed A, Car J, Brindley D, Wells G, Meinert E
Data Collection Approaches to Enable Evaluation of a Massive Open Online Course About Data Science for Continuing Education in Health Care: Case Study
JMIR Med Educ 2019;5(1):e10982
URL: http://mededu.jmir.org/2019/1/e10982/
doi:10.2196/10982
PMID: