Factors influencing students’ use of technology-enhanced learning (TEL) resources in anatomical education

Lauren Catherine McGregor Clunie

Submitted in accordance with the requirements for the degree of Doctor of Philosophy

The University of Leeds

Leeds Institute of Medical Education
School of Medicine

August 2020

Intellectual property statement

Academic publications arising from this thesis

1) Clunie, L., Morris, N.P., Joynes, V.L. and Pickering, J.D. (2018). How comprehensive are research studies investigating the efficacy of technology-enhanced learning resources in anatomy education? A systematic review. *Anatomical Sciences Education*. **11**(3), pp.303–319. https://doi.org/10.1002/ase.1762

The candidate was the lead author of this publication and was solely responsible for writing it. The role of the three co-authors was limited to help with the structuring and editing of the manuscript, with the exception of one author (J.D.P) who was also an independent reviewer for the inclusion of studies within the review.

The data from the publication is presented in Chapter 4. The data in the publication accounts for studies published until November 2016. Chapter 4 presents this data alongside an updated literature search incorporating studies published until March 2019. Furthermore, Chapter 4 differs from the publication by focusing the discussion of findings on the context of this thesis.

Acknowledgements

The completion of this thesis is thanks in large part to the people who challenged, supported, and stuck with me along the way. The greatest appreciation must be given to my supervisors Professor James Pickering, Professor Neil Morris and Dr Jennifer Hallam for their ongoing patience and guidance. More specifically, I'd like to thank James, who has not only shown me what it means to be a good researcher, but has also shown me what it means to be a good anatomy educator. The many lessons he imparted will undoubtably help me in my future career as an anatomy educator. I'd also like to thank Neil for always reminding me of the bigger picture, and for sharing, not only his wealth of knowledge and experience of the PhD process, but also his smarties! Finally, I'd like to thank Jenn for her seemingly endless methodological knowledge, for being an excellent female role model in academia, and for supporting me through some difficult times. Together, James, Neil and Jenn have made a formidable supervisory team whose detailed feedback and useful suggestions have enhanced every aspect of this thesis.

I am grateful to Dr Rebecca O'Rourke whose words of comfort and encouragement have seen me through tough times. I appreciate the helpful advice as well as the great opportunities that have enabled me to develop academically. I also appreciate the support from the other PhD students within LIME, often supplied in the form of memes and coffee breaks. In addition, I am thankful to the anatomy team from whom I have learnt so much, including many rude anatomy mnemonics! In particular, I treasure the friendships I've gained with James, Aaron, Nick and Tom. Sharing our anatomy PhD journey together has been a genuine pleasure.

Thank you to my Granny. While she didn't get to see me finish this journey, she taught me to keep working hard, even when times are tough – *"get yer heed through it, and yer arse will follow!"*. Thank you also to all my friends for their unwavering faith in me and ongoing words of encouragement. A very special thanks goes to Sean and James, who I not only shared a home with, but also shared all of the trials and tribulations of PhD life, regular life and, for a short while, vegan life! I'm especially grateful to the Clunie Clan who, despite being hundreds of miles away, have supported me through every step of this long journey. I feel incredibly lucky to have a family I can rely on for encouragement, for A.C. length phone calls and for always keeping me grounded through their awesome sense of humour. Finally, I thank my partner Pete. He may not have been around at the start of my journey, but has been instrumental in getting me to the end. More than anyone, he has witnessed the best and worst of PhD times and his support has been unfaltering. For being my rock – thank you!

Abstract

The use of technology-enhanced learning (TEL) resources is now ubiquitous within anatomy education. Multiple studies have investigated the effectiveness of TEL and have established positive outcomes with regard to assessment outcomes and student satisfaction. However, little research has examined the experience of students engaged in a multi-faceted, multi-modal anatomy curriculum. Therefore, this study set out to explore the factors that influence student perceptions and use of TEL resources for studying anatomy.

By first employing a systematic literature review, this study appraises the current methods of TEL evaluation, revealing a predominantly quantitative approach to evaluation. To improve the current understanding of student experiences, an exploratory sequential mixed methods design was employed to investigate the perceptions of medical students at the University of Leeds. Firstly, a new survey scale was developed based upon existing scales within anatomy TEL evaluation surveys and upon the conceptual framework. Next, the scale was piloted with Year 2 medical students (α=0.891; N=131) and analysed using exploratory factor analysis (EFA), the results from which were used to inform the development of focus group questions. Survey respondents (N=12) were recruited to three focus groups which provided further insight into the factors influencing TEL engagement. Finally, the survey scale was adapted following triangulation of both the quantitative and qualitative findings. The refined scale was completed by 129 medical students and analysed using EFA, the results from which revealed the final 23-item Anatomy TEL Utility scale with four emergent factors: (1) affective attitude towards TEL (α=0.850); (2) perceived effectiveness (α=0.785); (3) resource design (α=0.626); (4) personal norms and social influence (α=0.656).

The findings from this study revealed students view TEL positively and appreciate the increased flexibility, accessibility, and efficiency offered by many resources. In addition, due to time constraints and an overwhelming number of available resources online, students have a preference for institutionally-provided resources. Moreover, when selecting which resources to engage with, students are influenced by resource design and perceived effectiveness. That is, the aesthetic appeal, and the perceived value of the resource in achieving personal goals. Furthermore, the findings shed light on the significant influence educators have in determining students' perceptions of and engagement with TEL resources.

The findings from this study can support anatomy educators in understanding how and why students engage with learning resources. In addition, this study provides a theoretical, practical and methodological contribution to the field of anatomy education research.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

3D	Three-Dimensional
AR	Augmented Reality
CP	Clinical Pathology
EFA	Exploratory Factor Analysis
FG	Focus Group
HE	Higher Education
KMO	Kaiser-Meyer-Olkin
MBChB	Bachelor of Medicine and Bachelor of Surgery
PB	Paper-Based
PCA	Principal Component Analysis
RCT	Randomised Control Trial
SD	Standard Deviation
TEL	Technology Enhanced Learning
VLE	Virtual Learning Environment
VR	Virtual Reality

Chapter 1

Introduction to the Thesis

1.1 Introduction

This doctoral study focuses on the evaluation of technology-enhanced learning (TEL) within anatomy education. It explores the current landscape within anatomy TEL evaluation literature and establishes the comprehensiveness by which TEL is evaluated. Furthermore, this study fills an apparent gap in the literature by exploring the experiences of students currently engaged within a multi-modal discipline. Through the development of a methodologically robust survey, named the Anatomy TEL Utility scale, this study draws upon both quantitative and qualitative data to uncover the factors influencing student perceptions and use of TEL within anatomy education.

This chapter provides the background, context and rationale for this study, introduces its research aims and outlines the structure of the thesis.

1.2 Background and Context

Anatomy is learned by diverse groups of students, such as medical, dental, nursing, allied health profession and biomedical science students, in a variety of settings, including online, face-to-face and blended learning environments. Such varied contexts has played a role in the wide ranging and highly variable use of TEL within anatomy education (Estai and Bunt, 2016; Trelease, 2016). The abundance of approaches to implementing TEL within anatomy education was evidenced in a historical review by Robert Trelease (2016). Within this comprehensive review, the ongoing acceptance and integration of TEL within anatomy education is described through the lens of 'diffusion of innovations' (Rogers, 1983; 2010), which stipulates that mass acceptance and adoption of technology is dependent upon a number of factors. These include information about the effectiveness and functionality of a resource, the social systems associated with a resource and the length of time it has been around for. In other words, Trelease (2016) argues that anatomy educators select their use of TEL provision based on the expected outcomes (provided by studies of TEL evaluation), the perceived compatibility (with their own needs, values and technological skills) and the social norms associated with the resource, that is, how technologies are seen to be perceived by others in the field of anatomy education and within wider society (Trelease, 2016).

This is demonstrated by the ubiquitous use of virtual learning environments (VLEs) as a repository for teaching and learning resources. VLEs have been available since the late 1980's (Trelease, 2016) and as such have a large body of evidence related to their effective and successful use within anatomy education (Carmichael and Pawlina, 2000; Green et al., 2006; Nieder and Borges, 2012). Furthermore, the mass acceptance of these tools expands to Higher Education (HE) in general (Bricken, 1991; Craig and Amernic, 2006), which increases the socio-normative expectations of their use and improves the perceived compatibility with needs, values and technological skills of educators (Trelease, 2016). Within anatomy education specifically, VLEs are used as a repository for a host of different TEL resources such as lecture recordings (Bacro et al., 2010; 2013; Nieder and Borges, 2012; Beale et al., 2014), podcasts (Patasi et al., 2009; McEvoy et al., 2014), live or asynchronous discussion forums (Durham et al., 2009; Choudhury and Gouldsborough, 2012; Green and Hughes, 2013; Green et al., 2014) and online quizzes (McNulty et al., 2000; Inuwa et al., 2011; Lee et al., 2012; Johnson et al., 2013; Attardi and Rogers, 2015; Brown et al., 2015).

Moreover, the content available to students via a VLE is largely determined by anatomy educators who, not only design and develop learning resources, activities and interactions (Beetham and Sharpe, 2013), but also orchestrate the structure of such an online learning environment and provide supplementary learning resources, such as recommended reading lists and direct links to externally provided resources (e.g. Lewis et al., 2014; Curran et al., 2020; Motsinger, 2020). This 'gatekeeper' position is made increasingly straightforward due to the large-scale offering of freely accessible resources such as videos, eBooks, social media and mobile applications (e.g. Stirling and Birt, 2014; Pickering, 2015; Raney, 2016; Morris et al., 2016; Hennessy et al., 2016; Barry et al., 2016; Lone et al., 2018). Of particular note is the use of YouTube (Google, San Mateo, CA) which has been found to be the most popular source for anatomy-related video content (Jaffar, 2012; Barry et al., 2016). The success of this free-to-use resource can be attributed to its user-friendly interface and easy sharing of videos via deep links (Raikos and Waidyasekara, 2014; Curran et al., 2020). However, despite the evident popularity within anatomy education, there is limited research investigating the perceptions of stakeholders or the quality of educational videos posted to the site (Raikos and Waidyasekara, 2014; Barry et al., 2016; Curran et al., 2020). While anatomy educators may develop or recommend videos and webpages to students via the VLE, students are known to actively seek and engage with other externally provided resources via Google, YouTube and

Wikipedia (Kingsley et al., 2011; O'Carroll et al., 2015; Pascoe, 2020). As Trelease (2016) argues, these web-based resources have become the *"ubiquitous infrastructural technology underlying the conduct of contemporary post-secondary and pre-professional education"* (p. 589).

Despite the near ubiquitous use of web-based resources, the publication of articles concerned with evaluating resources such as videos or webpages appears to have declined in recent years in favour of more novel and innovative 3D visualisation technologies such as virtual reality (VR), augmented reality (AR), 3D printing and many more (Trelease, 2016). While expensive to implement and not widely available within anatomy curricula, these technologies show promise in providing the tactile and 3-dimensional learning experiences lost in some institutions through reduced opportunities to access cadaveric material (McMenamin et al., 2014; Yammine and Violato, 2015; Chan et al., 2015). However, despite showing such promise, VR, AR and 3D printing are currently utilised by a minority of institutions, limiting the applicability of studies investigating the effectiveness and functionality of such resources (e.g. McMenamin et al., 2014; Chan et al., 2015; Ma et al., 2015; De Faria et al., 2016; Bauer et al., 2017). A more commonly cited use of 3D visualisation technologies is via monoscopic 3D representations of the human body, often via mobile applications or webpages (Lewis et al., 2014). These technologies are becoming increasingly affordable to develop through segmentation of open-source CT, MRI or Visible Human[1] data (e.g. Hisley et al., 2008; Choi et al., 2017); via photogrammetry (e.g. Rea and Linn, 2017; Petriceks et al., 2018); or by using skilled digital animators (e.g. Anderson et al., 2013; Saltarelli et al., 2014). As such, the diffusion of monoscopic 3D visualiation technologies has seen a notable surge in recent years with an increasing number of students, educators and institutions investing in them (Trelease, 2016).

What is evident from the literature within anatomy education, and highlighted within the review by Trelease (2016), is the relative diffusion of innovations. From VLE's and other web-based resources which are now firmly embedded within the learning experience of anatomy students, to the increasing but not yet ubiquitous use of instructor-developed resources such as eBooks, podcasts, social media and videos, and to the increasingly popular use of 3D visualisation technologies (Trelease, 2016). Estai and Bunt's (2016) suggestion that anatomy should be

[1] The visible human project is a public-domain library of cryosections from one male and one female cadaver along with associated CT and MRI data (US National Library of Medicine, 1994).

taught through a multi-modal paradigm is now evidently a reality. However, it is also evident that there is not a 'one-size-fits-all' approach to implementing TEL within anatomy education. Each learning environment, educator and cohort of students will require a different approach in order to meet the expectations of all relevant stakeholders. Furthermore, in order to determine the optimum methods of implementing TEL into specific curricula, it is good educational practice to engage in a period of reflection on existing evidence and to engage in evaluation studies to determine TEL effectiveness prior to implementation (Pickering and Joynes, 2016).

Within the context of the University of Leeds, like many other anatomy curricula, a multitude of TEL resources are available to medical students to supplement their anatomy learning and, for the purposes of this thesis, is therefore defined as a 'multi-modal' anatomy curriculum. Evaluation of these resources has established that, when learning with anatomy drawing videos, students demonstrate significantly greater short- and medium-term learning gains (Pickering, 2017), defined as the tangible changes in learning outcomes achieved after a specific intervention (Pickering and Joynes, 2016). Furthermore, high levels of student satisfaction were demonstrated not only for drawing videos, but also for lecture recordings, a massive open online course (MOOC) and a dedicated anatomy eBook (Pickering, 2014a; 2015; Swinnerton et al., 2017; Pickering and Bickerdike, 2017). Moreover, a recent investigation into the relationship between student engagement and resource usage revealed that highly engaged students at the University of Leeds were more likely to utilise supplementary resources such as the MOOC and eBook, and determined there was no relationship between engagement and assessment outcomes (Pickering and Swinnerton, 2019). Through the use of an engagement survey scale, the study described how engagement impacts upon resource use and assessment outcomes, however, without additional qualitative inquiry, the study was not able to determine *why*. Furthermore, access to usage data for the aforementioned resources provided an examination of the influence of student engagement on TEL usage (Pickering and Swinnerton, 2019), however, this was limited to a small number of instructor-developed resources and did not account for the multitude of web-based resources available to students online.

While evaluation studies at the University of Leeds have been comprehensive and guided by an evidence-based approach to TEL implementation, questions still remain surrounding the ways in which students navigate their way through a multi-modal anatomy curriculum and the factors that may influence their decision to engage, or not to engage, with specific TEL resources. As will be evidenced throughout this thesis, this lack of understanding is apparent not only at the University of Leeds, but within wider anatomy education literature.

1.3 Research Rationale

Technology-enhanced learning (TEL) is widely perceived to be successful in supplementing anatomy education. This perception was confirmed by a recent meta-analysis which determined that students learning with TEL perform better than those who have limited or no access to TEL, and that greater learning gains are demonstrated when TEL supplements traditional learning as opposed to replacing it (Wilson et al., 2019). These findings, as well as those from multiple independent TEL evaluation studies (e.g. Granger et al., 2006; Mathiowetz et al., 2016; Lone et al., 2018; Chimmalgi, 2019), provide confidence that the increasingly ubiquitous use of TEL is supporting students to learn anatomy. However, there is a scarcity of studies investigating what students think or feel about TEL in anatomy. Questions exist related to how students use TEL, when they use it, what frustrates or motivates them and how they choose which TEL resources to engage with from the wide range of institutionally and externally provided resources. This thesis argues that turning the research lens towards the student experience can help anatomy educators understand the factors that may improve, or be detrimental, to student satisfaction and engagement with TEL.

1.4 Research Aims

The research aims of this thesis are two-fold. Firstly, to understand the comprehensiveness of TEL evaluation studies within anatomy education and, secondly, to understand the factors that influence student perceptions and use of TEL when studying anatomy.

In 2006, McLachlan and Patten described the need for robust evaluation of the effectiveness of TEL as *"the single most desirable improvement in anatomy teaching"* (McLachlan and Patten, 2006). More recently, Trelease (2016) concluded his comprehensive review of TEL within anatomy education by suggesting that TEL innovations *"currently suffer from a scarcity of statistically reliable learning efficacy evidence"* (p.594). The concerns of McLachlan, Patten and Trelease are particularly pertinent given the increasing integration and reliance on technology within anatomy education. Therefore, the first research aim is addressed through an extensive systematic review which investigates TEL evaluation studies within anatomy education. Using an evaluation framework as a benchmarking tool, the evaluation methodologies currently employed to evaluate TEL are critically analysed.

The findings from the systematic literature review reveal TEL evaluations utilise a predominantly quantitative approach. Such approaches are imperative for understanding the effectiveness of a resource at achieving outcomes such as improved learning gain or increased student satisfaction. However, without qualitative inquiry, how TEL is experienced by students within multi-modal curricula and within a variety of contexts is missed. The conclusions drawn from the systematic literature review are strengthened by calls within the field of medical education for increased attention to the experiences of both students and educators (Cook, 2009; Ellaway, 2011a; Cook and Ellaway, 2015). Therefore, the second research aim utilises an exploratory sequential mixed methods approach to investigate student experiences within the TEL-heavy anatomy curriculum at the University of Leeds. The purpose of this second study is to answer the following research question: *what factors influence student preferences and use of TEL resources within anatomy education?*

1.5 Structure of the Thesis

The thesis is presented across eight chapters. The remaining chapters are organised as follows:

Chapter 2: Literature Review

This chapter reviews the literature associated with the aforementioned research aims and is structured into three main literature domains. These are: review of the drivers for TEL introduction within anatomy education; the importance of evaluation research in determining the efficacy of TEL in achieving successful learning outcomes, and; review of the relevant theories associated with student engagement with TEL. Throughout the chapter, gaps in the literature are established with regards to the comprehensiveness of TEL evaluation studies within anatomy education, and the apparent lack of evaluation studies investigating student experience. This chapter concludes by introducing the four main research questions.

Chapter 3: Conceptual Framework and Research Design

This chapter utilises the findings from the literature review to describe the emergent conceptual framework of this thesis. This considers the theoretical underpinnings of student motivation, behaviour and learning and applies this to the context of engagement with TEL. Following this, the chapter considers the philosophical assumptions that drove the design and implementation of the research. The chapter also presents the research design of the thesis and justifies the methodological approach taken to achieve the research aims.

Chapter 4: Evaluation of TEL in Anatomy Education: Systematic Literature Review

This chapter presents the findings from the systematic literature review and addresses the first and second research questions. Undertaken early in the research process and published within Anatomical Sciences Education (Clunie et al., 2018), this chapter presents these findings in combination with an updated literature search and analysis. The chapter presents an overview of the comprehensiveness of current methodological approaches to evaluation within anatomy education literature. Furthermore, this chapter emphasises discussion of results most relevant to the research aims of the thesis, with particular focus on current evaluation practice with regards to student experience with TEL.

Chapter 5: Piloting the Anatomy TEL Utility Scale

Chapter 5 presents the first quantitative phase of the exploratory sequential mixed methods study. This includes the design, development and deployment of the pilot Anatomy TEL Utility scale with medical students at the University of Leeds. Analysis of the survey data reveal three emergent factors, and identifies areas for further investigation within the qualitative phase of the study.

Chapter 6: Focus Groups with Medical Students: Uncovering the 'why'

Chapter 6 presents the findings from the qualitative phase of the exploratory sequential mixed methods study. The findings, gathered from focus groups with medical students, provide context and additional depth of understanding to the findings presented in Chapter 5, as well as highlighting additional areas for consideration. This chapter concludes with a discussion of the findings within the context of the present study, where discussion within the context of the wider literature is reserved for Chapter 8.

Chapter 7: Refining the Anatomy TEL Utility Scale: Data Triangulation

This final results chapter presents the process of reviewing and refining the Anatomy TEL Utility scale. This is achieved through triangulation of the findings from Chapter 5 and 6. Chapter 7 continues with analysis of the final survey which reveals four emergent factors, before concluding with a discussion of the findings within the context of the present study. Discussion within the context of the wider literature is reserved for Chapter 8.

Chapter 8: General Discussion

This chapter synthesises and discusses six core findings from the study in light of the existing literature and highlights the implications of these findings for anatomy education. The chapter continues by discussing the methodological, theoretical and practical contributions of the study, research limitations, and directions for future research. The chapter concludes with a summary of the thesis.

Chapter 2
Literature Review

2.1 Introduction

This chapter reviews the published literature on three domains relevant to this thesis. The chapter begins by giving consideration to the current educational landscape within anatomy education and how this, as well as other factors have driven the introduction of TEL within the field. The second part of this chapter focuses on the enhancements to learning afforded by technology before reviewing the importance of and approaches to TEL evaluation within anatomy education. Furthermore, this chapter ends by reviewing the multiple relevant theories associated with student engagement and learning with TEL. These theories are interpreted and presented through the prism of three commonly cited domains of student engagement: affective engagement; behavioural engagement, and; cognitive engagement. Finally, this chapter concludes by summarising the reviewed literature and presents the research questions of the thesis.

2.2 Drivers for the Introduction of TEL in Anatomy Education

For centuries, anatomy education has traditionally been taught using lectures and cadaveric dissection (McLachlan and Patten, 2006; Sugand et al., 2010; Estai and Bunt, 2016; Ghosh, 2017). While this combination of approaches has resulted in the education of millions of healthcare professionals, in the last 30 years, the landscape within anatomy education has shifted somewhat. At present, modern anatomy curricula combine a multitude of pedagogical approaches such as cadaveric dissection and prosections (Griksaitis et al., 2012; Smith and Wilkinson, 2018), radiological anatomy (So et al., 2017; Patel et al., 2017), art-based approaches such as body painting (Finn and McLachlan, 2010; Azer, 2013) and a wide range of technology-enhanced learning (TEL) resources (Trelease, 2016). This relatively new 'multi-modal paradigm' is cited as being the best way to teach anatomy, with students benefitting from a diverse integration of learning modalities (Estai and Bunt, 2016).

The change in approach to anatomy education has been driven by a number of inter-related factors. Firstly, within the last three decades, U.K. medical schools began integrating clinical teaching into the pre-clinical years (McKeown et al., 2003; Field, 2009). This resulted in a reduction in the number of contact hours available for anatomy to allow for the provision of curricular time dedicated to the development of skills such as professionalism and communication skills (Heylings, 2002; Papa and Vaccarezza, 2013). Secondly, despite longstanding evidence of the success of cadaveric dissection in achieving both academic and non-academic outcomes for learners, its efficiency and cost-benefit in a now time-precious subject have been called into question (Estai and Bunt, 2016; McMenamin et al., 2018). Institutions must weigh up the relative cost-benefit of learning resources and find a suitable balance between student outcomes and financial cost (Estai and Bunt, 2016), emphasising the need for robust evaluation approaches (Pickering and Joynes, 2016). Simultaneous to these curricular changes, there has been an increase in the availability and affordability of personal technological devices such as laptops, smartphones and tablets (Poushter and Stewart, 2016). This has made TEL resources significantly more accessible to students and has opened a variety of opportunities for educators to develop and disseminate their own learning resources (Trelease, 2016).

Furthermore, the use of TEL in anatomy education is likely influenced by the motivations and priorities of the institutions from which they belong. This is particularly relevant to HE institutes within the U.K. where the introduction of national exercises for evaluating teaching quality, namely the Teaching Excellence Framework (TEF) and the associated National Student Survey (NSS) (Gunn, 2018), has led to increased attention on student satisfaction. This emphasis on satisfaction was evidenced in a survey of 108 U.K. HE institutions, where the main institutional drivers for the introduction of TEL were identified (UCISA Digital Education Group, 2018). The primary driver cited by HE institutions was ‘enhancing the quality of learning and teaching’. This was closely followed by two student-centric factors; ‘improving student satisfaction’, which has increased in priority within HE since the equivalent survey from 2016, and ‘meeting student expectations’ (UCISA Digital Education Group, 2018, p.12). This shows a clear emphasis on student experience and its role as a key driver of TEL development within HE institutions. These student-centred priorities for HE institutions are motivated by a number of factors, not least the consideration of the numerous national and international ranking systems that may impact upon prospective student applications (Hazelkorn, 2007). More commonly, however, is the motivation to meet the needs of a ‘new generation’ of students (Attwell and Hughes, 2010; Sharpe et al., 2010; Hopkins et al., 2018). Such motivation stems from the intuitive notion that the habits, preferences and expectations of an individual may be influenced by the shared societal and cultural experiences of the generation they belong to (Kennedy et al., 2008; Hopkins et al., 2018). If the experiences of the so-called millennial and net generation of students are influenced by the cultural environment they grew up in, then for many, this means lengthy exposure to and subsequent normalisation of technologies such as smartphones, tablet devices and general internet browsing (Kirschner and De Bruyckere, 2017; Hopkins et al., 2018). This has led some educators to presume that this latest generation of students have an innate digital literacy and preference to learn using technology (Prensky, 2001; Sharpe et al., 2010; White and Le Cornu, 2011; Hopkins et al., 2018). However, it is dubious to assign a single set of characteristics to an entire generation of learners (Kennedy et al., 2008; Borges et al., 2010; DiLullo et al., 2011); and while there is little doubt that technology plays a significant function in students' lives, there is a lack of evidence to suggest the latest generations of students learn any differently than those who have come before them (Kirschner and van Merriënboer, 2013; Kirschner and De Bruyckere, 2017). Furthermore, instruction that is designed based upon assumptions about generational differences in learning may indeed be detrimental to student learning (Kirschner and De Bruyckere, 2017).

2.3 Technology "Enhanced" Learning: What is enhanced?

The introduction of TEL is driven by a number of factors such as improving student satisfaction and to meet student expectations, so what benefits can TEL offer to improve these factors? Literature surrounding the 'enhancements' of TEL is wide ranging, however, largely focuses on the increased levels of efficiency, flexibility and inclusivity when compared to conventional (i.e. non technology-based) teaching methods (Laurillard, 2012; Beetham and Sharpe, 2013; Kirkwood and Price, 2014). Firstly, improved efficiency can be achieved by reducing financial costs, improving the ability to monitor student progress and maximising educator time by supporting the ability to share, and improve upon, existing resources (Laurillard, 2014). Secondly, students may experience increased flexibility of their learning, with internet-enabled devices providing access to learning materials at any time and from any place (Sharpe et al., 2006; Beetham and White, 2013). Finally, assistive technologies may offer a more inclusive learning environment by supporting students with disabilities or particular learning needs (e.g. language support) (Laurillard, 2014). In a critical review of TEL literature, Kirkwood and Price (2014) described these enhancements to the efficiency, flexibility and inclusivity of learning as 'operational improvements'.

Beyond these logistical benefits to learning, TEL has also been shown to increase learning gain, defined by Pickering and Joynes (2017) as a tangible change in learning outcomes following exposure to a specific intervention. This term and broad definition are used extensively within HE (Hake, 1998; Dimitrov and Rumrill, 2003), however, recent criticism of the term suggests it too heavily focuses on cognitive learning gains and fails to account for other relevant gains that may be offered by TEL (Rogaten et al., 2019). Therefore, Rogaten et al (2019) suggest that learning gains should be aligned to the affective, behavioural and cognitive domains of learning. Within this categorisation: affective learning gains offered by TEL include, changes in attitude or wellbeing; behavioural learning gains include changes to time on task or ability to work in a group, and; cognitive learning gains include changes to understanding or knowledge. While not explicitly referred to, there is evidence of all three categorisations of learning gain following the use of TEL within anatomy education. For instance, affective learning gains are evidenced by improved student satisfaction scores for resources such as lecture recordings, podcasts, video presentations, quizzes and discussion forums (e.g. Granger and Calleson, 2007; Johnson et al., 2013; McEvoy et al., 2014; Bickerdike et al., 2014; Green et al., 2014). In addition, studies investigating the use of social media noted reduced test anxiety from the students who engaged with it (Hennessy et al., 2016; Pickering and Bickerdike, 2017). Behavioural learning gain was reported by Mayfield et al (2013) who measured increased time-on-task following the inclusion of iPads within a dissection class. Furthermore, cognitive learning gains have been reported for a number of TEL resources within anatomy education, such as educational videos (e.g. Pickering, 2014a; Choi-Lundberg et al., 2016; Greene, 2018; 2019) and 3D visualisation technologies (e.g. Khalil et al., 2005; Hu et al., 2010; Keedy et al., 2011; Moro et al., 2017).

Moreover, it is important to consider that the introduction of technology-enhanced learning does not guarantee 'enhancement' to learning (Delgaty et al., 2017). Within medical education, accessibility, distractions from learning and privacy issues have all been suggested to have negative implications for students (Delgaty et al., 2017). Within wider HE literature, Selwyn (2016) investigated students perceptions of the 'digital downsides' of learning with technology and uncovered four main reasons why it may be perceived as having a negative impact upon learning. Of these reasons, the potential to be distracted by notifications, social media and other smartphone applications, as well as by other students off-task use of technology during teaching time was referred to most often (Selwyn, 2016). This was followed closely by reasons such as disruption to learning when technology fails to work correctly, difficulty in using technology due to poor resource design and a detriment to learning due to a reduced obligation for educators to engage with students (Selwyn, 2016). These findings are well supported elsewhere in the literature within both HE (Arkorful and Abaidoo, 2014) and medical education (Link and Marz, 2006; Wallace et al., 2012; Zureick et al., 2018).

In addition to the digital downsides identified by Selwyn (2016), it is important to consider the wider socioeconomic inequalities associated with TEL, often referred to as the 'digital divide'

(Hargittai, 2003; Huffman, 2018). For instance, in both rural or remote settings and in developing countries, the lack of technological infrastructure prevents large numbers of people from accessing online learning resources with ease (Hill and Lawton, 2018). Moreover, those who do live in areas with sufficient technological infrastructure may lack the appropriate knowledge, skills or economic ability to make use of it in an educational setting (Robinson et al., 2015; Huffman, 2018). Indeed, a recent U.K. Consumer Digital Index (2019) found that 22% of the population do not have essential digital skills for daily life (e.g. communicating or information handling), and that nearly half (47%) of all 'offline' users come from a low-income household (Lloyds Bank, 2019).

These wide ranging advantages and disadvantages of technology highlights the need to be pragmatic when introducing TEL, and emphasises the lack of a 'one-size-fits-all' approach to TEL in anatomy education. To increase the likelihood of successful outcomes, the selection and integration of technology must be achieved with consideration of the underlying pedagogical assumptions and implications (Smith et al., 2018), the characteristics of the local context and student demographics (Laurillard et al., 2009), the availability of existing evidence (Cook and Ellaway, 2015), instructional design principles (Gagne et al., 2005), as well as a pragmatic view of student engagement and the cost-benefit of implementing TEL (Ellaway, 2011a; Beetham and Sharpe, 2013; Cook and Ellaway, 2015).

2.4 Measuring Enhancement: Evaluating TEL in Anatomy Education

As previously described, the introduction of TEL is driven by various factors including the motivation to meet the needs of students by improving both operational outcomes and learning gains (Kirkwood and Price, 2014; Gibson and Sodeman, 2014; Rogaten et al., 2019). In order to determine if these outcomes have been met successfully, ongoing evaluation must be carried out. Evaluation of TEL is important for a host of reasons including: identifying areas for improvement; monitoring progress; gaining perspectives from all relevant stakeholders; determining if an approach is applicable in other settings, and; for sharing successful outcomes through scholarly activities (Ellaway, 2011a; Cook and Ellaway, 2015; Pickering and Joynes, 2016). In addition to this, evaluation is important for seeking support for the continued use of a resource by justifying the potential investments in time, cost, infrastructure and faculty development (Trelease, 2016; Pickering and Joynes, 2016).

For anatomy educators who wish to make informed decisions regarding the most effective TEL approaches available to them it is essential to, firstly, consider a comprehensive evaluation as part of the design, development and review of any new educational interventions, and secondly, to have an extensive literature base from which to draw upon the experiences of others (Trelease, 2016). Currently, there is a lack of understanding of the comprehensiveness of TEL evaluation within anatomy education. Understanding the current standards of evaluation is important since a lack of uniformity in evaluation approaches has consequences for establishing a consensus on the effectiveness of TEL, which makes implementing it into an active curriculum a difficult and daunting task (Ellaway, 2011a). Furthermore, there is a scarcity of evidence related to the methods of evaluations being carried out. Without this key information, it is difficult to determine the reliability of the literature base as a source of evidence for informed TEL integration.

2.4.1 Approaches to Evaluation within Medical Education

In order to determine if a TEL intervention is meeting the needs of relevant stakeholders (e.g. educators, students and the wider institution), a comprehensive evaluation should employ both qualitative and quantitative measures (Heineke and Blasi, 2001). According to Cook (2010), educational evaluation research can be orientated towards one of three paradigms: (1) Objectives-oriented approach, which focuses on pre-determined objectives such as student satisfaction or achieving learning outcomes (i.e. knowledge, skills and attitudes). This approach is used frequently in evaluation studies, however, Cook suggests there is a danger of this type of evaluation failing to account for unexpected outcomes, or understanding the reasons behind specific outcomes; (2) Participant-oriented approach, which evaluates the perceptions of relevant stakeholders by employing methods more heavily weighted towards qualitative data collection and analysis. This approach is more flexible that an objectives-oriented approach, however, requires time, resources and research expertise; (3) Process-oriented approach, which focuses on an educational intervention from inception, through implementation and onto review of outcomes. This approach is particularly resource-intensive, however, it does offer a comprehensive evaluation by incorporating elements of both objectives- and participant-oriented evaluation (Cook, 2010).

The choice of approach to evaluation depends upon a number of factors including, the educational intervention being evaluated, the research questions and the research paradigm of the educator (Cook and Ellaway, 2015). The methods for achieving these evaluation studies also vary depending on these factors and may include methods such as questionnaires, focus groups, observations, usability testing, usage metrics, assessment data, pre- and post-tests and cost-analysis (Cook, 2010; Cook and Ellaway, 2015; Pickering and Joynes, 2016). Determining the most appropriate approach for educational evaluation may be supported through an evaluation framework. These not only act as a guide for decision-making about data collection and analysis, but also support meaningful comparison across resources, learners, courses and institutions (Cook and Ellaway, 2015). Perhaps the most well-known of these is Kirkpatrick's (1994; 2010) four-stage evaluation model, which is widely cited as a means of evaluating the impact of a training or educational programme at four increasingly challenging levels – reaction, learning, behaviour and results. The model is designed with the intent that all four levels are addressed to determine the impact of a training programme on the individual learner, as well as the impact of their knowledge and behaviour in a wider context. However, it has been suggested that Kirkpatrick's model is focused primarily on quantitative outcomes, which fails to account for the narrative experiences of both learners and educators, and for unexpected outcomes requiring action (Cook and Ellaway, 2015). This view is supported by others who have suggested that Kirkpatrick's model provides an oversimplified approach (Holton, 1996; Yardley and Dornan, 2012), which limits its utility within a complex, multi-modal learning environment such as anatomy education.

Within medical education, Cook and Ellaway (2015) provide an evaluation framework that encompasses seven broad areas that are 'relatively unique to TEL'. These are: (1) needs analysis; (2) documentation of processes, decisions, and final product; (3) usability testing; (4) observation of implementation; (5) assessment of participant experience; (6) assessment of learning outcomes and; (7) evaluation of cost, reusability, and sustainability. Cook and Ellaway (2015) developed their framework by reviewing multiple existing evaluation models and theoretical constructs of inquiry. This comprehensive framework support a process-oriented evaluation and, as the authors suggest, provides an evaluation 'recipe' that meets the minimum requirements for evaluation of TEL within medical education (Cook and Ellaway, 2015).

A second comprehensive evaluation framework proposed within medical education is the Technology-Enhanced Learning Evaluation Model (TELEM) by Pickering and Joynes (2016). This framework builds on the work of Kirkpatrick (1994; 2010) and offers a four-level alternative that can be implemented for an individual TEL resource. The TELEM provides a step-by-step protocol for the evaluation of a TEL resource 'from its inception to the overall institutional benefit'. The authors state that a holistic understanding of the overall impact of a TEL resource on all relevant stakeholders can be achieved through engaging with all four levels of the framework (Pickering and Joynes, 2016). The four levels of TELEM are: *Level 0,* which ensures that technology is introduced for pedagogical purposes by first evaluating the initial need for TEL within the curriculum, for example to improve module evaluations or assessment outcomes. Following the decision to implement a TEL intervention and a resource has either been developed or procured, the first stage of evaluation (*Level 1*) can be undertaken. *Level 1* is divided into two sub-levels, where *Level 1A* is focused on affective outcomes such as perceptions, attitudes and satisfaction (e.g. using student surveys or focus groups), and *Level 1B* uses experimental methods such as pre- and post-tests to examine the TEL resource in isolation. This ensures the new resource provides at least equitable cognitive learning gains in comparison to an existing learning resource such as a textbook or cadaveric dissection. Once the resource has been proven to be well-perceived by students and that learning gain is equitable to that of an existing resource, *Level 2* measures the impact of a TEL resource on a whole cohort. This can be achieved by analysing assessment scores and usage data (i.e. quasi-experimental methods). Finally, *Level 3* evaluates the institutional impact of a TEL resource in terms of its cost utility (assigns a cost per student based on satisfaction rates), cost effectiveness (comparison of the outcomes of utilising alternative approaches or resources), and cost benefit (explores the impact of introducing a resource on the associated stakeholders).

Both Cook and Ellaway's Framework and the TELEM acknowledge and account for the multifactorial nature of TEL evaluation, the many confounding variables within educational research and the diversity of resources, students and other stakeholders (Cook and Ellaway, 2015; Pickering and Joynes, 2016). In accordance with Cook (2010), each model offers a framework for completing a comprehensive process-oriented approach to evaluation. However, in reality, due to financial limitations, time constraints within the curriculum and researcher paradigms, it is likely that researchers engage with specific parts or 'levels' of these evaluation frameworks depending upon the research aims (Cook, 2010). For instance, an outcomes-oriented approach to evaluation would focus more on measures of cognitive learning gains and may employ a *Level 1B* or *Level 2* approach in accordance with the TELEM. Alternatively, those undertaking a participant-oriented approach would employ a *Level 1A* investigation only. While these frameworks support the design and implementation of robust evaluation approaches, the degree to which evaluation frameworks are engaged with by educators within the field of anatomy education is currently unclear.

Furthermore, initial analysis of the literature suggests that TEL evaluation studies within anatomy education are extensive and highly variable. In addition, it seems there is a paucity of studies currently investigating the experiences of students engaged within multi-modal anatomy curricula. In order to determine the manner and extent to which these initial observations are true, a systematic review of the literature is required.

2.5 Student Engagement with Technology-Enhanced Learning

Examination of the aforementioned drivers for the introduction of TEL reveals, in essence, the longstanding desire to improve learning outcomes by increasing student engagement through the provision of effective and efficient learning activities (Laurillard, 2012). However, the ways in which students engage with and learn from TEL resources is a continuously changing interplay of affective, social, environmental, cognitive and meta-cognitive factors (Kahu, 2013). The complexity of engagement and learning is evident from the plethora of learning theories that have arisen from disparate academic disciplines (Schunk, 2012; Young et al., 2014). Moreover, many competing theories overlap and contradict one another, often introducing a variety of different terms for the same constructs, making it difficult to interpret and understand the intricacies of student engagement and learning with TEL resources in any discipline (Schunk, 2012), let alone within anatomy education.

Therefore, similar to Rogaten et al.'s (2019) distinction between three measures of learning gain, this section presents the multiple relevant theories associated with student engagement with TEL through the prism of three commonly cited domains of engagement, that is: affective, behavioural and cognitive engagement (Skinner and Belmont, 1993; Krause and Coates, 2008; Eccles, 2016). It should be noted that a distinction is made between Rogaten et al.'s (2019) learning gains and the domains of engagement based on the focus of 'measurement' assigned to learning gains, as opposed to the more theoretical consideration given to the domains of engagement. Together, the three domains of engagement are described as being a 'meta-construct' that combines multiple closely related constructs associated with student engagement (Skinner and Belmont, 1993; Krause and Coates, 2008; Eccles, 2016), where: (1) affective engagement relates to affective reactions such as enjoyment and interest while using a TEL resource; (2) behavioural engagement refers to the effort, persistence and contribution to a task, and; (3) cognitive engagement refers to the willingness and thoughtfulness to exert the effort required to learn new knowledge (Skinner and Belmont, 1993; Krause and Coates, 2008; Eccles, 2016). The following sections investigate the multiple relevant theoretical models related to student engagement and learning, and gives consideration to these constructs within the context of learning using TEL.

2.5.1 Constructs Related to Affective Engagement

Affective engagement encompasses multiple affective domains such as enjoyment and interest (Krause and Coates, 2008). These constructs overlap significantly with research associated with theories of motivation, so much so, some scholars often use the terms 'motivation' and 'engagement' interchangeably (Eccles 2016). Motivation can be defined as the direction and persistence of intention and activity within any setting or context (Ryan and Deci, 2000).

The most commonly cited theory of motivation within educational literature defines two types of motivation: firstly, intrinsic motivation is to do something because it is inherently enjoyable or satisfying, and secondly, extrinsic motivation is to do something in order to yield a reward (Deci and Ryan, 1985; Ryan and Deci, 2000). Self-Determination Theory (SDT), introduced by Ryan and Deci (2000), states that intrinsically motivated actions can be sustained for longer and exhibit greater learning outcomes as compared with extrinsically motivated actions which are said to last only as long as external incentives are available (Ryan and Deci, 2000). With this in mind, educators that develop or introduce TEL resources or learning activities that seek to improve affective reactions such as enjoyment and satisfaction may encourage deeper affective engagement with learning material driven by the student's intrinsic motivation.

SDT states that a student will be more intrinsically motivated if three basic needs are met, these are: (1) competence, they feel they have the ability to complete the task successfully; (2) autonomy, they believe the outcome of the task is entirely under their control and; (3) relatedness, they feel a sense of connection to others completing a similar task (Deci and Ryan, 1985; 2004). SDT postulates that these self-beliefs will vary depending on the task at hand, and will be different for every student. Each new learning experience will produce changes in feelings of competence, autonomy and relatedness; which in turn, will impact upon a students' quality of motivation throughout a learning activity, module or academic year (Kusurkar et al., 2012).

While intrinsic motivation to complete a task or course is an idyllic concept, in reality, and particularly within high-stakes settings such as medical education, actions cannot be truly intrinsically motivated (Amrein and Berliner, 2003). Pressures to complete essential activities that are not deemed to be interesting, and the requirement to engage with material which will assess appropriate knowledge and competency, are all mandatory aspects of training to become a doctor. For example, students committed to learning kidney anatomy because they acknowledge its value in their chosen career are extrinsically motivated, as are students learning kidney anatomy just to pass an assessment. This reality then raises questions around how students acquire the motivation to carry out such activities and how this motivation affects persistence and regulation of learning.

2.5.2 Constructs Related to Behavioural Engagement

Behavioural engagement refers to the effort, persistence and contribution to a task (Krause and Coates, 2008). The best predictor of behaviour is intention, which is the cognitive representation of a student' readiness to complete a given behaviour (Armitage and Conner, 2001; Hill et al., 2006). A student's intention to complete a learning activity, and their persistence during such a behaviour, can be explained using the expectancy-value theory of motivation and the theory of planned behaviour (Eccles, 1983, 2016; Hill et al., 2006).

Firstly, the expectancy-value theory of motivation (Wigfield, 1994; Wigfield et al., 2009; Partridge et al., 2013) is used to determine why individuals might choose one behaviour over another and assumes that individuals are goal-oriented. This is relevant to students engaged in multi-modal programmes and who are required to decide between a number of resources. This model is divided into expectancy beliefs, which refers to the anticipation of success that might result from a behaviour, and subjective task-value (Wigfield et al, 2009). Eccles and Wigfield (2002) distinguish between four different types of task value: (1) Interest value, is associated with perceived enjoyment of the task and can be divided into 'situational' and 'personal' interest (Fredricks et al., 2004; Hidi and Renninger, 2006). Situational interest is transitory and is akin to the 'novelty' effect, where students interest levels peak in response to key features or capabilities of a new resource but are not sustained. Personal interest, on the other hand, is relatively stable and more likely to result in sustained decision-making to pursue learning activities and a willingness to complete tasks (Hidi and Renninger, 2006; Eccles and Wigfield, 2001; 2002); (2) Attainment value, which is the importance of carrying out a task in order to confirm one's own knowledge to be true; (3) Utility value is the perceived importance of the behaviour with regards to future goals which, in the case of medical students, is likely the goal of passing assessments, and; (4) Cost value, which considers the perceived negative aspects of performing a behaviour. While cost value may be associated with financial costs of a resource, it may also refer to cost in time and energy (Eccles and Wigfield, 2001; 2002; Schunk et al, 2014).

Secondly, the theory of planned behaviour (TPB), developed by Fishbein and Ajzen (1980), is a model used to predict deliberate behaviour. This theory states that an individual's behaviour is determined by their intention to perform the behaviour, which in turn is determined by three key factors: attitude towards the behaviour; perceived behavioural control, and; subjective norms (Ajzen and Fishbein, 1980; Armitage and Conner, 2001). Firstly, attitude towards a behaviour is largely determined by subjective-task value and intrinsic motivation. Secondly, perceived behavioural control is closely associated with a sense of competence and autonomy regarding the behaviour in question (e.g. using a TEL resource). Finally, subjective norms relate to the perception that others believe the behaviour to be worthwhile (Ajzen and Fishbein, 1980; Armitage and Conner, 2001). This final factor of TPB is associated with the concept of social influence, which describes a change in attitude or behaviour as a result of a belief or action from another person (French and Raven, 1960). In line with social cognitive theory, this is important given that students may form perceptions of subjective norms through observation and imitation of educators and peers (Bandura, 1986; Schunk, 1989). Moreover, one meta-analysis distinguished between two types of subjective norms (Manning, 2009), where injunctive norms are an individual's perception of what other people want them to do, and descriptive norms are based on the inferred or observed behaviour of others. Manning (2009) found that descriptive norms have a stronger relationship with behavioural outcomes as compared to injunctive norms.

As a general rule, TPB postulates that the more favourable an attitude towards a given behaviour and the more positive the perceived subjective norm, the stronger the intention will be to perform a behaviour (Hill et al., 2006). Evidence of the efficacy of TPB in predicting behavioural outcomes is now well established both generally (Armitage and Conner, 2001; Manning, 2009) and specifically within medical education (Archer et al., 2008; Cooper et al., 2016; Hadadgar et al., 2016). Moreover, TPB has formed the basis for the well-established technology acceptance model (TAM). Developed by Davis (1989), TAM is both a predictive and explanatory model of the factors that influence TEL adoption in non-leisure settings. The model states that the perceived ease of use of a technology will have a causal effect on the perceived usefulness of said technology. In line with TPB, TAM states that these factors can impact on an individuals' attitude towards, intention to use and actual use of technology (Davis, 1989). This original model was the basis for supporting the development of the field of technology acceptance research, however, it now predates the ubiquitous nature of many technologies (Legris et al., 2003) and has been superseded by a more comprehensive framework (Venkatesh and Davis, 2000; Venkatesh et al., 2003; 2012), discussed in more detail in section 2.6.

Both the expectancy-value theory of motivation and TPB are closely related to the affective and cognitive constructs associated with engagement. These two models are important in understanding, and in some cases, predicting on-task behaviour. In relation to TEL engagement, a students' attitude towards the resource, their belief in how others perceive the resource, their perception of their own ability to use the resource and, their expectation that using the resource will lead to achievement of personal goals, will all play a role in both the active participation and persistence with which a student engages with it.

2.5.3 Constructs Related to Cognitive Engagement

Cognitive engagement is defined as the level of investment a student has within a task or course (Krause and Coates, 2008). The constructs related to cognitive engagement arise from cognitive theories of learning, such as, self-regulation and cognitive load theory (Zimmerman, 1990; Chandler and Sweller, 1991).

Cognitive engagement is, in essence, the willingness to exert and reflect upon the effort required to achieve the appropriate learning outcomes. This ability to regulate one's own learning is theorised by both Knowles (1975) and Zimmerman (1990) via the respective theories of 'self-directed learning' and 'self-regulated learning'. These terms are defined similarly in that they both involve a goal-oriented task supported by active participation, metacognitive abilities and motivation. Although these terms are often used interchangeably, the major difference between them lies in the context and application of the term. Self-directed learning is normally associated with learning outside of the traditional educational environment and activities are driven by the learner (Knowles, 1975). In contrast, self-regulated learning is associated with traditional educational settings and can be facilitated by an educator who sets tasks and activities (Zimmerman, 1990). In the context of learning with TEL resources within an active anatomy curriculum, where many of the resources are provided by the instructor, the theory of self-regulated learning is the most applicable.

The concept of self-regulated learning can be defined as: *"an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals"* (Pintrich, 2000, p.453). According to Zimmerman (2011), this is a cyclical process occurring over three broad phases: forethought, performance and self-reflection. The forethought phase is the process of task-analysis through goal setting and strategic planning. The performance phase involves self-monitoring of learning processes and on-task behaviour, and the self-reflection phase is a self-judgement of the learning experience and subsequent actions taken (Zimmerman, 2011; Panadero and Alonso-Tapia, 2014). Ability to self-regulate learning has been found to have a profound impact upon task performance (Zimmerman and Schunk, 2011;

Panadero and Alonso-Tapia, 2014); and may be influenced by factors such as intrinsic motivation, perceived task-value and expectancy-beliefs (Zimmerman, 2011), in other words, the amount of affective and behavioural engagement the student has with a specific learning resource or task.

The role technology plays in specifically supporting the regulation of learning is variable between students (Yot-Domínguez and Marcelo, 2017); although it has been suggested that effectively designed technology can play an important role in improving regulatory behaviours (Li and Zheng, 2018). Indeed, there is a plethora of literature related to the design of TEL resources using cognitive load theory (CLT), which gives appropriate consideration of the human cognitive architecture (Sweller, 2003; Ellaway, 2011b; Young et al., 2014). CLT categorises the three types of cognitive load that act on working memory when presented with new information: intrinsic load, extraneous load and germane load (Sweller, 1988). Intrinsic load is based upon the inherent complexity of the educational content presented. Extraneous load relates to the processing of information not related to the educational content and, is therefore dependent upon the design of the resource. Germane load, on the other hand, is related to the effort required to understand the information presented and to create a schema (i.e. when information within working memory is shifted and retained within long-term memory). As such, improving a students' cognitive engagement with TEL resources relies upon such a resource being designed and developed in a manner that attempts to reduce extraneous load in order to support germane load (Kirschner et al., 2006; Hadie et al., 2018). The design of such resources may be supported by frameworks such as Mayer's cognitive theory of multimedia learning (CTML) (Mayer and Moreno, 2003; Mayer, 2005). Through the provision of 12 instructional design principles, the framework supports the development of efficient and effective TEL resources. These include principles such as the redundancy principle (i.e. people learn better from images and narration, than from images, narration and on-screen text), the signalling principle (i.e. people learn better when the organisation of material is highlighted appropriately) and the multimedia principle (i.e. people learn better from pictures and narration, than from narration alone) (Mayer 2009). Employing such principles to effectively design a resource can play a significant role in improving regulatory learning behaviours (Li and Zheng, 2018).

2.6 Review of Technology Acceptance Models

Through the three main domains of student engagement, the previous section has outlined the factors that may influence the level and persistence of engagement with learning activities.

Many of these constructs were developed from the field of psychology and are directly applicable to students' use of technology. As previously mentioned, a good example of this is TAM (Davis, 1989), however, a more up to date model of technology acceptance has since been established known as the Unified Theory of Acceptance and Use of Technology (UTAUT). Developed by Venkatesh and Davis (2000), the model is an amalgamation of prior technology acceptance research (Taylor and Todd, 1995; Venkatesh et al., 2003; 2012). The original UTAUT (Venkatesh et al., 2003) is composed of four constructs. These include: performance expectancy, defined as 'the degree to which an individual believes that using the system will help him or her to attain gains in job performance' (p.447); effort expectancy, defined as 'the degree of ease associated with the use of the system' (p.450); social influence, defined as 'the degree to which an individual perceives that important others believe he or she should use the new system' (p.451); and, facilitating conditions, defined as 'an individuals' perceptions of the resources and support available to perform a behaviour' (Venkatesh et al., 2003). In 2012, the same authors published the UTAUT2, which updated the research model to include three additional constructs: hedonic motivation, price value and experience (Venkatesh et al., 2012). Following extensive studies investigating the explanatory power of the original UTAUT and the newer UTAUT2, Venkatesh et al (2003; 2012) confirmed that behavioural intention to use a technology is largely determined by the constructs of performance expectancy, effort expectancy and social influence. This research group have repeatedly found that all three factors have an impact on intention to use a technology when tested empirically, but that these effects vary with age, gender, and previous experience. As an example, the authors found that females are more strongly influenced by effort expectancy and facilitating conditions than males (Venkatesh and Morris, 2000; Venkatesh et al., 2003; 2012). Furthermore, the constructs of performance expectancy, effort expectancy and social influence are closely linked with the aforementioned constructs of expectancy beliefs, subjective task value, perceived competence and autonomy, as well as relatedness to others and subjective norms (Deci and Ryan, 2004; Hill et al., 2006; Eccles and Wigfield, 2001; 2002), highlighting the evident links between theories of engagement and the use of TEL.

With regards to studies utilising technology acceptance models such as UTAUT and UTAUT2 (henceforth jointly referred to as 'UTAUT'), it appears the majority of studies focus on technology adoption in a corporate setting rather than for education related activities. Nevertheless, educational versions have been developed. Studies investigating the acceptance of specific technologies such as new e-learning systems (e.g. Park, 2011; Chen, 2011) or the use mobile devices in an educational setting (e.g. Wang et al., 2009; Abu-Al-Aish and Love, 2013) have utilised technology acceptance models. However, it is apparent that models like UTAUT are not specific enough for education based technology adoption, with several studies citing the need to include additional constructs to make it applicable in an educational setting. For instance, in studies investigating the inclusion of tablet devices, Wang et al (2009) added constructs surrounding 'perceived playfulness' and 'self-management of learning', while Abu-Al-Aish and Love (2013) included constructs of 'quality of service' and 'personal innovativeness'. In addition, Chen (2011) used the original UTAUT framework to investigate the adoption of an e-learning system and found that the additional construct 'educational compatibility' (i.e. how well aligned the system is to student expectations) was the most significant dimension in predicting acceptance and use of the e-learning system, more so than the original UTAUT constructs. The authors suggest that the emphasis on educational compatibility infers that if a TEL resource meets a student's educational needs, they will use it regardless of other factors. The authors go on to suggest that in e-learning systems, the use of the system may be improved through appropriate design and development of the educational environment to ensure it meets student needs (Chen, 2011).

While the UTAUT highlights important factors that may influence students use of TEL, the necessity for researchers to add education-specific constructs suggests that the items within the UTAUT sub-scales do not accurately reflect the whole picture for students' engaged in a multi-modal, high stakes learning environment. Indeed, it appears neither the original UTAUT or UTAUT2 have previously been used within anatomy education, suggesting it is not fit for purpose. Furthermore, literature specifically investigating students' expectations of and experiences with using TEL resources in HE have found the following factors as having a substantial impact: (1) a students' attitude towards technology (Volery and Lord, 2000; Park, 2011; Lai et al., 2012); (2) the design of the resource, in terms of elements such as usability, flexibility and interactivity (Volery and Lord, 2000; Sun et al., 2008; Wu et al., 2010; Lai et al., 2012; Chow and Shi, 2014); (3) the perceived usefulness of the resource in achieving intended goals (Sun et al., 2008; Paechter et al., 2010; Wu et al., 2010; Park, 2011; Joo et al., 2017) and; (4) social influence (Volery and Lord, 2000; Sun et al., 2008; Paechter et al., 2010; Park, 2011; Lai et al., 2012; Chow and Shi, 2014). These findings were achieved without employing UTAUT as a framework, in fact, many studies have developed a survey instrument specific to their own educational setting and associated theoretical framework (e.g. Volery and Lord, 2000; Sun et al., 2008; Paechter et al., 2010; Wu et al., 2010; Lai et al., 2012).

Reviewing existing TAMs, particularly UTAUT, highlights key constructs to consider in relation to students experiences with TEL. However, it is evident that UTAUT is not fit for purpose as a standalone measure of technology acceptance within an educational setting. Moreover, the use of survey scales developed specifically to measure students' experiences of TEL do not currently have widespread use across multiple educational fields and, along with UTAUT, are seemingly absent within anatomy education literature. Furthermore, the subject of anatomy is largely taught using cadaveric material alongside diverse, numerous and highly specific TEL resources (Estai and Bunt, 2016) generating a relatively unique learning environment. For these reasons, it can be postulated that an anatomy-specific survey investigating students' experiences with TEL is required.

2.7 Student Experiences with Technology in Anatomy Education

Within anatomy education, a small number of studies have investigated the various constructs related to student engagement outlined in section 2.5. These studies tend to focus on engagement with learning anatomy in general, as opposed to specifically using technology. For example, Smith and Matthias (2010) developed the Anatomy Learning Experiences Questionnaire (ALEQ) which incorporated items related to working with cadaveric specimens, challenges in learning anatomy, perceived relevance of anatomy to clinical contexts and preferred learning activities and resources (Smith and Matthias, 2010). While the study was purely quantitative, the authors described alignment between items on the ALEQ and themes identified from a phenomenological study of learning approaches to anatomy (Wilhelmsson et al., 2010). In addition, many of the items within the ALEQ were derived from and subsequently compared with the Approaches and Study Skills Inventory for Students (ASSIST), a validated scale designed to investigate deep, strategic and surface approaches to learning (Entwistle et al, 2000; Entwistle and Tait, 2013). The ASSIST scale has been used elsewhere within anatomy education (Pandey and Zimitat, 2007; Ward, 2011; Bockers et al, 2014), however, Choi-Lundberg et al (2017) argue that the ASSIST scale is not wholly appropriate for anatomy education as it does not relate to typical anatomy teaching within a multi-faceted medical curricula. Consequently, the authors altered the ALEQ to be more specific to anatomy learning outcomes, and rather than compare this to existing validated scales, carried out factor analysis to determine three underlying constructs related to experiences of learning anatomy (Choi-Lundberg et al, 2017). The three factors – challenges in anatomy, applications and importance of anatomy and, learning with cadaveric material – were correlated with assessment outcomes in medical students, revealing that the 10-item subscale related to challenges in anatomy was predictive of success, suggesting this could be used as a measure for identifying struggling students (Choi-Lundberg et al, 2017).

The numbers of studies investigating these various psychometric factors is small within anatomy education. It appears just two studies have investigated the experiences of students with TEL (Johnson et al, 2013; Davis et al, 2014). In the first, Johnson et al (2013) used a 26-item survey to explore students perceptions of learning resources before and after the inclusion of additional online resources. They found that there was no significant difference between students opinions of online learning between these two time points. Since this was in contradiction to the highly positive open comments left by students, the authors followed up with a focus group with survey respondents (Johnson et al, 2013). These discussions revealed that students already had access to a wide range of online resources and were consequently unconcerned with the addition of more resources. Furthermore, the students described their perception of the educators as having a role in guiding students to reputable and relevant sites (Johnson et al, 2013). In a similar study, Davis et al (2014) used a 31-item survey to investigate students preferred teaching methods and learning preferences. They found that most students favoured cadaveric dissection over other teaching methods and mature students were most likely to prefer TEL resources. The authors compared views of educators and students and found that students were less enthusiastic about TEL and supported its use as purely supplementary to cadaveric dissection (Davis et al, 2014). Unlike the study by Johnson et al, the authors did not use additional methods to investigate the reasons behind these views. Their study, therefore, falls short in understanding which aspects of the various resources available to students impact upon their engagement with TEL.

With regards to these two studies, it is particularly noticeable that many of the affective, behavioural and cognitive constructs of engagement described in section 2.5 have not been considered as part of the data collection, analysis or interpretation of results. In addition, it is notable the items that are included focus exclusively on positive attributes of TEL, without consideration of the aforementioned possible 'digital downsides' of technology such as distractions, digital competency or privacy concerns (Selwyn, 2016). This highlights a lack of theoretically informed, robust investigations in anatomy education and leaves questions unanswered with regards to the role TEL is playing for students currently engaged within a multi-modal anatomy curriculum.

2.8 Research Questions and Objectives

This literature review has highlighted the drivers for the introduction of TEL within anatomy education. Principally, TEL is employed as a means of improving learning outcomes by increasing student engagement through the provision of effective and efficient learning activities. Ensuring that these outcomes are met requires ongoing evaluation of educational practices, however, the current level of TEL evaluation being carried out within anatomy education is unknown. Furthermore, this chapter highlighted the multidimensional nature of students' experiences with TEL by reviewing the many variables that may influence student engagement with TEL resources. At present, it appears there is a scarcity of studies currently investigating the experiences of students engaged within multi-modal anatomy curricula. However, in order to determine the manner and extent to which these initial observations are true, a systematic review of the literature is required.

Consequently, this thesis set out to explore these gaps in the literature following two main research objectives. The first, an outward facing examination of the current landscape of TEL evaluation literature within anatomy education, and the second, a comprehensive institutional study exploring student experiences with TEL and the factors influencing their engagement with such resources.

The first study in this thesis examined the current methods of evaluation within anatomy education literature. This was achieved through a systematic literature review and sought to answer the following research questions:

RQ1: How comprehensively are TEL resources being evaluated within anatomy education?

RQ2: To what extent, and in what ways, are student experiences with TEL investigated within anatomy education? And, within these studies, what factors are perceived to be important in measuring student experience?

The second study in this thesis explored the factors influencing student perceptions and use of TEL for studying anatomy using an exploratory sequential mixed methods approach. As will be described in the proceeding chapters, this three-part study employed MBChB students at the University of Leeds currently engaged within an active anatomy curriculum and sought to answer the following research questions:

RQ3: What are students' perceptions of anatomy TEL resources? And, is there a relationship between these perceptions and variables such as assessment scores, gender and resource preference?

RQ4: What factors influence student perceptions and use of TEL resources within anatomy education?

a) What are the prominent themes surrounding students' perceptions and use of TEL in anatomy education?
b) In what way does qualitative inquiry support the reported perceptions of TEL in anatomy education established via a survey?
c) In what way do the results of a newly developed survey relate to the findings from the pilot survey and qualitative inquiry?

The following chapter outlines the emergent conceptual framework, the research design and methodological approaches to address these research questions.

Chapter 3

Conceptual Framework and Research Design

3.1 Introduction

The purpose of this chapter is to outline and justify the methodological approaches taken to answer the research questions. This is achieved by, firstly, reviewing the research gap this thesis will address. Secondly, the emergent conceptual framework of the thesis is described. This framework utilises the theoretical underpinnings of student motivation, behaviour and learning, discussed in the previous chapter, and applies these to the context of engagement with TEL in anatomy. Next, the philosophical assumptions driving the design and development of the research are highlighted, providing context and justification for methodological choices. Finally, the research design and rationale for engaging in a mixed methods study is presented.

3.2 Identifying the Research Gap

Chapter 2 revealed three relevant domains within the literature. Firstly, due to a number of relevant drivers, the current landscape within anatomy education is becoming increasingly multi-modal with a growing reliance on technology. Secondly, robust evaluation of both existing and new TEL resources is imperative for determining the effectiveness of TEL in achieving outcomes such as improved affective, behavioural and cognitive learning gain. Finally, student engagement with TEL is a complex, multidimensional construct with several intrinsic and extrinsic factors influencing student motivation, behaviour and learning with TEL resources.

At present, there is a lack of understanding related to the comprehensiveness of current TEL evaluations within anatomy education. More specifically, there appears to be a paucity of robust, in-depth evaluations of the many factors influencing student engagement with TEL. In order to address this gap in the literature, this study describes a comprehensive systematic review of current TEL evaluation literature within anatomy education, with particular focus on the evaluation of student experiences. While this approach provides details of the current landscape in TEL evaluation literature, the major limitation of such an approach is the review of published articles only. Therefore, this approach does not account for the unknown number of resources available to students outside of their institutional setting. The lack of evidence surrounding the use of TEL resources available through online open access and commercial providers is particularly notable given that evidence shows students readily engage with externally provided resources via Google, YouTube and Wikipedia (Kingsley et al., 2011; O'Carroll et al., 2015; Pascoe, 2020); with one study finding that Google is the first port of call for the majority (75.7%) of medical students' when searching for information (Kingsley et al., 2011). This suggests that the extent of the use of online resources, particularly those available from external providers, is currently unknown (Trelease, 2016). This raises concerns surrounding the experience of students actively engaged within anatomy curricula, how they manage and navigate a multi-modal environment and, most importantly, the factors that influence their use of TEL. Understanding the reality for students currently studying anatomy, may help educators understand the factors that may improve, or be detrimental, to student engagement with TEL. This study addresses this gap in the literature by using a robust mixed methods study to explore the factors influencing student perceptions and use of TEL in anatomy education at the University of Leeds.

3.3 Conceptual Framework

This study argues that there is a need for more comprehensive evaluations of student experiences within multi-modal anatomy curricula. In Chapter 2, some of the specific variables that may positively or negatively impact upon student engagement with TEL were described (section 2.5). It is apparent that no single conceptual or theoretical framework exists that would suitably describe the relationship between these variables with regards to anatomy education. Therefore, a new conceptual framework was established specifically for this study. This was achieved through consideration of the various factors that may influence students attitude towards and engagement with TEL and was informed by the theoretical models described in section 2.5.

Figure 1 summarises the conceptual framework that was formulated early in the project and was used to inform the approach to data collection, analysis and interpretation. In considering the factors that may influence students' attitude towards and engagement with TEL, it is likely there are multiple factors that are both extrinsic and intrinsic to the student. This classification is in line with the theory of motivation described by Deci (1985). Extrinsic factors that may be influencing attitude towards and engagement with TEL are social influence, cognitive load, curriculum design and, while not investigated in this study, it acknowledged that socioeconomic background plays a role in determining normative beliefs, access and previous experience.

With regards to the extrinsic factors investigated in this study, social influence is the belief a student has about the perceptions of educators and peers with regards to TEL. This is in line with the constructs of relatedness and subjective norms, as described by SDT and TPB (Ajzen and Fishbein, 1980; Armitage and Conner, 2001; Deci and Ryan, 2004). Furthermore, reference to cognitive load as an extrinsic influencing factor acknowledges that TEL engagement may be variable depending upon the anatomical content being learned, and the TEL resources available for such content. For instance, resources such as 3D visualisation technologies may help to reduce cognitive load when learning structures inherently difficult to visualise in three dimensions (Yammine and Violato, 2015). In addition, cognitive load refers to the load imposed on a student as a result of resource design. That is, how well a resource aligns with instructional design principles, such as Mayer's principles of multimedia learning (Mayer, 2009), in order to reduce extraneous load during use. Moreover, curriculum design will also have a large influence on attitude towards and engagement with TEL by impacting on the time students are able to dedicate to anatomy revision as well as the timing of, and stakes involved in summative assessments. This is particularly relevant as participants in this study are medical students who are not only engaged in a multi-modal anatomy curriculum, but also within a busy, content-heavy medical education programme.

The factors influencing TEL engagement that may be intrinsic to the student include, subjective task-value, personal goals, perceived competence in using TEL, and metacognitive abilities. As established by theoretical models such as expectancy-value (Eccles and Wigfield, 2001; 2002), students complete learning behaviours, such as engaging with TEL resources, when there is perceived value in doing so. This is particularly relevant when students have the choice of a multitude of learning resources available to them from both their institution and online sources. For instance, a students' subjective interest value may be linked to the perceived enjoyment of a particular aspect of anatomical content or a particular type of resource. Subjective cost value may be linked to the perceived cost in time or energy required to engage with a resource. These are likely linked to curriculum design and a perceived need for time efficiency, as well as cognitive load where poorly designed resources may impose greater load and require additional energy. Furthermore, subjective attainment value and utility value are linked to students own personal goals. Students engaged in an anatomy curriculum are likely to be motivated to pass summative assessments, progress to the next year and, in the case of medical students, to become a successful doctor. Each of these goals may play varying roles when students are deciding which learning resources to engage with. As such, it can be argued that students will be more intrinsically motivated to use resources they perceive to be enjoyable, time and energy efficient, and aligned with their own personal goals.

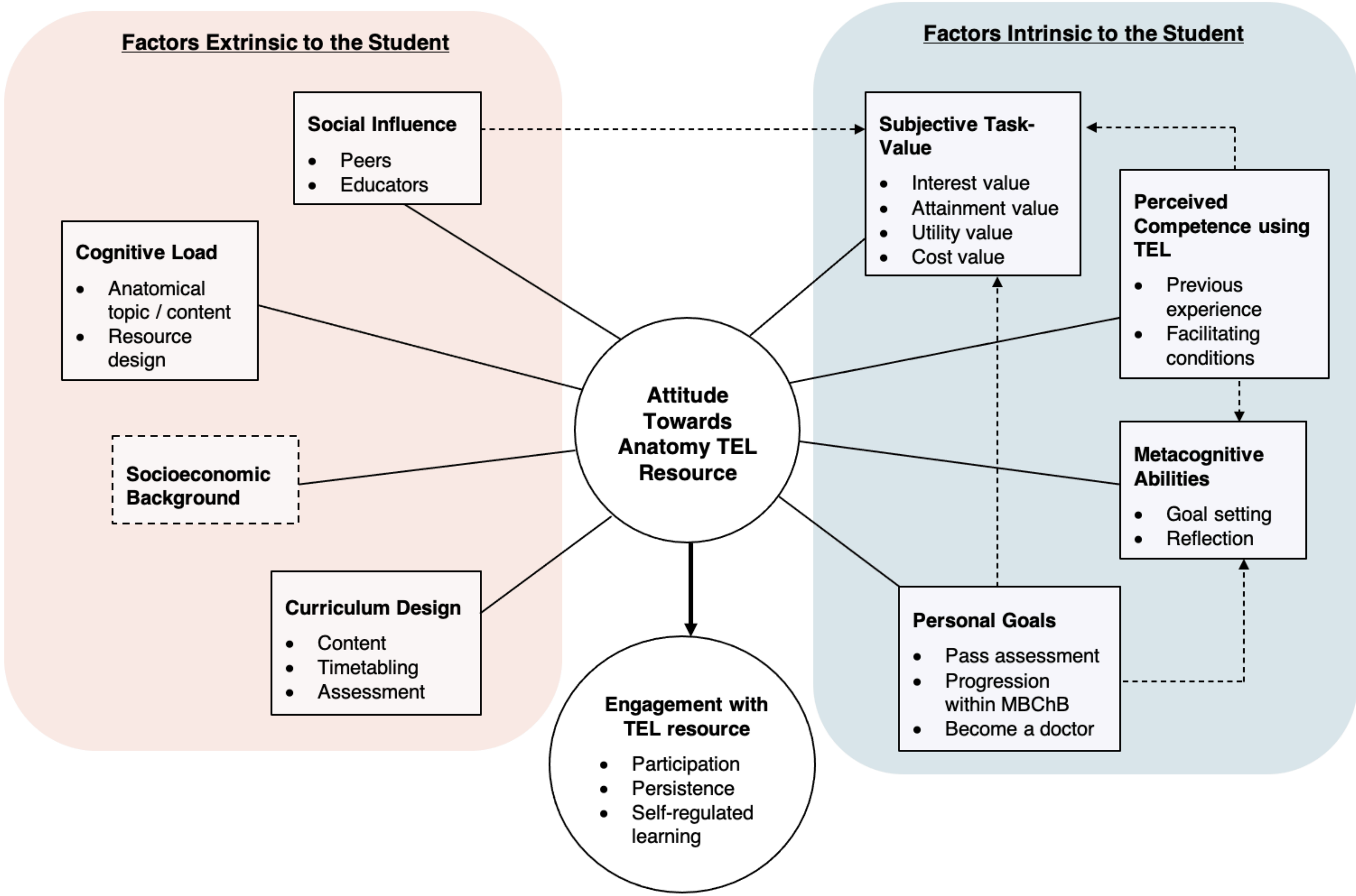


Figure 1: Conceptual Framework of the Thesis Schematic representation of the various factors that may influence students attitude towards and eventual engagement with TEL in anatomy education. While this framework is informed by a number of theoretical models (described in section 2.5), it is acknowledged that the relationship between these factors is multi-faceted

Furthermore, a students decision to engage with a TEL resource may also be influenced by their perception of their own ability to use the resource. This perception is most likely a by-product of their previous experiences using technology in an educational setting, and the perceived level of support provided by their educator, peers and institution (Venkatesh and Davis, 2000; Armitage and Conner, 2001; Venkatesh et al., 2003). These factors may influence a student's feeling of competence and autonomy, which in turn may impact upon their intrinsic motivation to complete a relevant task (Deci and Ryan, 2004). Without the belief that they have the ability to use a TEL resource successfully, students are less likely to want to engage in with it (Ajzen and Fishbein, 1980). Moreover, students' attitude towards and engagement with TEL will be influenced by their awareness and understanding of their own learning processes (i.e. metacognition). The ability to track and reflect upon their experiences of utilising a TEL resource and subsequently planning or altering learning behaviours as a result, will ultimately impact upon the resources a student decides to utilise at various points throughout the curriculum (Zimmerman, 1990). In addition, while metacognitive abilities will vary between students, it is likely that many will reflect upon both the extrinsic and intrinsic influencing factors described here eliciting questions such as: How easy is it to use? Will it benefit my personal goals? Is it an efficient use of my time? Will it motivate my learning?

Finally, this conceptual framework postulates that all of the above factors are interrelated in a multi-facted, complex manner and act together with varying degrees in order to determine a students' attitude towards and eventual engagement with a TEL resource. That is, the level of participation and persistence with which students are willing to engage with a TEL resource, if at all. Of particular interest is the persistence exerted when engaging with TEL – in other words, what factors influence a student's retained and returning engagement? To some extent, the ability to self-regulate learning plays a role, with students who are particularly adept at planning, executing and reflecting upon their own learning experiences (Zimmerman, 2011). However, it seems this is not the whole picture and further investigation is required to explore this subject in more detail.

3.4 Philosophical Assumptions

Drawing on the meta-theoretical perspective of critical realism, this thesis recognises that anatomy students are exposed to a variety of TEL resources from both inside and outside of their institution. This ontological stance aligns with critical realism in that the researcher believes there is an objective, physical world that exists independent of an individual's perceptions or theories, however, personal experiences of that reality can vary greatly. What an individual believes or perceives is shaped by their assumptions and prior experiences (Archer et al., 2016). At the University of Leeds, students enrolled on the MBChB programme are provided with anatomy TEL resources such as lecture recordings, dissection videos, eBooks, screencast videos and a MOOC (see section 1.2 and 5.2 for more detail). These resources are designed to encompass the majority of learning objectives, however, the reality of studying such a vast topic area means students also have access to mobile applications, YouTube videos and innumerable webpages. The manner in which students engage with these resources will depend on a host of personal attributes and external influences and will, not only be unique to each individual, but be variable at different time points throughout the academic year.

Furthermore, the epistemological position of this study postulates that student experiences with TEL while enrolled in an anatomy course can be studied to a certain extent by measuring objective variables and understanding subjective views. The researcher believes that while generalisations can be made, it is impossible to obtain a complete understanding of a studied phenomenon since an individual's understanding of that phenomenon is naturally their own construction, rather than a purely objective view of reality. This stance aligns with critical realism by acknowledging that, in essence, every theory, model, framework or conclusion is inevitably an abstract and imperfect attempt to comprehend a small part of a complex reality (Archer et al., 2016)

3.5 Research Design

As outlined in section 2.8, this thesis carries out two main studies in order to better understand student experiences with TEL, firstly by exploring the existing literature base via systematic review, and secondly, by undertaking a mixed methods study exploring the perceptions of medical students at the University of Leeds. Table 1 describes the study protocol for this thesis.

A systematic review was chosen as the method for answering RQ1 and RQ2. There exists innumerable studies evaluating TEL within anatomy education literature which, without a systematic approach, would provide an unmanageable volume of data (Cook and West, 2012; McCutcheon et al, 2016). A systematic review of the literature offers a means of efficiently collating and integrating the existing information. The systematic nature of the method provides an exhaustive examination of the current levels of evaluation being employed within anatomy education (Cook and West, 2012).

The second study answers RQ3 and RQ4 by employing an exploratory sequential mixed methods approach. The principle aim of this study is to achieve an understanding of the factors that influence student perceptions and use of TEL in anatomy education. The major strength of mixed methods research is the ability to enhance descriptions and understandings, and to corroborate findings from multiple sources (Lavelle et al., 2013). The main principle of any mixed methods approach is to use both quantitative and qualitative methods together in a single study (Bryman, 2006; Sandelowski, 2003; Tashakkori and Creswell, 2007). This approach was chosen for this study as it aligned with the researcher's paradigms and provides a more methodologically robust approach since the benefits of one method can compensate for the limitations of another (Teddlie and Tashakkori, 2009).

3.5.1 Rationale for an Exploratory Mixed Methods Study

The sequence of data collection and analysis in the second study was QUAN-QUAL-QUAN, with the three main stages of the study characterised as: (1) pilot survey; (2) follow-up focus groups and; (3) integration of findings to develop the Anatomy TEL Utility scale, a validated survey scale specific to the perceived utility of TEL for learning anatomy

This particular design of mixed methods research is a commonly used method for developing a survey instrument (Creswell and Plano Clark, 2011). As such, it has also been referred to as the 'instrument development design' (Creswell et al., 2004). According to Creswell and Plano Clark (2011, p.86), this design is useful *"when the researcher needs to develop and test an instrument because one does not exist, or to identify important variables to study quantitatively when the variables are unknown".* This study develops and tests a survey instrument because, while other validated scales exist, no single scale encompasses the multidimensional nature of learning anatomy with TEL. Furthermore, a preliminary conceptual framework has been established (Figure 1) as a means of considering the relationship between the many variables within this topic, however, further investigation is required in order to determine the importance of these variables and to establish if others exist.

Firstly, a pilot survey was developed, informed by the findings from the systematic literature review, and then analysed using exploratory factor analysis (EFA). Survey instruments have many strengths, including generalisability, as well as statistical validity and reliability, however, they also have methodological weaknesses such as respondents misinterpreting questions and the limited capacity to explain the reasons for patterns in the data or to understand the questions that may be ambiguous or misinterpreted (Gravetter and Forzano, 2012). Qualitative

Table 1: Overview of study design

Phase	Procedure	Outcome
Systematic literature analysis	• Systematic review of studies evaluating TEL resources in anatomy	• The majority of studies utilise student surveys however there is a lack of consistency and rigour in the methods used • There is a bias towards positivist research approaches
↓ Quantitative data collection	• Integration of literature analysis and conceptual framework to develop pilot survey items • Pilot survey deployed to Year 2 MBChB students	• Development of a 30-item pilot Anatomy TEL utility scale • Raw numeric data • Participant demographics

↓ Quantitative data analysis	• SPSS data analysis
	  ○ Frequencies
	  ○ Factor analysis (PCA)
	  ○ Correlations
	  ○ Non-parametric analysis
		• Descriptive statistics
		• Examination of relationships between variables
		• Associations between and within groups
		• Emergent factors (N=3)

↓ Qualitative data collection	• Development of focus group schedule • Invite survey respondents to attend focus groups • Transcribe audio files from focus groups	• Open-ended questions in a semi-structured format • 12 survey respondents volunteer to participate • Three transcribed focus groups with notes

↓ Qualitative data analysis	• NVivo data analysis
	  ○ Coding and thematic analysis
	  ○ Repeat analysis after four months
		• Codes and themes
		• Conceptual model of themes identified

↓ Integration of Quantitative and Qualitative Findings	• Independent analysis of quantitative and qualitative findings • Integration of quantitative and qualitative findings	• Quan = three emergent factors from pilot survey • Qual = five themes identified from focus groups • Refined survey instrument ○ 28-item scale
↓ Quantitative data collection and analysis	• As described above	• 23-item Anatomy TEL Utility scale with four emergent factors • As described above

approaches such as interviews or focus groups complement these limitations by allowing for a more in-depth understanding of the phenomenon being studied. By first developing a pilot survey instrument based upon existing validated survey scales, and with consideration of the many anatomy-specific and general educational factors, underlying constructs from the pilot survey items could be identified using EFA. These constructs were explored further by employing focus groups which allowed a deeper understanding of how students perceive and interpret their own experiences with TEL in anatomy.

Focus groups were chosen as the qualitative method within this exploratory design because information exchange within a group setting can be interactive and dynamic which allows for an exploration of contrary opinions and reflection (Stalmeijer et al., 2014). However, employing a small sample size increases the chances of bias, making it difficult to generalise findings (Krueger, 2002; Stewart and Shamdasani, 2015). Nevertheless, for this study, the use of multiple methods of data collection and robust data triangulation offsets the strengths and weaknesses of one method against another. Such a mixture of approaches is required to reduce any bias that could be generated from using a single methodological approach. In addition, measuring the same phenomenon using different data sources provides corroboration on data accuracy and enhancement of the study's conclusions (Teddlie and Tashakorri, 2009). Finally, the quantitative and qualitative findings were triangulated in order to refine the survey scale, leading to the development of the Anatomy TEL Utility scale.

Developing an understanding of the factors that may positively or negatively affect learning can help to provide anatomy educators with an understanding of the lived experiences of students engaged in a multi-modal anatomy curriculum. The findings from this study may help to build recognition of what TEL in anatomy education is actually achieving, in comparison to what it is hoped it might be (Trelease, 2016).

3.6 Account of Reflexivity

Within educational research, and indeed within the wider social sciences, the researcher plays a significant role in the research process making true objectivity an impossibility (Finlay, 2002). When beginning to theorise the research problem, it is important to acknowledge that researcher bias is the starting point from which the researcher is drawn to the problem and will continue to impact the way data is collected, analysed and interpreted (Wolcott and Fontana, 2006). For this reason, it is imperative that I reflect upon my own experiences as an anatomy student, as well as my more recent experiences as an anatomy educator.

Having completed anatomy training at both the undergraduate and postgraduate level, I am acutely aware of the issues novice learners face when approaching anatomy education. At the time of my undergraduate training, social and cultural norms dictated that sourcing information online could be jeopardous to progress since such information was knowingly unregulated and therefore deemed untrustworthy. As a result, I rarely deferred from the recommended resources and those provided by my institution. Since transitioning into a teaching role, I am aware of the increasingly vast and diverse nature of TEL within anatomy education as well as a social and cultural shift towards increased acceptability of online sources of information. I strongly believe that technology, when used appropriately, can successfully support anatomy students and improve engagement. However, due to my previous experiences, I have an inherent scepticism towards online resources. When using them myself I ensure they align closely to the curriculum I am teaching on, however, I do acknowledge that as a qualified anatomist, cherry-picking appropriate resources is a lot easier now than it was as a novice. I am interested in understanding the experiences of students currently enrolled in an anatomy curriculum, and what measures they put in place (both consciously and unconsciously) to determine if a TEL resource is worth using or not.

By reflecting upon and articulating my own background and experiences as the lead researcher in this study, I acknowledge the filter through which the research questions are developed, as well as the manner in which this study's resultant data is analysed and associated findings are interpreted (Sutton and Austin, 2015). This is particularly relevant to the interpretive nature of conducting and analysing focus groups. As a demonstrator within the Division of Anatomy at the University of Leeds, the participants of the focus groups were aware of my presence and had all been formally taught by me. This had the potential to limit effective and transparent interactions between myself and the students. However, as a demonstrator, I had no responsibility for curriculum development, assessment or marking, which meant the possible effect of any perceived power relationship on student answers was low. My lack of influence over course decision-making meant that I could engage the students in more candid discussions regarding their perceptions and opinions of TEL in anatomy.

My own personal experiences may not only impact upon how students engaged with me during focus groups, but also how I analysed and interpreted the data collected from them. This potential influence was monitored through continuous reflection with supervisors, colleagues and a research journal.

3.7 Summary

This chapter has emphasised the research gaps identified in Chapter 2 and described how this study addresses such gaps. The research design was informed by the philosophical assumptions of the researcher and the emergent conceptual framework, both of which were described within this chapter to provide context for the key considerations and rationale behind methodological approaches. The following chapter details the systematic literature review, addressing RQ1 and RQ2, the findings from which help to inform the proceeding chapters.

Chapter 4

Evaluation of TEL in Anatomy Education: Systematic Literature Review

4.1 Introduction

This chapter describes a systematic literature review conducted with the aim of developing a better understanding of the nature and scope of TEL evaluation within anatomy education. The aim of this systematic review was to answer the following research questions:

RQ1: How comprehensively are TEL resources being evaluated within anatomy education?

RQ2: To what extent, and in what ways, are student experiences with TEL investigated within anatomy education? And, within these studies, what factors are perceived to be important in measuring student experience?

These research questions are addressed within this chapter, with the exception of the second part of RQ2 which is addressed in Chapter 5.

This review was published in the journal Anatomical Sciences Education in 2018. Since publication, the results of this systematic review have been updated using the same methods protocol detailed in section 4.2. The results presented in this chapter include studies featured in the published systematic review (see supplementary paper; Clunie et al., 2018) as well as studies published from November 2016 until March 2019. The published systematic literature review was focused on addressing RQ1. The updated literature search and analysis focused on updating the findings for RQ1, while also addressing RQ2.

4.2 Methods

As suggested by Cook and West (2012), this review was conducted and reported in accordance with the standards set by the evidence-based Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA).

4.2.1 Categorisation of Included Studies

Due to the anticipated large numbers of included studies in this review, a benchmarking tool was employed in order to categorise them. As established in section 2.4.1, many evaluation frameworks currently exist such as the seven stage evaluation 'recipe' proposed by Cook and Ellaway (2015) or the four-level TELEM proposed by Pickering and Joynes (2016). While Cook and Ellaway (2015) provide a comprehensive model for evaluating TEL, many of their stages include processes not normally reported within published literature (e.g. environmental scans, and documentation of resource development). Comparatively, the TELEM acknowledges the importance of an evaluation of need prior to the development or procurement of resources, however, by assigning this stage *Level 0* the model recognises this stage is largely not discussed in the literature (Pickering and Joynes, 2016). The proceeding three levels of the TELEM (shown in Figure 2) provide a holistic and accessible benchmarking tool. The TELEM was deemed an appropriate framework for this review as it covers the vast majority of current evaluation approaches, therefore allowing studies to be consistently scrutinised and clearly categorised in accordance with their methods of evaluation in a way that is easily visualised.

4.2.2 Search Strategy

An electronic search of the following databases was conducted: MEDLINE (U.S. National Library of Medicine, Bethesda, MD), the Educational Resources Information Centre (ERIC; United States Department of Education, Washington, DC), Scopus (Elsevier, Amsterdam, The Netherlands), and Google Scholar (Google Inc., Mountain View, CA). Search terms included words related to the educational field characteristics (such as medical education, anatomical education, gross anatomy, anatomical sciences), delivery concept (such as e-learning, computer-assisted learning / instruction, web-based learning, blended learning, mobile learning, flexible learning and multimedia learning) and the type of resources (such as animation, 3D models, eBooks, virtual reality, augmented reality, digital anatomy, applications (or 'apps'), and 3D printing). No date restriction was implemented since the use of technology in anatomy education is a relatively new phenomenon and is therefore self-limited. The last date of search was 28th March 2019. Additional studies were identified by citation chaining which involved manually searching reference lists of other reviews, related review articles and authors' files.

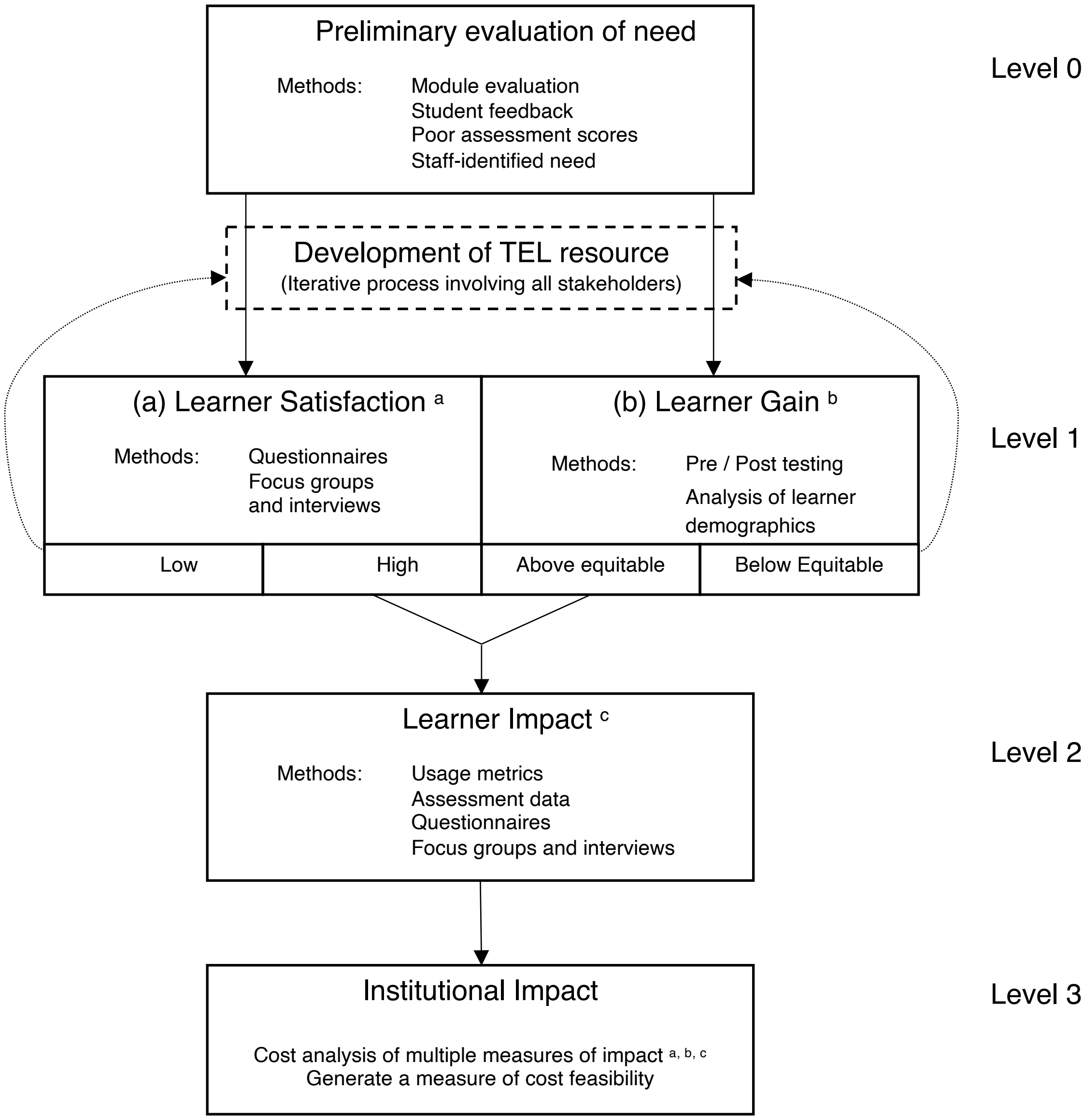


Figure 2: Technology-Enhanced Learning Evaluation Model (TELEM)

Adapted from Pickering and Joynes 2016. [a] Cost utility; [b] Cost effectiveness; [c] Cost benefit

4.2.3 Inclusion and Exclusion Criteria

All titles and abstracts were screened, retrieving the full text for all potentially eligible abstracts and abstracts with insufficient information. Inclusion of studies was considered after review of the full text. Studies were included if they were specific to 'basic science' anatomy (including neuroanatomy, embryology and histology), evaluated a resource designed to aid anatomy learning, were specific to student outcomes and fit at least one of the levels of the TELEM (Figure 2). Studies were excluded if they focused on veterinary anatomy, TEL outside of anatomy education, or if they focused on clinical training, including the use of radiological imagery. Other reasons for exclusion are presented within the PRISMA flowchart (Figure 3).

There were no geographical restrictions and only texts that were available in English were included. The full text of all included studies were reviewed by the researcher, 25% of included studies were reviewed by an independent reviewer (J.D.P; primary supervisor) and any conflicts were discussed until a consensus was reached.

4.2.4 Data Extraction

Following full-text review, included studies were analysed and the following data was extracted: length and type of study, year of publication, sample size and subject area (e.g., medicine, allied healthcare, and biomedical science), learning and teaching setting (e.g., classroom, self-directed, and anatomy laboratory), instructional modality (e.g., computer assisted learning, mobile device, social media, virtual reality), evaluation methodology (e.g., learner satisfaction surveys, comparison of assessment scores) and details regarding study methods.

4.2.5 Data Analysis

Following data extraction, each study was categorised according to one or more of the levels of the TELEM. To assess inter-rater reliability the percent agreement was calculated, along with the Kappa coefficient to take into consideration the possibility of chance agreement. In addition, descriptive analysis was performed on the final list of included studies according to the corresponding TELEM level and year of publication.

4.3 Results

4.3.1 Descriptive Analysis of Included Studies

The electronic databases yielded 4,137 studies, with a further 134 identified from additional sources and citation chaining, resulting in a total of 4,271 studies[2]. Upon removal of duplicates and an initial screening for eligibility, 1,108 were considered for full review. Of these, 898 studies were excluded. Following initial review of the literature, 210 studies were deemed to be eligible to

---

[2] This value includes the number of papers from the published systematic review and the updated search (March 2019).

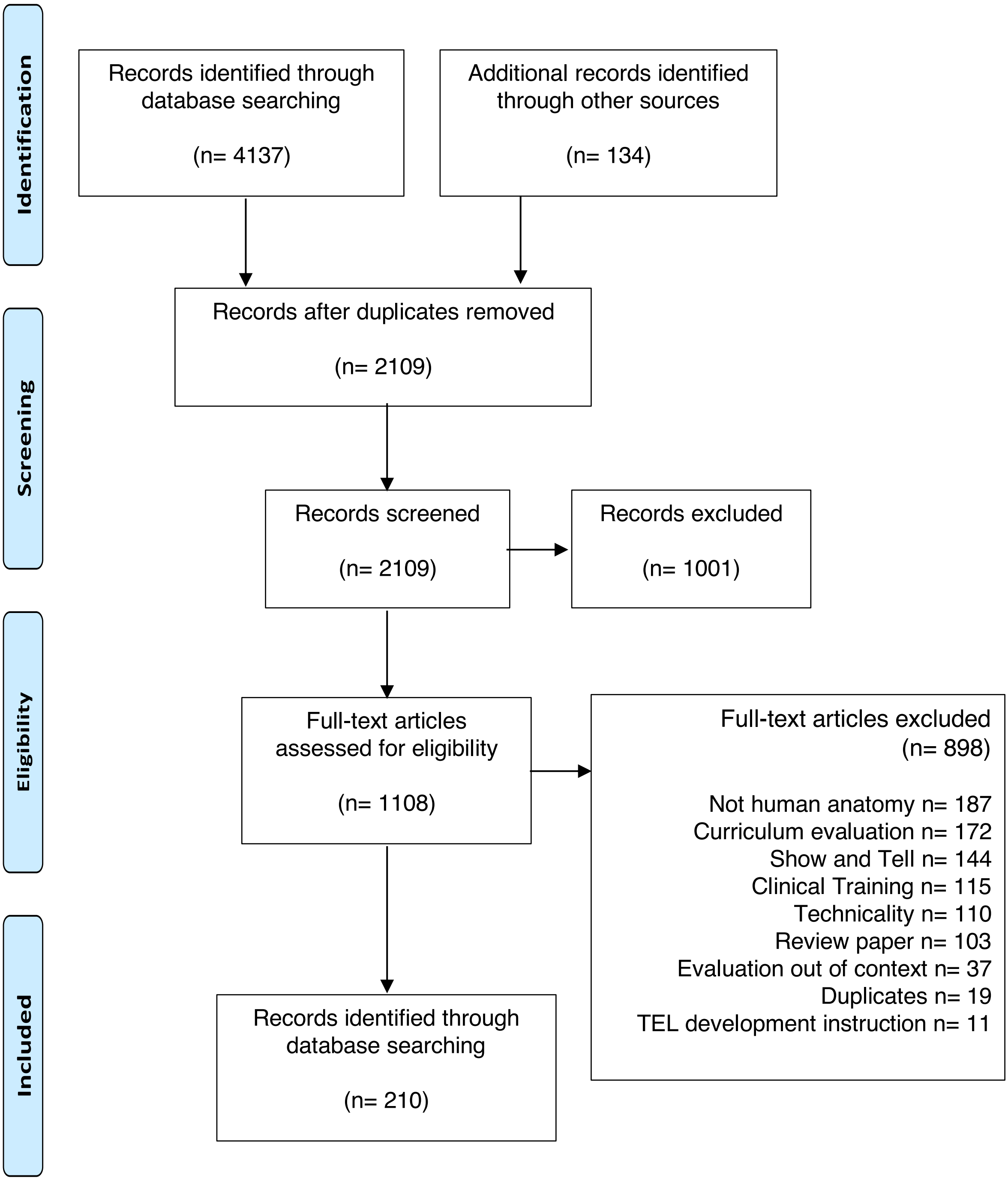


Figure 3: Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) flow diagram

be retained for systematic analysis. The studies retained within the systematic review were assigned one or more levels of the TELEM (Figure 2). Reviewer disagreement was present for three studies, which were subsequently discussed and a consensus reached (Kappa coefficient of 0.92).

4.3.2 Studies by Year of Publication

Assessing the studies by year of publication revealed three decades of TEL evaluation within anatomy education. The earliest study to report an evaluation in anatomy education was in 1987 and detailed student satisfaction with anatomy videotapes (Ogunranti, 1987). The next included study was not published until 9 years later and investigated the effectiveness of a histology-based computer software for medical students (Mars and McLean, 1996). Since then, there has been a steady increase in the levels of evaluation of TEL resources in anatomy education, with 74.3% (156 of 210) of these published since 2010. Figure 4 displays the number of evaluation studies in five year periods, including the frequency for each type of evaluation as categorised using the four levels of the TELEM. It is notable that not only are the frequency of studies evaluating TEL increasing, but the number of studies carrying out evaluations using multiple methods is also increasing.

4.3.3 Types of TEL Resources Evaluated

Reviewing the retained studies yielded a wide variety of resources (Figure 5). The majority of resources being evaluated were instructor-developed resources (50.0%; 105 out of 210). These included: eBooks (N= 4), videos (N= 22), in-class resources (N= 12; e.g. audience-response systems) and, e-learning modules either as part of a blended curriculum (N= 52) or as part of an online distance learning course (N= 15). The second most popular resource being evaluated was 3D visualisation technologies (29.5%; 62 out of 210). These include: 3D computer models (N= 29), virtual microscopy (N= 23), augmented reality (N= 5), holographic models (N= 2), stereoscopic models (N= 1) or a comparison between 3D computer models and augmented reality (N= 2). These results may be explained by the fact that until 2012, TEL evaluation studies were only focused on instructor-developed resources and 3D visualisation technologies. Since 2012, newer TEL resources have been evaluated in the literature including: purpose-built hardware (6.7%; 14 out of 210) such as head-mounted VR devices or the Anatomage Table (Anatomage, San Jose, CA); commercial resources (6.2%; 13 out of 210) such as Netter's Interactive 3D Atlas (Elsevier Inc., Philadelphia, PA); mobile devices (5.2%; 11 out of 210) and; social media (2.4%; 5 out of 210).

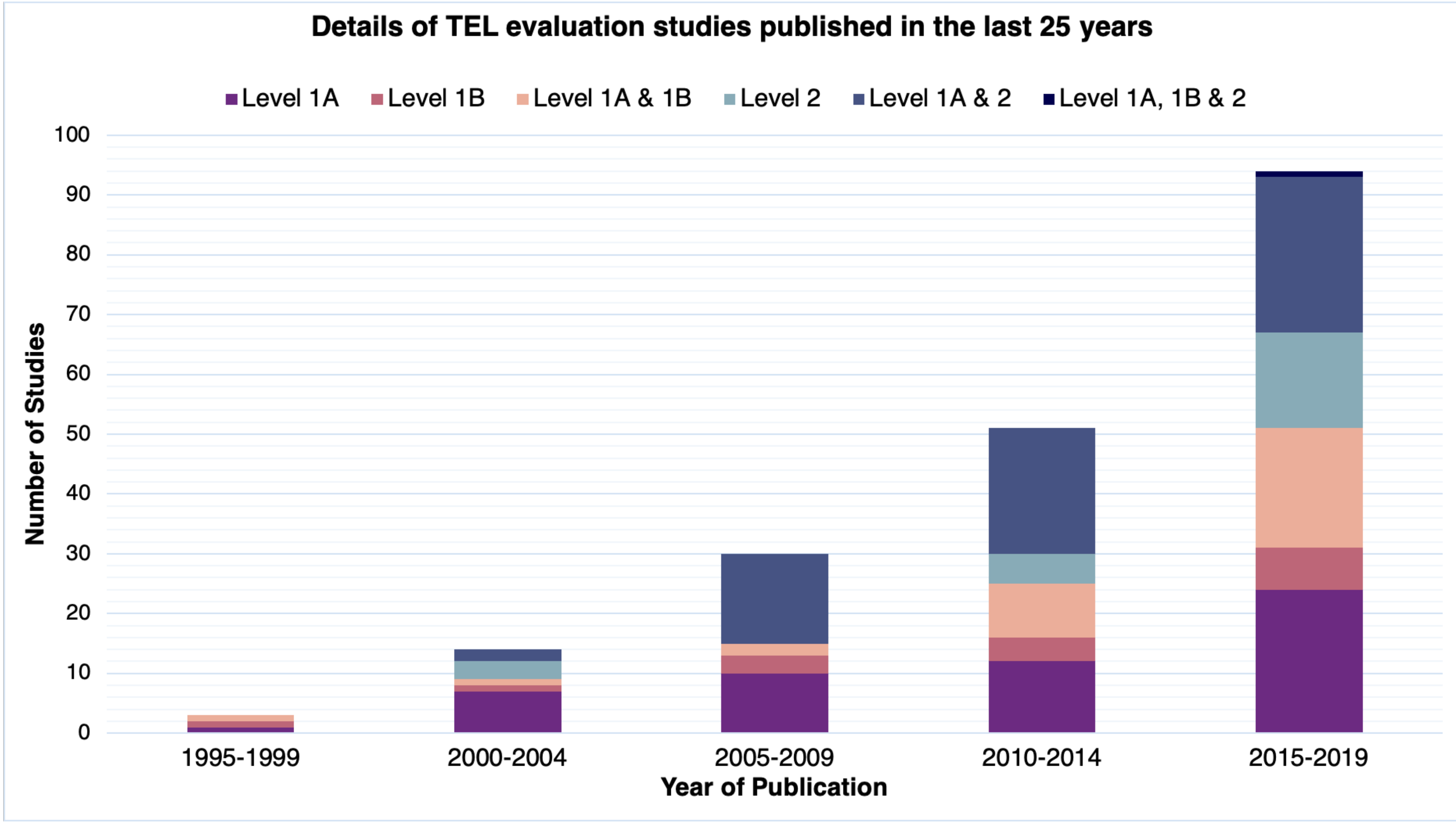


Figure 4: Stacked bar chart detailing the 210 included anatomy TEL evaluation articles

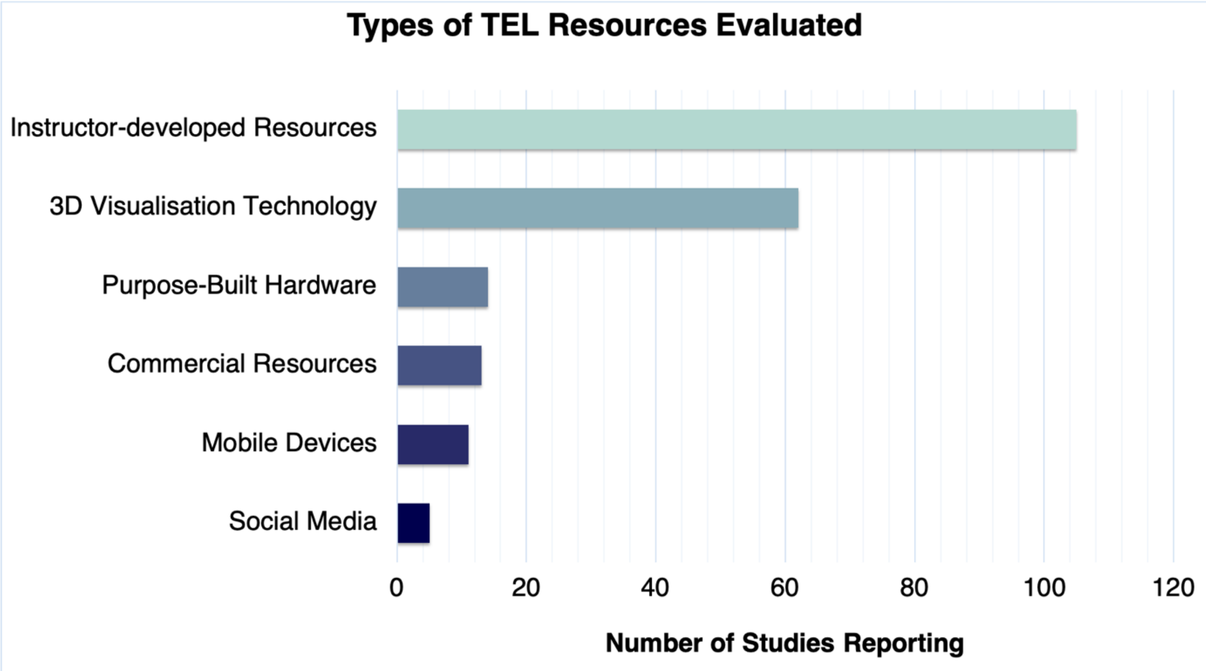


Figure 5: Bar chart displaying the types of TEL resources evaluated

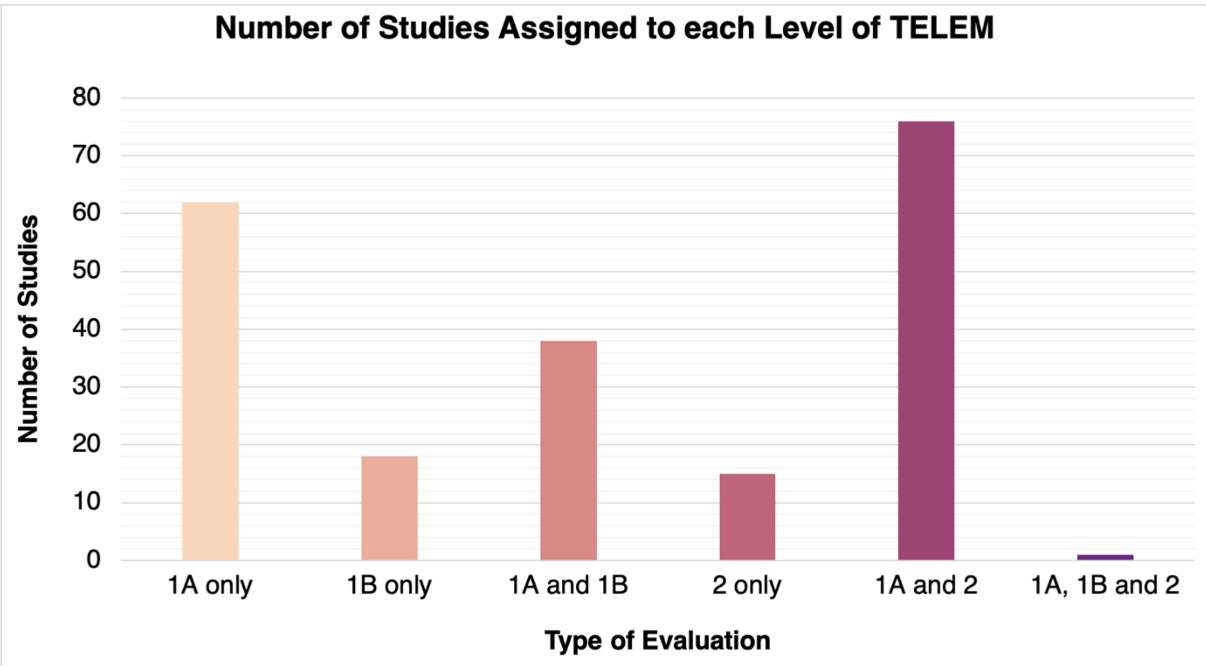


Figure 6: Bar chart displaying the various approaches to evaluation

4.3.4 Approaches to Evaluation

Analysis of the retained studies revealed a small majority of studies carried out an evaluation using multiple approaches (54.8%; 115 out of 210) as compared to those using a single evaluation approach (45.2%; 95 out of 210). Figure 6 details the number of studies assigned either one or more levels on the TELEM. For a full list of included articles and assigned levels on the TELEM, see Appendix 1.

The majority of studies carried out an evaluation at *Level 1A* by measuring student perceptions (84%; 177 out of 210), either as a single evaluation approach (35.0%; 62 out of 177) or in combination with either *Level 1B* (21.5%; 38 out of 177) or *Level 2* (42.9%; 76 out of 177). Measures of cognitive learning gain through *Level 1B* or *Level 2* approaches accounted for 70.5% (148 out of 210). The majority of those were assigned to *Level 2* (62.2%; 92 out of 148) by employing a whole cohort study to measure assessment scores and usage analytics. A minority were assigned to *Level 1B* (38.8%; 56 out of 148) by using pre/ post-test study designs. No studies reported an evaluation at *Level 3*, and only 1 study reached three levels on the TELEM (Lone et al., 2018).

Studies Reporting *Level 1A* Evaluation

The most popular approach employed to evaluate student perceptions of TEL within anatomy education was via student surveys (87.0%; 154 out of 177), by utilising Likert scale items (42.9%; 66 out of 154), open-ended questions (3.2%; 5 out of 154) or, as in the majority of cases, a combination of both (53.9%; 83 out of 154). In a small number of these studies, a survey was complimented by qualitative methods such as focus groups (3.9%; 6 out of 154) or interviews (2.6%; 4 out of 154). Only two studies employed qualitative methods as a single approach to evaluating affective outcomes. Both studies focused on understanding student perceptions of supplementing the traditional curriculum with e-learning activities through focus groups (Lochner et al, 2016) or interviews (Ocak and Topal, 2015). The remaining studies in this category reported on student feedback but did not reveal the details of the methods used to collect this information (10.7%; 19 out of 177).

Studies Evaluating Cognitive Learning Gain (*Level 1B* and *Level 2*)

Measurements of cognitive learning gain were carried out using experimental methods such as randomised control trials (RCTs) or quasi-experimental methods such as cohort studies comparing assessment scores or usage metrics. The majority of *Level 1B* studies employed a pre-/post-test design (64.3%; 36 out of 56), while the rest used post-test data alone (33.9%; 19 out of 56), or in the case of one study, a subjective drawing test (Das and Mitchell, 2013).

Studies evaluating TEL at *Level 2* of the TELEM utilised a quasi-experimental approach, either by comparing an 'experimental' cohort with a retrospective 'control' cohort (65.2%; 60 out of 92), or by evaluating the impact of TEL within the same cohort by comparing users and non-users (34.8%; 32 out of 92). These studies either simply compared assessment scores at the end of the respective course (77.2%; 71 out of 92) or made correlations between usage metrics and assessment outcomes (22.8%; 21 out of 92).

Studies Reporting *Level 3* Evaluation

From the total number of included studies, none reported carrying out a cost-feasibility analysis at *Level 3*. However, it was noted that 31.4% (n=66) made at least one mention of cost, for example, reporting on the costs of mobile 'apps' (Raney, 2016). A further 8 studies dedicated a section or paragraph to cost, for example, discussing the issue of cost-effectiveness (O'Byrne et al., 2008) or comparing traditional resources to a new TEL resource (Hisley et al., 2008; Raynor and Iggulden, 2008).

Approach to Evaluation by Resource Type

Analysis of the evaluation approach according to resource type revealed that studies which did not collect data on student perceptions evaluated 3D visualisation technologies (N= 12), commercial resources (N= 4), purpose-built hardware (N= 3) or instructor-developed resources (N= 14). These studies concentrated exclusively on evaluating cognitive learning gains via *Level 1B* (N= 15) or *Level 2* (N= 18) which may reflect research aims more focused on determining a resources efficacy in achieving learning outcomes, as opposed to understanding student perceptions.

Moreover, *Level 2* approaches were demonstrated in the majority of studies evaluating instructor-developed resources (59.1%; 62 out of 105), mobile devices (63.6%; 7 out of 11) and social media (60.0%; 3 out of 5). Additionally, while just 27.4% (17 out of 62) of studies evaluating 3D visualisation technologies used a *Level 2* approach, the majority of these (64.7%; 11 out of 17) were evaluating virtual microscopy. This evidence suggests that some resources are more readily embedded within an active curriculum, making longitudinal cohort studies easier to carry out. This finding is unsurprising given that, in accordance with Trelease's (2016) historical review of TEL, instructor-developed TEL resources such as online modules and videos (McNulty et al, 2000; Elizondo-Omana et al, 2004) have a much longer history in anatomy as compared to resources such as virtual or augmented reality (Moro et al, 2017; Barmaki et al; 2019).

Furthermore, the majority of studies (78.6%; 11 out of 14) evaluating purpose-built hardware utilised a *Level 1B* approach. For example, two studies examined the use of VR compared with conventional resources such as cadaveric specimens (Maresky et al, 2019) or textbooks and web-based resources (Stepan et al, 2017). They found that students in the experimental group performed better than or equal to the control group, respectively (Maresky et al, 2019; Stepan et al, 2017). In addition, 46.2% (6 out of 13) of studies evaluating commercial resources and 38.7% (24 out of 62) of studies evaluating 3D visualisation technologies also employed a *Level 1B* approach. This suggests there is an awareness that more rigorous evaluation is required for resources that are procured from external sources.

4.4 Discussion

As discussed in Chapter 2, the increasingly diverse multitude of TEL resources being introduced into anatomy education globally must be met with a holistic approach to their evaluation (Cook et al., 2010). In order to determine the extent to which TEL resources are being evaluated within the field, this systematic literature review employed the TELEM as a benchmarking tool (Pickering and Joynes, 2016).

The results from this review highlight the current status of evaluation of TEL resources in anatomy education. The general findings show the number of evaluation studies has increased annually, with a greater variety of new and innovative TEL resources being evaluated since 2012. This result confirms the suggestion from Trelease (2016) that the diffusion of TEL innovations within anatomy education have been steadily increasing due to the increased affordability and improvements in technological hardware and software (Trelease, 2016). Indeed, as demonstrated by Figure 4, not only the highest number of published evaluation papers, but also the greatest proportion of studies reporting a multi-method approach to evaluation were carried out between 2015 and 2019. Nevertheless, it should be noted that of all included studies, only one reported employing *Level 1A, Level 1B* and *Level 2* approaches in their evaluation (Lone et al., 2018), suggesting that more work is required to increase the holistic nature of TEL evaluations in anatomy. This is particularly pertinent given that, for instance, the limitations of *Level 1B* studies can be supported by the strengths of *Level 2* studies, and vice versa.

4.4.1 Studies Evaluating Cognitive Learning Gain (*Level 1B* and *Level 2*)

The systematic review revealed a large proportion of studies evaluated the effectiveness of TEL resources by measuring cognitive learning gain. Of these, nearly two thirds reported using a *Level 2* approach. Comparing the assessment results of a cohort with access to a TEL resource to a retrospective cohort without access may be a time efficient method of evaluation, however, *Level 2* approaches are caveated by a series of confounding variables. This type of evaluation is at risk of too readily attributing changes in assessment scores to TEL resource usage without accounting for immovable and confounding variables such a curriculum design, student characteristics and the availability of other resources for learning anatomy (Krause and Coates, 2008; Burgoon et al., 2012). Some *Level 2* studies included within this review attempted to reduce the impact of these variables by measuring assessment data over several years (e.g. McNulty et al, 2004; Neider et al, 2012), or by measuring users and non-users within the same cohort (e.g. Green et al, 2006; Bacro et al, 2013).

While *Level 2* approaches account for learning in ‘real-world’ settings, the aforementioned confounding variables make it difficult to attribute learning to the introduction of TEL, even over longitudinal studies. *Level 1B* approaches significantly reduce the influence of confounding variables by employing experimental methods such as pre- and post-testing in RCT studies (Hake, 1998; Dimitrov and Rumrill, 2003). While establishing a true control and experimental group is not possible when working with human participants due to individual characteristics, it is still widely acknowledged as the best method for developing a robust evidence-base (Coe, 1999). Despite this, only a quarter of studies employed a *Level 1B* approach. This is likely due to logistical issues such as curriculum time constraints, ethical considerations and student recruitment issues (Boileau et al, 2018). Nevertheless, it is evident that gathering causal evidence of the impact of TEL through *Level 1B* approaches is achievable, and is increasing within anatomy education research (Figure 4). Moreover, perceived setbacks such as recruitment issues become less problematic when enough studies measuring the same phenomenon are combined using a meta-analysis (Fitz-Gibbon, 1984; 1985).

Recently, a number of meta-analyses have been carried out within anatomy education (Yammine and Violato, 2015; Wilson et al., 2016; 2018; 2019). These studies have investigated a large number of *Level 1B* studies, revealing a number of interesting outcomes. For instance, following analysis of 36 studies, Yammine and Violato (2015) found 3D visualisation technologies, such as software offering a 3D digital representation of the human body, significantly improve user satisfaction and acquisition of spatial knowledge compared with conventional teaching methods. While acquisition of factual knowledge was equitable across resources, the improvements in spatial understanding and student satisfaction support the use of 3D visualisation technologies within anatomy education (Yammine and Violato, 2015). Furthermore, in a series of meta-analyses by Wilson et al (2016; 2018; 2019) 72, 26 and 19 studies were examined, respectively, and revealed the following findings: virtual microscopy achieves better assessment outcomes and student satisfaction compared with traditional microscopy (Wilson et al., 2016); acquisition of factual knowledge is equivalent whether students are exposed to cadaveric dissection or technology (Wilson et al., 2018) and; students who are exposed to supplementary TEL resources significantly outperform students who have minimal or no access to the same resources (Wilson et al., 2019). This most recent study compared learning outcomes for students using TEL, with those taught using conventional didactic methods. A significant positive relationship with TEL and assessment outcomes was only apparent for those who used supplementary TEL. This is in contrast to TEL interventions introduced to replace an existing resource in which no effect was reported. In addition, they found that continuous exposure to a TEL intervention was associated with significantly increased assessment scores as compared to a single isolated intervention (Wilson et al., 2019). These findings support commentary from other educators who have suggested that anatomy should be taught using an integrated multi-modal approach (Estai and Bunt, 2016; Guimarães et al., 2017), and that TEL should be implemented throughout a module or course as opposed to a single intervention study in order to negate the ‘novelty effect’ and to evaluate the resource within an active multi-faceted curriculum (Tam et al., 2009).

These comprehensive, albeit small-scale, meta-analyses have shown consistently positive effects of TEL. These findings are also supported by other high quality meta-analyses within the wider field of medical education which have shown that methods such as internet-based learning (Cook et al., 2008), blended learning (Liu et al., 2016) and mobile learning (Dunleavy et al., 2019) all reveal large positive effects compared with no intervention. Furthermore, when compared with traditional methods of instruction, each of these interventions are found to be equitable to or better than traditional methods (Cook et al., 2008; Liu et al., 2016; Dunleavy et al., 2019). Finally, to further evidence the impact of TEL more broadly within HE, Tamim et al (2011) carried out a second-order meta-analysis spanning 40-years of literature and found a small to moderate positive effect in favour of TEL when compared with non-TEL interventions.

The evidence from these meta-analyses suggests these small pooled effect sizes for cognitive learning gain provide reassurance that there are no large or concerning differences between TEL and traditional methods of instruction (Cook, 2009). Despite these promising results, the aforementioned inherent issues with *Level 1B* approaches are evident, with meta-analyses within anatomy education demonstrating small sample sizes and significant heterogeneity in their included studies (Yammine and Violato, 2015; Wilson et al., 2016; 2018; 2019). It could be argued that the data from these studies are inconclusive due to the high levels of unexplained heterogeneity and that calls for greater numbers of standardised evaluation studies are needed to determine the true statistical effect size. Conversely, it may be equally important to consider that such high levels of heterogeneity suggests that there are factors influencing the success of TEL that are not currently being measured in anatomy education literature.

4.4.2 Studies Evaluating Student Perceptions of TEL (*Level 1A*)

Understanding student perceptions of a TEL resource is a basic but essential stage of evaluation (Wiers-Jenssen et al., 2002). Theoretically, students will be more motivated to use a TEL resource if they believe they will be competent using it, have an interest in and assign value to engaging with it (Wigfield, 1994; Wigfield et al., 2009; Eccles, 2016). In this review, the majority of included studies carried out an evaluation to measure students' perceptions of a TEL intervention. This is important because; firstly, while several meta-analyses have revealed that TEL is at least equitable to traditional approaches of instruction in terms of cognitive learning gains, it is important to establish the same findings apply to levels of satisfaction, and; secondly, perhaps more important than establishing positive attitudes towards TEL, negative attitudes can help educators identify issues with regards to usability, accessibility and general dissatisfaction (Cook, 2009; 2010). This feedback supports the continued development and refinement of the use of TEL within anatomy education.

Studies Employing Quantitative Methods

Most *Level 1A* studies employed surveys as a method of gathering data on affective outcomes such as attitudes towards and satisfaction with TEL. A contributing factor towards the high proportion of studies employing a survey is likely the perceived ease of either implementing resource-specific survey items into an existing module feedback survey (e.g., Choudhury et al., 2010; Barbeau et al., 2013; Wilkinson and Barter, 2016), or delivering an intervention-specific survey (e.g., Brewer et al., 2012; Stirling and Birt, 2014; Ferrer-Torregrosa et al., 2015). In addition, the use of large scale surveys are driven by a motivation to gain insight into the general levels of satisfaction, engagement and motivation while using a TEL resource (Dixson, 2015; Stepan et al., 2017).

In general, studies categorised at *Level 1A* of the TELEM found attitudes towards TEL resources to be positive. For example, Granger et al (2006) showed a positive response from students who were exposed to an online learning resource that included dissection videos and access to the Visible Human Project[1] (National Library of Medicine, Bethesda, MD). Similarly, students exhibited significantly more positive attitudes towards a 3D computer model when compared to students who only accessed a textbook (Battulga et al., 2012). Furthermore, student surveys allowed Beale et al (2014) to determine the value of both face to face and online instruction for an embryology module. Students rated the ability to interact with the educator as an advantage of face to face instruction, while the online material could be paused, replayed and viewed at any time (Beale et al., 2014). These studies highlight the importance of providing TEL that offers advantages such as improved flexibility of learning as part of a multi-modal blended curriculum.

Although there is value in attitudinal evaluations for establishing the utility of a TEL resource, it should be noted that these evaluations do not necessarily provide an accurate reflection of student behaviour or infer a correlation with improved or sustained learning outcomes (Dixon, 1990; Holton, 1996). Indeed, satisfaction levels have been found to be unrelated to academic performance (Rienties and Toetenel, 2016). This was evidenced by Mathiowetz et al (2015) who found that students who learnt using an online learning module had a significantly less positive experience than those who learnt with cadaveric material. However, when comparing the assessment scores of both groups, there was no significant difference (Mathiowetz et al., 2016). This shows that learning occurred despite less positive perceptions and attitudes towards the online learning module. However, the authors did not investigate the reasons for these differences in perception leaving them to speculate that this may be due to varied time spent studying anatomy between groups, or that the differences were a reflection of students' preferred learning style (Mathiowetz et al., 2016).

Further analysis of studies employing surveys revealed a largely basic approach to data analysis, with a majority of studies (83%; 128 out of 154) failing to report measures of internal consistency. This raises questions about whether these surveys were reliably measuring the same construct (Artino et al., 2014). Furthermore, there is evidence that authors engaging in simple descriptive analysis of survey results, without mention of the validity or reliability of their scale, are subsequently concluding success of their evaluated TEL resource. For example, Chakraborty and Cooperstein (2018) employed dichotomous yes / no responses in their survey investigating student perceptions of the use of anatomy mobile applications and concluded, *"the overwhelming consensus of the students who used the apps was that they liked them"* (p.

343). Similarly, Fairén González et al (2017) used an 8-item Likert scale survey to measure student perceptions of VR and found significantly more positive reviews in one cohort compared to a retrospective cohort. The authors speculated that improvements to the VR system following student feedback had accounted for the change in student perceptions, subsequently concluding that VR is a *"powerful learning tool"* (p. 51) in anatomy. However, despite reporting the data, the authors failed to recognise that not only were differences observed between the two cohorts, differences in perceptions were also observed within each of the cohorts depending upon whether the students attended the morning or afternoon session (Fairén González et al., 2017). This, again, suggests that there are other variables influencing the success of TEL that are not currently being measured in anatomy education literature.

The aforementioned concerns associated with the scarcity of studies reporting measures of validity and reliability are somewhat mitigated within studies using an existing validated survey scale. However, analysis of the surveys employed within anatomy education revealed the majority (80%; 123 out of 154) had not employed existing validated survey scales, instead choosing to develop their own survey scale. Since surveys must reflect individual study aims and objectives (Jones et al., 2013; Topping, 2014; Pickering and Swinnerton, 2019), this finding suggests there is a lack of relevant and appropriate validated scales for measuring student perceptions of TEL within anatomy education. Validated survey scales are more methodologically robust than self-developed scales as they have previously been extensively tested for validity, reliability and accuracy, and can support direct comparisons between different student groups, institutions and types of resource (Jones et al., 2013). Of the 31 studies (20%) that did employ an existing validated survey scale, a large proportion (N= 12) utilised a validated instrument for measuring spatial ability (e.g. Van Nuland and Rogers, 2015; Cui et al., 2017; Guimarães et al., 2019), while others measured metrics such as student motivation (Helle et al., 2011), resource usability (Choi et al., 2017; Wismer et al., 2018) and learning approaches (Svirko and Mellanby, 2017). The findings from this systematic review revealed that the use of existing validated instruments has been increasing in recent years. This is a positive change in methodological approach that will allow for future comparison of students' experiences dependent upon various factors. However, future work must focus on producing validated anatomy-specific TEL evaluation surveys in order to see the use of this robust methodology continue to increase.

Studies Employing Qualitative Methods

The majority of studies within *Level 1A* employed quantitative data alone, with qualitative methodologies, such as focus groups and interviews, featuring in just 5.7% (12 out of 210) of the total number of studies. It is widely acknowledged that qualitative data can provide meaningful understanding of students' opinions, experiences and motivations (Cleland and Durning, 2015). As an example, Lochner et al (2016) carried out focus groups with healthcare professional students to evaluate the use of pre-class online activities such as quizzes and videos. Not only did students say they enjoyed the online activities, one described the experience as *"structured freedom"*, where the activities were structured by aligning to the curriculum but were freely available to be used whenever and wherever suited the student best. In addition, multiple students attributed the weekly learning activities with decreasing anxiety levels by reducing the delay in self-study and consequent 'cramming' before an exam (Lochner et al., 2016). Although the richness of this data cannot be achieved through surveys or other quantitative methods, it is widely believed that qualitative approaches in isolation are insufficient for establishing the effectiveness of a TEL intervention (Teddlie and Tashakkori, 2009; Creswell and Plano Clark, 2011; Smith et al., 2018). This belief is reflected in the anatomy education literature with just 1% of studies (N= 2) employing qualitative methods in isolation (Ocak and Topal, 2015; Lochner et al., 2016). Despite this, it is evident that anatomists are increasingly employing methodologies from traditional educational research (Cleland and Durning, 2015). This is highlighted by an evident correlation between studies utilising qualitative methods, the first of which published in 2008 (Durham et al., 2008), and the introduction of the field of educational research within anatomical sciences, arguably demarcated as an independent field of research following the creation of the journal of Anatomical Sciences Education, established in 2007.

Studies Employing a Mixed Methods Approach

When quantitative data is combined with either focus group or interview data, a fuller, richer and more authentic insight into the role that TEL might be playing in supporting learning can be achieved (Tavakol and Sandars, 2014; Stalmeijer et al., 2014; Smith et al., 2018). According to Alderman et al (2012, p.273), the reliability of survey data is elevated when used *"in conjunction with information from other sources and robust links are established between the data"*. This methodology was conducted by 4.8% (10 out of 210) of the included studies. The benefits of using multiple data sources was evidenced by Hennessy et al (2016) who established through a Likert scale survey that the use of Twitter (Twitter, Inc., San Francisco, CA) in a neuroanatomy course received positive feedback on the perceived usefulness, value, and impact on motivation. Focus groups were employed to explore this feedback further and found the reasons for this positive feedback included: an appreciation of the ability to return to the Twitter page during revision to check previously posted questions and answers; an appreciation of the concise nature of tweets by keeping questions and answers *“straight to the point”* and; a perceived reduction in anxiety, and increase in motivation, by creating a supportive network (Hennessy et al, 2016). Combining methods allowed the authors to establish a much deeper understanding of the role Twitter was playing for their cohort of students. Similarly, employing a mixed methods approach for improving and refining a TEL resource was also evident in a study by Tworek et al (2013) who employed focus groups and a validated survey scale with students, as well as other relevant stakeholders. The development of a virtual learning resource became an iterative process, influenced by continuous evaluations of perceptions of the resource (Tworek, 2013). In another example, Durham et al (2008) evaluated an online tutorial using an exploratory sequential mixed methods approach by employing interviews to inform the development of a survey scale. Themes from the interview data such as ‘supporting and guiding learning’ and ‘critique of the learning material’ were phrased into survey items. The overall findings were positive and the small number of suggestions for modifications, such as reducing the volume of text, were acted upon by the authors following analysis of the data (Durham et al, 2008).

These studies evidence the advantages of undertaking a mixed methods approach to holistically evaluate TEL. However it is clear, despite the intended aim of *Level 1A* of TELEM to determine student satisfaction with a resource, there are additional variables and nuance to ‘student satisfaction’ that are currently only being investigated by a minority of anatomy educators. Understanding these additional variables and their impact on engagement with TEL may support educators in the design and dissemination of anatomy TEL resources.

4.4.3 Is There a Bias Towards Positivist Approaches to Evaluation?

The findings from this systematic review have highlighted a strong preference for quantitative evaluations of TEL within anatomy. This suggests there may be a bias towards positivist research approaches (Brown and Dueñas, 2020) from the authors conducting these evaluation studies. This is highlighted through a comparison of the findings from the current review with findings from a systematic review of TEL evaluation approaches within wider HE literature (Lai and Bower, 2019). This timely review revealed that 40.5% employed a mixed methods approach by carrying out both quantitative and qualitative research, which is significantly more than the 4.8% of studies within anatomy education doing the same. Moreover, the majority

(66.6%) of studies evaluating the effectiveness of TEL utilised a validated survey instrument (Lai and Bower, 2019), compared to just 14.5% within anatomy education. These findings suggest there are considerable steps required within anatomy education research to increase the number of robust, holistic TEL evaluations.

At present, anatomy TEL evaluations are largely focused on gathering evidence of cognitive learning gains and student satisfaction. While these are important in understanding the effectiveness of TEL in a variety of contexts, this outcome-oriented approach to evaluation has been criticised for failing to account for unexpected outcomes, or understanding the reasons behind specific outcomes (Cook, 2010). Understanding *why* TEL is successful is important for optimising future development and dissemination of resources to students. Moreover, understanding the possible negative impact of TEL on anatomy education is equally important. Unfortunately, it appears there is a clear focus on the largely positive attributes of TEL without consideration of 'digital downsides' such as possible distractions, digital competency and issues with accessibility or privacy online (Selwyn, 2016). This finding is explored further in Chapter 5, however, it highlights another shortcoming within the current anatomy TEL evaluation literature.

Moreover, the failure to comprehensively explore student experiences with TEL may be related to the background of the authors conducting the evaluation studies. Recently, Schaefer et al (2019) employed a large-scale survey to investigate the qualifications of anatomy educators in the United States (U.S.). Their results revealed the majority of educators have a basic science background and have not completed post-doctoral education training (Schaefer et al, 2019). These findings support the conclusion there is a positivist bias in anatomy TEL research, since basic scientists are inevitably more familiar with the 'gold standard' of RCT studies and with analysis of numerical data (Sullivan, 2011) This positivist paradigm fails to acknowledge the complexities of individual students who learn in a variety of contexts and come from a variety of backgrounds (Clark, 2002; Cook, 2009).

4.4.4 Considering the Heterogeneity of Studies

As this systematic literature review, and other relevant meta-analyses (Yammine and Violato, 2015; Wilson et al., 2016; 2018; 2019) have established, there are high levels of heterogeneity in the approaches to TEL evaluation. Within anatomy education research, unexplained heterogeneity and the inherent complexities of working with human participants are often cited as research limitations which prevent the study from establishing a global effect of one learning resource compared to another (Wilson et al, 2019). However, Cook questions whether it is worth expending resources seeking this global effect since it *"will forever be elusive [as] there is too much heterogeneity"* (2009, p.159), and instead, argues that seeking explanations for the observed heterogeneity may be a more worthwhile venture (Cook, 2009). Furthermore, recent reviews of anatomy teaching pedagogies have demonstrated a trend towards a multi-modal teaching paradigm where multiple TEL and non-TEL resources are employed throughout a module or programme (Estai and Bunt, 2016; Wilson et al, 2018). However, a predominantly positivist approach to research has resulted in a paucity of studies evaluating the reality of learning anatomy in an active, multi-faceted curriculum. That is, student perceptions and engagement with learning resources are likely fluid and changeable dependent upon a variety of factors. What those factors are and the degree of influence they have on student engagement with TEL resources is yet to be established within anatomy education.

4.5 Conclusion

Using a methodologically robust systematic review of the literature, this chapter has appraised the current landscape within anatomy education with regards to TEL evaluation. The preceding sections have detailed the comprehensiveness of TEL evaluation studies which, in line with RQ1, concludes that while numerous evaluation studies have been carried out, only a small minority utilise a holistic multi-method approach. Moreover, in line with RQ2, this study has highlighted the majority of TEL evaluation studies investigate student perceptions using a survey scale. However, only a small number of these studies report on measures of reliability or validity of such scales and an even smaller number of studies have engaged in qualitative methods of inquiry.

This review has demonstrated there has been a significant increase in the amount of TEL evaluation in recent years; so much so, meta-analytic studies have been able to utilise a series of *Level 1B* studies to establish the various positive effects of TEL resources such as 3D visualisation technologies and computer-based learning. This developing evidence base provides some level of confidence to anatomy educators that these resources are at least equitable to, if not better than, traditional approaches. However, these studies are caveated by small sample sizes and significant heterogeneity, suggesting that more work is needed to improve the quality of evaluation studies and to extend investigations to uncover explanations for observed heterogeneity.

Furthermore, it appears that despite the vast majority of studies engaging in *Level 1A* evaluations, the methods used are largely superficial and lacking in investigation of the various factors that may influence student engagement with TEL within anatomy education. The findings from this review suggest TEL evaluation research has a bias towards positivist research approaches within anatomy education. This is emphasised when the current approaches to evaluating TEL are compared with those from evaluation studies from other disciplines within HE. While anatomy education appears to be increasing the volume and rigour of TEL evaluation studies, there is certainly room for improvement. The lack of evaluations combining both quantitative and qualitative evaluation of student perceptions prevents educators from understanding the lived experience of students' engaged within multi-modal curricula. This understanding is vital for the design, development and implementation of new TEL resources within anatomy education. Therefore, in order to improve understanding of student experiences, the following three chapters will detail a holistic mixed methods evaluation which, in line with *Level 1A* of the TELEM, investigates the perceptions of MBChB students currently engaged in a multi-modal anatomy curriculum at the University of Leeds.

Chapter 5

Piloting the Anatomy TEL Utility Scale

5.1 Introduction

In this chapter, the first quantitative stage of the mixed methods study is described. This chapter will detail the design, development and analysis of a 30-item pilot survey completed by Year 2 MBChB students from the University of Leeds. The results from this study answer the second part of RQ2, "What factors are perceived to be important in measuring student experience?". Furthermore, as the first stage of the three part mixed methods study, this chapter will also begin to answer the following research questions:

RQ3: What are students' perceptions of anatomy TEL resources? And, is there a relationship between these perceptions and variables such as assessment scores, gender and resource preference?

RQ4: What factors influence student perceptions and use of TEL resources within anatomy education?

In order to answer these research questions, existing surveys within anatomy education were analysed to determine the overarching concepts related to student perceptions currently being measured by the majority of TEL evaluation studies. The overarching concepts from the literature were combined with concepts from the previously defined conceptual framework (Chapter 3) to develop a series of 30 survey items. This pilot survey was titled the Anatomy TEL Utility scale. To determine the underlying constructs from the survey, the results were analysed using factor analysis. These underlying constructs, referred to in this chapter as 'Factors', were used to measure the relationship with assessment, gender and resource use.

Following details of the context of the present study, this chapter begins with a description of the methods employed in analysing existing literature, designing and developing the pilot survey, data collection and data analysis. From here, the results of the pilot survey are explored in detail, firstly examining the results from factor analysis, followed by an account of the relationships existing between factor scores, assessment scores, gender and resource preference. Finally, the chapter ends with a discussion and summary of the results.

5.2 Context of the Present Study

At the University of Leeds, anatomy is taught within the first two years of the MBChB programme as part of integrated modules. In Year 1, anatomy teaching commences at the start of term two (January) as part of the Body Systems module. The anatomy component of this module is assessed via two anatomy 'spotter' examinations and is taught via lectures, ultrasound / living anatomy sessions, small group tutorials, self-directed learning and anatomy practical sessions with cadaveric prosections. In Year 2, anatomy teaching begins in term one (September) as part of the Control and Movement module. The anatomy component of Control and Movement is assessed via the integrated end of year exam and, at the time of the present study, was taught via lectures, living anatomy sessions, small group tutorials and anatomy practical sessions using cadaveric dissection[3].

In addition to the aforementioned face-to-face anatomy teaching, educators provide students with a range of anatomy TEL resources to support students' self-directed learning. The TEL resources provided to students at the University of Leeds are outlined per year group and per anatomical region in Table 2.

5.3 Methods

The first quantitative stage of this exploratory sequential mixed methods study sought to develop and then pilot the Anatomy TEL Utility scale in order to collect general perceptions of the TEL resources available to Year 2 MBChB students at the University of Leeds. The pilot survey in this study was designed based upon existing surveys within anatomy education literature and the previously defined conceptual framework (Chapter 3).

5.3.1 Development of Survey Scale

Analysis of Existing Anatomy Education Literature

As established in Chapter 4, student surveys are the most commonly utilised method of evaluating student perceptions of TEL (i.e. Level 1A of the TELEM). Of the total number of

---

3 The Control and Movement module is now taught using cadaveric prosections.

Table 2: Technology-Enhanced Learning resources available at the University of Leeds

<table>
<tr><td></td><th colspan="6">Available TEL Resources per Region of Body</th></tr>
<tr><th rowspan="2">Year One</th><td colspan="2">Thorax</td><td colspan="2">Abdomen</td><td colspan="2">Pelvis</td></tr>
<tr><td colspan="2">• Lecture Slides
• Lecture Recordings
• Dissection Videos
• Online Quizzes</td><td colspan="2">• Lecture Slides
• Lecture Recordings
• Dissection Videos
• Online Quizzes
• eBook
• “Exploring the Human Abdomen” FutureLearn MOOC
• Screencast Videos (available via VLE or YouTube)</td><td colspan="2">• Lecture Slides
• Lecture Recordings
• Dissection Videos
• Online Quizzes
• Screencast Videos (available via VLE or YouTube)</td></tr>
<tr><th rowspan="2">Year Two</th><td colspan="3">Musculoskeletal System</td><td colspan="3">Neuroanatomy and Head & Neck</td></tr>
<tr><td colspan="3">• Lecture Slides
• Lecture Recordings
• Dissection Videos
• Online Quizzes
• Screencast Videos (available via VLE or YouTube)</td><td colspan="3">• Lecture Slides
• Lecture Recordings
• Dissection Videos
• Online Quizzes
• Screencast Videos (available via VLE or YouTube)</td></tr>
</table>

included studies (N = 154[4]) from the systematic literature review, all articles reporting a Level 1A approach were reviewed in order to identify existing surveys that focused on perceptions of TEL in anatomy education. This process began by identifying articles that included a student survey as a research method (N = 127[4]). The articles that utilised Likert statements within their survey (N = 104[4]) and included a list of those statements within the article (N = 56) were analysed for relevant Likert statements related to student perceptions of TEL within anatomy education. Analysis revealed that 43 articles included at least one relevant Likert statement (Mean = 4 statements; Range = 1-10) resulting in 172 relevant statements. Thematic analysis (Braun and Clarke, 2006; Clarke and Braun, 2018) was used to identify recurring question themes throughout the literature, resulting in a total of 21 themes associated with survey items

---

[4] These values are less than those detailed in Chapter 4 as they were calculated prior to an updated literature search.

currently used in anatomy education literature. As an example, the 5 most commonly used and 5 least commonly used survey items are identified in Table 3.

Table 3: Examples of survey items used within anatomy education literature

	Rank	Survey Item	N=
Most Common	1	Using "X" helps my learning	28
	2	"X" helped my understanding of anatomical structures	16
	3	I find "X" easy to use	14
	4	I found "X" useful	10
	5	"X" makes my learning more efficient	10
Least Common	23	"X" is challenging to use	3
	24	"X" is frustrating to use	2
	25	"X" improves my student experience	2
	26	I am comfortable using "X"	2
	27	I have the relevant computer skills to use "X"	1

Developing an Item Pool

Following thematic analysis of existing survey items within the literature, 21 question themes were identified. Items within each theme were amalgamated into a single item that captured the principle nature of each theme (example shown in Figure 7). Where applicable, the wording of these items were matched or closely aligned with the wording of items from existing validated surveys. To provide an example of this method of item development, the theme of "ease of use" was evident in survey items from 14 articles investigating student perceptions of TEL in anatomy education. The final item included in the Anatomy TEL Utility scale, *"I find TEL resources easy to use"*, was worded to amalgamate the 14 items from the literature and was aligned closely with item EOU6 (Effort Expectancy) from UTAUT *"I would find the system easy to use"* (Venkatesh et al., 2003; pg 460). In another example, the theme of "stimulates interest" was evident in 5 existing surveys in the literature. The final item, *"Studying anatomy using TEL resources is intellectually stimulating"*, was aligned with *"I am* *finding my course intellectually stimulating"* from the intellectual engagement scale (Krause and Coates, 2008).

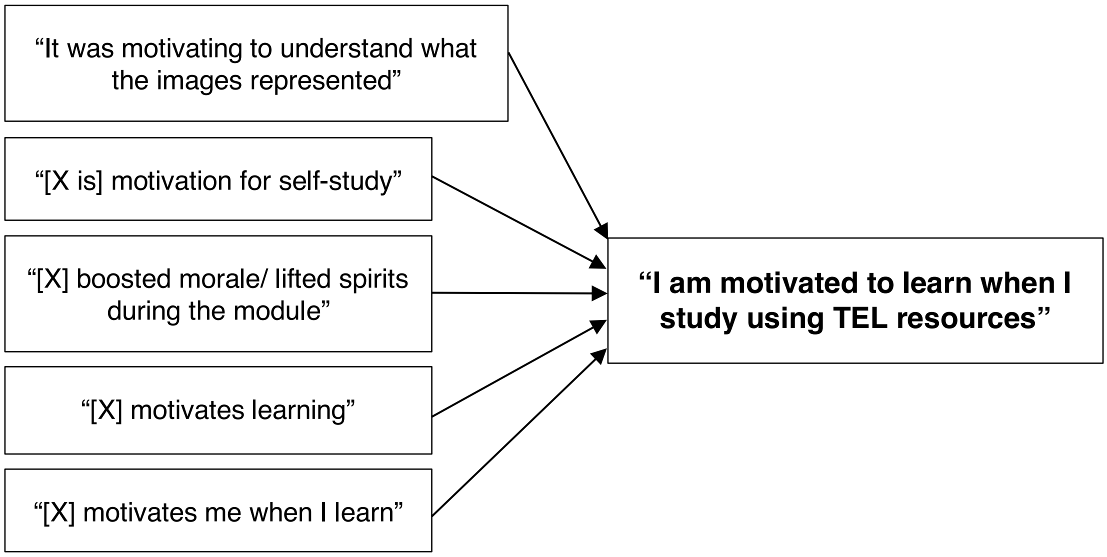


Figure 7: Example demonstrating the development of survey items

This process resulted in a total of 21 survey items. Upon analysis of this item pool, it became evident that some key concepts were not currently addressed in the literature. For example, items associated with digital skills and comfort using technology were included in just three of the existing survey scales within anatomy education (Durham et al., 2009; Hu et al., 2010; Stirling and Birt, 2014). Given this study aimed to investigate students perceptions of TEL from both institutional and external sources, this concept was imperative as navigating, assessing and engaging with resources in online spaces requires some level of digital literacy (Mesko et al., 2015). Moreover, concepts such as social influence and accessibility were not included within existing surveys. Furthermore, other potentially negative influences on TEL use were also ignored in the existing literature, such as the possibility of distractions online and concerns around safety or privacy when working in an online space (Selwyn, 2016). This apparent gap within anatomy education literature resulted in an additional 9 items being added to the Anatomy TEL Utility scale. Moreover, each individual survey item, whether aligned to an existing validated scale or not, was developed using 'best practice' for developing survey items (DeVellis, 1991; Dillman et al., 2014). For a summary of the development of the 30-item pilot survey, see Appendix 2.

Measures of Validity and Reliability

In line with existing literature utilising factor analysis as a method of survey evaluation (Tinsley and Tinsley, 1987; Henson and Roberts, 2006), measures were taken to ensure the validity of the pilot Anatomy TEL Utility Scale. Firstly, content and face validity were achieved through consultation with PhD supervisors. Content validity measures the readability and clarity of each survey item, as well as evaluating the degree to which the instrument comprehensively measures the topic of interest (DeVellis, 1991); and, face validity, although a more informal step, is important for analysing the survey for common errors such as double-barrelled, ambiguous or leading questions (Collingridge, 2014). Secondly, predictive validity assesses the ability of a survey instrument to predict a particular outcome, behaviour or attitude at a future event (Drost, 2011). In the context of this study, predictive validity was achieved through correlation coefficients to determine the association with anatomy-specific assessment scores and gender, where, the stronger the correlation the greater the predictive power. Finally, the construct validity of the refined scale was achieved using exploratory factor analysis (EFA). This technique provides empirical evidence that the contents of the construct being measured are statistically valid and is particularly useful when the construct of interest is composed of many known or unknown dimensions (Field, 2009). EFA is described in more detail in Section 5.3.3.

Furthermore, to ensure the reliability of the scale, the internal consistency of the items within the scale were measured. Cronbach's coefficient alpha (Cronbach, 1951) was employed to determine the extent to which the items within the scale and emergent factors were measuring the same underlying construct.

Structure and Design of Survey Instrument

The structure of the survey instrument was designed in an attempt to optimise survey responses. Firstly, survey items were presented on a rating scale. Likert (1932) scaling is the most commonly used rating scale in anatomy education (as evidenced in Chapter 4) and was therefore deemed the most appropriate for this study. Items were offered on a five-point scale, where the first, middle and last points were labelled as: 'strongly disagree', 'neutral' and 'strongly agree', respectively. Most items were positively worded (e.g. "I feel more confident in anatomy when I study using TEL resources") so that respondents could clearly agree or disagree with the statement. To account for the possibility of satisficing responses (i.e. responding in the same manner to all items), a number of negatively worded items (e.g. "I do not enjoy learning anatomy using TEL resources”) were incorporated into the scale and later reverse-coded.

Finally, the beginning of the survey was designed to include three brief sections. Respondents were presented with two statements, the first required respondents to provide consent to their data being used, the second, an optional check box for those interested in participating in a follow up focus group. Next, demographic information was required in the form of gender, age and student ID number (used as the soul identifier for respondents to maintain anonymity). Finally, respondents were provided with a brief introduction to the context of the survey and a list of TEL resources currently available to them. This served to engage interest and to prompt recollection of their own experiences with these resources prior to completing the survey. The introductory part of the survey concluded with four tick box statements which aimed to categorise respondents based on their preference for resource use. In this instance, four possible responses were used in order to clearly define respondents into those with higher affinity towards technology versus those with a lower affinity. Offering a mid-point on this scale may have encouraged satisficing by offering an opportunity not to have to make a clear choice (Krosnick and Presser, 2010).

5.3.2 Data Collection Procedure

Ethical approval for this study was granted by the University of Leeds School of Medicine Ethics Committee (reference MREC17-002; Appendix 3). The final version of the pilot survey administered via hard-copy to Year 2 MBChB students is available in Appendix 4. The first lecture of term two (January 2018) was selected as an appropriate session for administering the survey because students were required to collect paper workbooks for their term two modules. Therefore, attendance during this class is historically higher than later in term. Moreover, this sample of medical students were selected because, by the second term of Year 2, they had been exposed to 12 months of learning and revising within the anatomy curriculum. This exposure meant that students should be familiar with anatomical terminology, have had experience with all available TEL resources (Table 2) and would have established anatomy-specific learning behaviours.

Data Cleaning

After collating the completed surveys, the responses were entered into an excel spreadsheet (Microsoft Excel, 2018) in their raw format (i.e. Likert responses were coded from 1-strongly disagree to 5-strongly agree), with all negatively worded items (no. 2, 8, 9 and 12) reverse-coded. Respondents who reported their resource use as 'paper-based only' and 'paper-based more than TEL' were placed in the paper-based (PB) group, while those who reported 'TEL more than paper-based' and 'TEL only' were placed in the TEL group.

Single survey item responses were found to be missing for four respondents. Since there was no pattern to the missing item responses, the missing data points were replaced with the overall mode for each of the four respective survey items. Outliers were detected using Z-scores, where a score greater than an absolute value of 3.29 (i.e. outside 3 standard deviations of the mean) led to the exclusion of three respondents' data. The dataset was then exported to SPSS (IBM Corp. Released 2017. Version 25.0) for data analysis.

5.3.3 Statistical Analysis of Survey Data

The first stage of analysis determined descriptive statistics for gender and reported resource use. Statistical significance was determined using Chi-squared (χ^2) with 2 x 2 contingency tables formed from gender and resource use. Exploratory factor analysis (EFA) formed the second stage of analysis to determine if a factor structure emerged from the survey instrument. The final stage of analysis used non-parametric tests to determine the relationship between factor scores, assessment scores, gender and resource use.

Exploratory Factor Analysis (EFA)

Factor analysis is a variable reduction technique used to identify latent constructs (named hereafter as 'factors') from a large number of variables (i.e. refine the length of a survey while retaining validity and increasing reliability; Tinsley and Tinsley, 1987), and is particularly recommended for surveys without a priori theory (Thompson, 2004). In this study, EFA was conducted using principal components analysis.

Prior to performing EFA, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were performed. The primary objective of factor analysis in this study was to generate a solution that is interpretable and parsimonious. Therefore, in order to make the output from EFA easier to interpret, Varimax rotation was used to attain a 'simple structure' (Tabachnick and Fidell, 2007; Gie Yong and Pearce, 2013). The process of factor extraction (i.e. deciding which factors to retain) utilised a range of analytical and subjective techniques in an iterative process (Field, 2009). The criteria used in this study were: (1) Kaiser's criterion, established via scree plot analysis and ensuring included factors have an eigenvalue >1; (2) Parallel analysis, achieved using an online software (Vivek et al., 2007) to conduct principal components analysis on a number of random correlation matrices with the same number of survey items and participants. The resultant eigenvalues were averaged and compared with the eigenvalues produced within the current study to determine which factors are a result of random noise (Watkins, 2005); (3) Factor loading analysis, where each factor must have at least 3 items loading and must load with an absolute value >0.4; (4) Subjective interpretation to ensure the extracted factors make sense in a real-world setting, and; (5) Internal consistency, where a factor was retained if it had a Cronbach's alpha >0.7 (Field, 2009).

Following the iterative process of factor extraction, item removal and survey refinement, the final step involved interpretation of the variables within each factor and determining a factor theme. Assigning meaning to a factor is, in essence, a reflection of the researcher's conceptual framework, judgement and theoretical underpinnings (Henson and Roberts, 2006).

Factor Scores

Individual scores were calculated for the whole survey and for each of the emergent factors by summing the responses from each of the retained items (following completion of EFA). The minimum possible score was calculated as the number of retained items multiplied by 1 (i.e. if all responses were "strongly disagree") and the maximum possible score was calculated as the number of retained items multiplied by 5 (i.e. if all responses were "strongly agree"). Respondent scores were then used to calculate a mean, median and standard deviation (SD). Normality (Shapiro-Wilk) tests revealed that the distribution of whole survey scores, emergent factor scores and assessment scores were not normally distributed, with P values of <0.01 recorded for all. Since all variables violated the normal distribution, non-parametric tests were used to evaluate the relationships between factor scores, gender and reported resource use, as well as the associated correlations between factor scores and assessment outcomes, using Spearman Rank Test. Statistical significance was set at 0.05 for all statistical tests.

Mann Whitney U Test

The Mann-Whitney U test was chosen since it performs well with samples without normal distribution and can be used when the sizes of the two sample groups are unequal (Field, 2009). In this study, this test was used to detect if there was a difference in factor scores when comparing dichotomous groups of students based on gender or reported resource use (PB or TEL).

Kruskal-Wallis Test

The Kruskal-Wallis test detects differences between the mean ranks of independent variables with more than 2 groups on a continuous variable. Since previous research has found differences in gender with regards to technology use (Venkatesh et al, 2012), this test was used to determine if factor scores differed based on reported resource use categorised by gender. Four groups were generated and named as follows: Male PB; Female PB; Male TEL and; Female TEL. Any significant differences between the mean ranks of the groups were analysed further using Dunn's (1964) *post-hoc* pairwise comparisons with Bonferroni corrections to establish which groups differed significantly.

5.4 Results

5.4.1 Demographics and Completion Rates

During the academic year 2017/18, the Year 2 MBChB cohort consisted of 249 students. Of these, 131 (52.6%) completed the pilot survey, with 88 (67.1%) identifying as female and 43 (32.8%) identifying as male. The gender distribution of those who completed the survey did not differ significantly from the MBChB Year 2 cohort (female, 158 [63.7%]; male, 90 [36.3%]; χ^2 (1, n = 248) = 0.45, P = 0.513). The majority of respondents were aged 19, 20 or 21 (23.4%, 29.0% and 10.7% respectively), with 1 student aged 18, and the remainder were aged 22 and over (12.2%) or did not disclose their age (23.7%). With 63.1% of the sample aged between 19 and 21, and with such a large proportion of missing data, no further analysis of age categories was carried out.

5.4.2 Resource Use Preference

In addition to acquiring demographic data, respondents self-reported their perceived proportionate use of technology-based resources versus paper-based resources. Table 4 provides a summary of respondents' self-reported study behaviour. No gender differences were observed between those who preferred paper-based resources (PB) and those who preferred technology-based resources (TEL), χ^2 (1, n = 131) = 0.66, P = 0.413.

Table 4: Summary of reported resource use for males and females

Resource Use Preference	Male N = 43	Female N = 88	Total N = 131
Paper-based resources (%)	18.6%	25.0%	22.9%
Technology-based resources (%)	81.4%	75.0%	77.1%

5.4.3 Exploratory Factor Analysis

Initial analysis of the dataset revealed an adequate KMO measure (0.800) and Bartlett's test of Sphericity, χ^2 (435) = 1383.55, $P < 0.05$, which indicate that the scale is factorable. Subsequently, EFA revealed an initial 9 factor structure. Each factor had an eigenvalue >1 and together the 9 factors explained 64.31% of the total variance. The internal reliability of the 30-item scale was calculated as slightly below adequate with a Cronbach's alpha α = 0.688 recorded. The factor structure was assessed for each of the criteria listed in section 5.3.3. With this initial output revealing an inadequate α-score, a scree plot without a clear point of inflection and factors 5, 6 and 9 all with less than 3 items loading, further cycles of EFA were required.

The initial analysis revealed that removal of item no.16 would result in a good reliability score by increasing the Cronbach's alpha to α = 0.763. Removal of this item reduced the factor structure down to 8 factors, however, factors 5 and 8 had less than 3 items loading. Incrementally reducing the number of factors resulted in 5 factors explaining 50.3% of the total variance, however, only factor 1 and 3 revealed a reliability score > 0.7, and parallel analysis suggested only 3 factors should be retained. Furthermore, there were limited apparent conceptual or theoretical links to real-world settings following subjective analysis, therefore, further EFA cycles were carried out.

This process continued over multiple iterations (see Appendix 5) and resulted in the removal of items 16, 19, 20, 21, 23, 24, 25, 27, 28, 29, and 30 from the scale. All remaining items had a factor loading value > 0.4, with each of the emergent factors having at least 3 items loading. The KMO (0.861) and Bartlett's Test of Sphericity, χ^2 (171) = 1009.98, $P < 0.05$, of the final items were above the minimum requirements for factorability of a matrix. EFA of the remaining 19 items revealed a 3-factor structure (Table 5), with each factor having a Kaiser's criterion >1

No.	Survey Item	Emergent Factor		
		1	2	3
6	TEL resources are useful for studying anatomy	.840		
7	I believe TEL resources help me to learn anatomy	.728		
14	I am motivated to learn when I study using TEL resources	.594		
13	TEL resources positively affect my experience in anatomy	.587		
18	I need to use TEL resources to study anatomy in order to score highly in my assessments	.583		
15	I feel more confident in anatomy when I study using TEL resources	.562		
11	Studying anatomy using TEL resources is intellectually stimulating	.514		
3	TEL resources allow me to work at my own pace	.485		
17	I use TEL resources when revising for my anatomy assessments	.445		
5	TEL resources accommodate my preferred learning method	.440		
1	I find TEL resources easy to use		.753	
4	I have the digital literacy skills to use TEL resources effectively		.660	
26	I am confident I know what resources are available to me and where to find them		.655	
10	TEL resources improve my ability to visualise where anatomical structures are located within the body		.615	
22	I know how to strategically use the TEL resources available to me in order to perform well in my anatomy assessments		.590	
9	TEL resources make my learning less efficient (R)			.818
12	I do not enjoy learning anatomy using TEL resources (R)			.773
8	Using TEL resources to study anatomy is not an efficient use of my time (R)			.733
2	Using TEL resources to study anatomy is frustrating (R)			.718
	Internal Consistency (α)	.835	.784	.811

Extraction method: Principal Components Analysis. Rotation method: varimax. Total variance explained = 52.17%. (R) = item was reverse coded. Factor 1 = Affective Attitudes Towards TEL; Factor 2 = Perceived Digital Competency; Factor 3 = Perceived Efficiency. Note: due to the nature of EFA (in particular, through the method of principal components analysis), it is a coincidence that the third factor consists solely of reverse coded items.

.

Table 5: Rotated components matrix of the 19-item pilot scale

and collectively accounting for 52.2% of the total variance. Analysis of the scree plot, parallel analysis and subjective interpretation of the individual items loading onto each factor led to the 3-factor structure being retained. The internal reliability of the final 19-item scale was calculated as good, with a Cronbach's alpha $\alpha = 0.891$ recorded.

Although the internal consistency and total variance explained increased in later iterations, this was at the expense of survey item no. 17 or 18, respectively. These items were retained as statistical improvements were minimal and subjective analysis found that these items contributed conceptually to the emergent Factor 1 *Affective Attitude Towards TEL* as will be discussed in more detail below.

Factor Structure and Correlations

The iterative process of EFA identified a 3-factor structure for representing the constructs that underlie the survey instrument. Each factor accounts for a different construct and is described below with their associated number of loaded survey items, as well as the internal reliability and total variance explained by the factor:

Factor 1: Affective Attitude Towards TEL

Relates to the extent to which the respondent's attitude towards TEL in anatomy influences their perceptions of a resource's utility. This relates to affective measures such as perceived confidence, motivation to learn and how intellectually stimulating they find such TEL resources. For example, item no. 15 *"I feel more confident in anatomy when I study using TEL resources"* and item no. 7 "*I believe TEL resources help me to learn anatomy"*. Factor 1 revealed 10 items loading, 36.0% variance explained and a high internal consistency ($\alpha = 0.835$).

Factor 2: Perceived Digital Competency

Relates to the respondent's perceptions of their own competency within the digital environment. This relates to their belief that they have the appropriate skills to source TEL resources, to use them strategically and their perceived ease of use. For example, item no. 1 "I find TEL resources easy to use" and item no. 4 "I have the digital literacy skills to use TEL resources effectively". Factor 2 revealed 5 items loading, 9.2% variance and a high internal consistency ($\alpha = 0.784$).

Factor 3: Perceived Efficiency

Relates to the extent to which the respondent believes TEL resources allow them to efficiently achieve intended outcomes. This relates to the level of enjoyment or frustration experienced with a resource, and to both the perceived time and learning efficiency. For example, item no. 9 “TEL resources make my learning less efficient” and item no. 2 “Using TEL resources to study anatomy is frustrating”. Factor 3 had 4 items loading, 7.0% variance and a high internal consistency (α = 0.811).

Emergent Factor Validity

To assess if the individual factors within the pilot Anatomy TEL Utility Scale were related, inter-factor correlation was measured. Correlation analysis was performed between the three factors identified (Table 6) and revealed a significant positive relationship between each of the emergent factors.

Table 6: Spearman correlations to test for the inter-factor relationships within the Pilot Anatomy TEL Utility Scale

	Factor 1	**Factor 2**	**Factor 3**
Factor 1	1.00	0.634**	0.407**
Factor 2		1.00	0.292**
Factor 3			1.00

** Correlation is significant at the 0.01 level. Factor 1, Affective attitude towards TEL; Factor 2, Perceived digital competency; Factor 3, Perceived efficiency.

5.4.4 Factor Scores

Individual scores were assigned to respondents for each of the three emergent factors using the method outlined in Section 5.3.3. For Factor 1, *affective attitude towards TEL* (10 items), the possible minimum and maximum scores were 10 and 50; for Factor 2, *perceived digital competency*, (5 items), possible scores were between 5 and 25; for Factor 3, *perceived efficiency* (4 items), possible scores were between 4 and 20, and; for the overall Anatomy TEL Utility scale (19 items), possible scores were between 19 and 95.

The average score for respondents on the overall Anatomy TEL Utility scale was 77.5 ± 7.3 (81.6% positive perception of the utility of TEL, n = 128[5]). Average scores for the emergent factors included: Factor 1 – 42.5 ± 4.4 (85.0% positive affective attitude); Factor 2 – 20.1 ± 2.8 (80.3% influence of perceived digitally competency), and; Factor 3 – 15.0 ± 1.7 (75.0% influence of perceived efficiency).

Comparisons between Gender

A Mann Whitney U test was performed to assess if any differences in emergent factor scores existed between gender. No statistical difference was observed for Factor 1, U = 2092.0, z = 1.456, P = 0.145; and Factor 2, U = 2170.0, z = 1.863, P = 0.062. However, scores for females were significantly higher than males in Factor 3, U = 2262.5, z = 2.378, P = 0.017, and in the overall survey scale, U = 2205.0, z = 2.028, P = 0.043.

Comparisons between Resource Use Preference

A further Mann Whitney U test was performed to assess if any differences in emergent factor scores existed between the PB group and TEL group. No statistical difference was observed for Factor 3, U = 1630.5, z = 1.139, P = 0.255. However, scores for the TEL group were significantly higher than those in the PB group in Factor 1, U = 2021.5, z = 3.346, P = 0.001; Factor 2, U = 1836.0, z = 2.299, P = 0.021, and; in the overall survey scale, U = 1980.0, z = 3.104, P = 0.002.

Comparisons between Resource Use Preference grouped by Gender

A Kruskal-Wallis test was performed to assess if any differences in overall scale or emergent factor scores existed between the PB and TEL groups when grouped by gender. A significant difference was recorded in the overall scale and for all three emergent factors (overall scale, χ^2 (3) = 16.000, P = 0.002; Factor 1, χ^2 (3) = 16.161, P = 0.003; Factor 2, χ^2 (3) = 9.488, P = 0.029; Factor 3, χ^2 (3) = 8.242, P = 0.023). Pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. For overall scale score, Factor 1 and Factor 3, the Male PB group scored significantly lower than the Female

[5] Analysis of respondents' factor scores and respective z-scores revealed three outliers which were removed from further statistical analysis.

TEL group (P = 0.005; P = 0.048 and; P = 0.005, respectively). No significant differences were observed between any of the groups for Factor 2 following pairwise comparisons.

Comparison with Assessment Outcomes

Results from 106[6] survey respondents' end of Year 1 exam (Body Systems module), anatomy spot test, and from the gross anatomy subset of questions in the spot test were collected. No significant correlation was observed between the overall scale and the emergent factor scores, with any of the assessment outcomes. In addition, a Mann-Whitney U test was performed to determine if any differences were present between reported resource use preference and assessment outcomes. No significant differences were observed between the PB group and TEL group for the end of year exam, $U = 899.0$, $z = -0.382$, $P = 0.702$, nor with any of the other assessment outcomes: anatomy spot test, $U = 805.0$, $z = -1.117$, $P = 0.264$; and the gross anatomy subset of exam questions from the spot test, $U = 745.0$, z = -1.588, $P = 0.112$.

5.5 Discussion

In this section, the development of the pilot Anatomy TEL Utility scale is discussed following identification of themes deemed important within the anatomy education literature (RQ2) and correspondence with existing validated survey scales. Next, the three emergent factors are discussed with comparison to the literature informing development of the scale. By highlighting students current perceptions of TEL and the factors that may influence those perceptions, these emergent factors begin to address RQ3 and RQ4. Finally, the relationship between factor scores and assessment outcomes, gender and resource preference are discussed, addressing the second part of RQ3.

5.5.1 Development of the Pilot Survey

The process of developing the pilot survey revealed the underlying themes deemed important in the evaluation of TEL resources within anatomy education. Of the 21 themes established from the literature, the most heavily utilised were: ease of use, helps learning and visualisation of anatomical structures. These themes are important in ensuring a TEL intervention is

---

6 22 students from the BSc Clinical Studies programme at Bradford University join the MBChB programme at the University of Leeds in Year 2. Therefore, assessment data from the previous academic year was not available for this group.

deemed an appropriate learning resource by survey respondents and align closely with some of the key constructs from validated survey scales such as UTAUT and ALEQ (Venkatesh et al., 2003; Smith and Matthias, 2010). However, analysis of the individual survey items within each question theme revealed significant disparity in wording. For example, out of 14 articles which listed a survey item measuring 'ease of use', there were 9 variations in the wording of those items. This lack of consistency in survey items utilised from one study to the next is linked to the notable paucity of validated survey instruments being employed across studies evaluating TEL in anatomy (evidenced in section 4.4.2). This lack of consistency makes it difficult to compare perceptions of TEL from a range of student groups (e.g. medical / dental / biomedical sciences), across different resources (e.g. dissection videos / screencast videos) and between institutions (e.g. a TEL-heavy institute / TEL-light institute). It is evident there is a need for a validated survey scale developed specifically for gathering perceptions of TEL within anatomy education. This would not only provide consistency in the individual survey items used between studies, it would also improve the overall reliability and validity of the results of such studies allowing for robust evidence-based conclusions to be drawn (Tsang et al., 2017).

5.5.2 Emergent Factors Influencing Perceived Utility of TEL

Three emergent factors were established: (1) *affective attitude towards TEL*; (2) *perceived digital competency* and; (3) *perceived efficiency*. Emergent Factor 1 represents the affective attitude respondents may have to the utility of TEL which, in line with RQ3, revealed the majority of respondents have a strong, positive attitude towards TEL in anatomy. This result aligns closely with the conceptual framework and is supported by the findings from the systematic literature review that revealed the majority of studies within anatomy education report high levels of student satisfaction with TEL (e.g. Kivell et al., 2009; Yammine and Violato, 2015; Alfalah et al., 2018).

The second emergent factor was *perceived digital competency*. This construct is related to respondents perceived ease of use and personal competence in using anatomy TEL resources. Unlike the item loadings in Factor 1, *perceived digital competency* is rarely identified within anatomy TEL evaluation surveys, with just three studies incorporating related item (Durham et al., 2009; Hu et al., 2010; Stirling and Birt, 2014). Despite this, this construct is considered within the conceptual framework of this thesis within 'perceived competence using TEL'. This finding also aligns with literature outside of anatomy education and links closely with self-determination theory which stipulates that students intrinsic motivation to perform a behaviour is increased if they perceive they have the competence to successfully perform the behaviour (Ryan and Deci, 2000; Ten Cate et al., 2010). Since this factor does not feature predominantly within anatomy TEL literature, but may theoretically have an impact on TEL engagement, it will be explored further during the focus groups.

The final emergent factor was defined as *perceived efficiency*. Examining the items loading within this factor in more detail, it is difficult to draw parallels with the conceptual framework. One possible link may be drawn between principles of resource usability and the items drawing upon the concepts of frustration and efficiency (Zaharias and Poylymenakou, 2009; Sandars, 2010; Van Nuland et al., 2016). Further uncertainty surrounding Factor 3 is evident in the loading of item 12 (enjoyment). While it may be intuitively more suited to Factor 1, it repeatedly loaded highly with the other three items in Factor 3. Consequently, identifying an unambiguous theme tying these items together was challenging and for this reason, was named according to the predominant theme within the items loading (Field, 2009). Furthermore, the concepts existing in the individual items loading in Factor 3 have not previously been identified or specifically grouped together in existing validated survey scales or theoretical models. Despite this, the loading values for all four items were particularly high and the internal consistency of the factor was good, suggesting there is a strong relationship between them.

In line with RQ4, the three emergent factors from this pilot survey have unveiled evidence of factors influencing students perceptions of the utility of TEL resources in anatomy education. A student's affective attitude towards TEL, perceptions of their own digital competence and perceptions of the efficiency of a resource may all have an influence on students' use of TEL while studying anatomy. These findings are encouraging, however, further investigation is required in order to better understand how these factors might play a role within anatomy education.

5.5.3 Relationship between Emergent Factor Scores, Gender, Preferred Resource Use and Assessment

Any relationship that exists between the emergent factors, gender, preferred resource use and assessment is likely a complex interplay of many variables, including many outside the scope of this study. Despite this, it is important to determine the strength and direction of the relationship between the measured variables in order to develop a better understanding of the role TEL plays in student learning.

No differences in gender were observed for *affective attitudes towards TEL* (Factor 1) and *perceived digital competency* (Factor 2), a finding that is consistent with others investigating students' perceptions of TEL in anatomy (Choi-Lundberg et al., 2015; Gazave and Hatcher, 2017; Strkalj et al., 2018). In contrast, females scored significantly higher than males in their *perceived efficiency* (Factor 3). The literature suggests there is no consensus with regards to gender differences and TEL use, with some reporting females are more strongly influenced by perceived ease of use (Venkatesh and Morris, 2000; Ong and Lai, 2006), while others report no significant difference between genders (Whitely, 1997; Padilla-Meléndez et al., 2013). Furthermore, in a study examining the usability of a computer-based learning tool for neuroanatomy, no gender differences in perceptions of usability were reported (Gould et al., 2008). However, due to the nature of the items loading within the factor, any link between these findings and previous studies is tenuous. Qualitative investigation of this relationship may provide a better understanding of this relationship and provide additional context for this study.

Moreover, one of the more intuitive results from the pilot survey was differences between the PB group and TEL group with those in the TEL group scoring significantly more positively in their *affective attitudes towards TEL* and their *perceived digital competence.* A recent study investigating the impact of previous experiences with technology found that "*students' positive prior digital experience significantly influences their perceived digital competence and their attitude toward digital technologies*" (Kim et al., 2018, p.1). While the current study did not collect data regarding previous experience, the findings from Kim et al (2018) may support an explanation for the difference in responses between the PB and TEL groups. Furthermore, although the TEL group demonstrated a more positive attitude towards TEL and a greater perceived digital competency, this was not reflected in their assessment outcomes.

Finally, no relationship was found between assessment outcomes and any of the emergent factor scores. These findings conform with a previous study at the University of Leeds which found that students enrolled within the Body Systems module demonstrate high levels of engagement with anatomy TEL resources. However, this high level of engagement was not correlated with assessment outcomes (Pickering and Swinnerton, 2019). The alignment of these findings with those from the current study are encouraging since they were conducted with a homogenous group of students. Furthermore, the fact there is no relationship between the emergent factors and assessment scores also supports the argument that engagement and satisfaction cannot be considered accurate proxies for learning (Mayer, 2004; Kirschner and van Merriënboer, 2013; Kirkwood and Price, 2014; Rienties and Toetenel, 2016; Trelease, 2016; Pickering and Swinnerton, 2019).

5.6 Conclusion

This chapter has highlighted the design, development, deployment and analysis of the pilot survey. Firstly, the various concepts perceived to be important in measuring student perceptions of TEL within anatomy education were established through thematic analysis of the existing TEL evaluation surveys, and subsequently developed into survey items. This process revealed gaps in the literature, particularly those associated with possible negative aspects of TEL. Using the existing literature base and informed by the conceptual framework, the 30-item Anatomy TEL Utility scale was generated.

The results from this survey have established affective attitude towards TEL, perceived digital competency and perceived efficiency as some of the factors influencing students' perceptions of the utility of TEL resources. While the findings from the pilot survey largely conform to the existing literature, questions have arisen surrounding the influence of perceived digital competence, and in particular, perceived efficiency. For these reasons, the proceeding chapter describes the qualitative inquiry required to develop an understanding of how and why these factors play a role in the perceived utility of TEL resources for students studying anatomy at the University of Leeds.

Chapter 6

Focus Groups with Medical Students: Uncovering the 'why'

6.1 Introduction

The previous chapter established that affective attitudes towards TEL, perceived digital competence and perceived efficiency are important factors influencing a students' perceptions of TEL within anatomy education. These findings begin to answer RQ3 and RQ4, however, questions remain around *how* and *why* these factors influence perceptions of TEL.

In the current chapter, the second stage of this exploratory study aims to answer the first part of RQ3, as well as RQ4 and the following associated sub-questions:

RQ3: What are students' perceptions of anatomy TEL resources?

RQ4: What factors influence student perceptions and use of TEL resources within anatomy education?

a) What are the prominent themes surrounding students' perceptions and use of TEL in anatomy education?
b) In what way does qualitative inquiry support the reported perceptions of TEL in anatomy education established via a survey?

To achieve this, respondents of the pilot survey were invited to participate in the qualitative stage of this study. Of the 131 respondents from the pilot survey, 12 students volunteered to participate in focus groups (11 female, 1 male). In order to maximise variety of discussion, participants were randomly assigned to three focus groups, with four participants in each group (Stalmeijer et al., 2014).

This chapter begins with a description of the design and development of the focus group question schedule informed directly by the results of the pilot survey. The chapter then presents the findings from thematic analysis of the focus group discussions, which resulted in five main themes and a number of associated sub-themes. Finally this chapter concludes with a brief discussion of the qualitative findings within the context of the results of the pilot survey.

Discussion of the findings from this chapter within the context of the wider literature is conducted within Chapter 8.

6.2 Methods

6.2.1 Development of Focus Group Schedule

The design and development of the focus group question schedule was directly informed by the results of the pilot survey. Factor analysis of the pilot survey revealed three emergent factors: (1) *affective attitude towards TEL*; (2) *perceived digital competency* and; (3) *perceived efficiency*. For factor 1, the items loading within the factor were logical with concepts such as motivation, confidence and perceived usefulness which tie closely with theoretical models of motivation from the literature (Ajzen and Fishbein, 1980; Armitage and Conner, 2001; Deci and Ryan, 2004). On the contrary, review of the items loading within factor 2 and 3 revealed the specific relationships between items are not explicitly referred to within anatomy education literature or within validated survey sub-scales. For example, Factor 3 *perceived efficiency* revealed four items correlating highly with one another, however, the link to existing theoretical frameworks is tenuous. These four items were as follows:

1. TEL resources make my learning less efficient (R)
2. I do not enjoy learning anatomy using TEL resources (R)
3. Using TEL resources to study anatomy is not an efficient use of my time (R)
4. Using TEL resources to study anatomy is frustrating (R)

With links to affective attitude [Q2], usability [Q4] and cost value [Q1 & 3] (Armitage and Conner, 2001; Sandars, 2010; Schunk, 2014), it is evident that while the individual items hold merit with regards to the conceptual framework, the theoretical relationship between them remains uncertain. For this reason, the concept of efficiency was explored in more detail in the focus groups, with particular attention paid to both positive and negative assertions.

Moreover, the process of factor analysis of the pilot survey resulted in the removal of 11 items from the original scale. These items covered topics such as privacy, distraction and accessibility, which have been found to be potentially important factors influencing students use of TEL (Link and Marz, 2006; Wallace et al., 2012; Selwyn, 2016; Delgaty et al., 2017; Zureick et al., 2018). While the findings in Chapter 5 demonstrated no statistical relationship for these concepts with the other items in the scale, exploring this qualitatively will determine whether this lack of relationship is indeed reflective of student perceptions at the University of Leeds.

Following analysis of the pilot survey, a focus group schedule was developed in order to help explore these findings in more detail. The aims of the focus groups were to, firstly, ensure topics arising from the pilot survey were explored in sufficient detail, and secondly, to offer participant groups the opportunity for natural discussion and elaboration (Stalmeijer et al., 2014; Sutton and Austin, 2015). For this reason, a semi-structured question schedule was determined to be the best approach. The focus group schedule comprised of five broad and open questions. In developing these questions, the topics of digital competency (factor 2) and efficiency (factor 3) were not explicitly referred to as it was deemed more appropriate to allow comments related to these concepts to arise naturally in the discussion, with the moderator then prompting to encourage elaboration. The same reasoning was applied to concepts covered by items removed from the pilot survey. The final focus group schedule, therefore, included the five main questions and a series of question prompts (Appendix 6) that supported the moderator in fostering discussion and elaboration on key topics of interest

6.2.2 Credibility, Dependability, Transferability and Confirmability

In line with Lincoln and Guba (1985), methodological rigour was achieved through the process of credibility, dependability, transferability and confirmability. Firstly, credibility was achieved through prolonged engagement with the process of analysis, including referential adequacy, where the focus group data was analysed, set aside and then analysed again (Lincoln and Guba, 1985). In addition, a subset of data was analysed by an independent reviewer (Postdoctoral student, School of Education, University of Leeds) who was unrelated to the project. Secondly, dependability, is achieved through detailed description of the methodological approach (Shenton, 2004). Thirdly, transferability is demonstrated through detailed description of the research context and by using rich verbatim extracts from the participants to report the findings. This is to assist the reader in making judgements on whether the themes are true to the participants' accounts (Lincoln and Guba, 1985). Finally, confirmability is achieved through researcher reflexivity and reflection (Noble and Smith, 2015), an account of which is included in Section 3.6. By maintaining a research journal and through discussions with supervisors, any potential impact of prejudices and biases was monitored.

6.2.3 Data Collection Procedure

A total of three focus groups were carried out within the School of Medicine at the University of Leeds on three consecutive days during March 2018. Participants were Year 2 MBChB students from the 2017/18 academic year. An email was sent via a third party (Education Service Officer, Division of Anatomy) to students who had previously completed the pilot survey and, by ticking a box at the top of the survey, had consented to being contacted regarding participation in a focus group (N = 59). Prior to attending, participants were provided with an information sheet and consent form (Appendix 7 and 8, respectively) informing them of the purpose of the study and providing assurances on data confidentiality. To maintain the anonymity of the participants data to the researcher, no direct links were made between focus group participants and their respective survey data or assessment outcomes. The researcher was the lead moderator in all three focus groups and was supported by an assistant moderator who noted any important quotes, pertinent issues, and non-verbal expressions. Non-verbal expressions provided additional insight into the levels of consensus as topics arose and included noting down visible signs of agreement or disagreement (e.g. nodding or shaking head) from the listening participants. Following each focus group, the lead and assistant moderator discussed key observations and pertinent quotes which helped inform the analysis process. All discussions were audio recorded using two dictaphones (SONY IC Recorder, IC-PX312; Sony Corp., Tokyo, Japan) and then transcribed verbatim.

6.2.4 Ethical considerations

Ethical approval for this study was granted by the University of Leeds School of Medicine Ethics Committee (reference MREC17-002; Appendix 3). To maintain the anonymity of the participants to the researcher, the student IDs (provided by respondents who completed the pilot survey) associated with those who consented to being contacted regarding focus groups were sent to the MBChB Year 2 Co-ordinator who sent out a recruitment email. From here, focus group participants were reassured via the information sheet, consent form and verbally at the beginning of each focus group that all identifiable information would be removed and direct quotes used for the purposes of dissemination would be anonymised. Furthermore, participation was entirely voluntary and participants were informed they could withdraw at any time, however in this study, none of the focus group participants withdrew prior to completion of data collection.

6.2.5 Data Analysis

The transcribed focus group discussions were imported into NVivo qualitative data analysis software (QSR International Pty Ltd. Version 11) where all data analysis took place. To increase the credibility of the findings, two cycles of data analysis were carried out. Once immediately following data collection (April – May 2018), and again four months later (September – October 2018). A thematic analysis approach was employed for generating codes and themes within the dataset (Braun and Clarke, 2006). This process involved: (1) familiarisation with the data by labelling relevant words, phrases or sentences; (2) assigning preliminary codes in order to describe the content; (3) identifying patterns and themes within the codes; (4) reviewing, defining and naming the themes. While this was a predominantly inductive approach, assignment of codes was informed by the findings from the pilot survey.

6.2.6 Reporting Qualitative Findings

Throughout this chapter, the qualitative findings are presented under the headings of the five themes and associated sub-themes identified during data analysis. The number of participants contributing to each theme and the total number of comments made are noted as a means of weighting each theme. Quotations are reported in order to bring the voice of the participants to the study as suggested by Creswell and Poth (2017) and are presented in speech marks and italics. To maintain anonymity, all names and identifying features have been removed and each quotation is assigned a participant number. For example, [FG2, P3] represents participant 3 from the second focus group. It is noted within square brackets where identifying features have been used, or to indicate to the reader the context of the quote. Irrelevant words such as 'like' or 'ehm' have been removed for clarity. Where more than one irrelevant word was present, the notation '…' is used.

6.3 Findings

Since discussions were predominantly led by the participants, a wide variety of learning resources were referred to. To demonstrate the relative weighting of comments with regards to the type of resources being discussed, a breakdown of the total number of comments and number of participants commenting for each learning resource is provided in Table 7. The purpose of this table is not to reflect the relative popularity of each TEL resource, but to give additional context to participant comments.

Table 7: Number of comments associated with specific learning resources

Type of Resource	Number of Participants Commenting	Total Number of Comments
YouTube Videos	12 (100%)	71
Paper Textbooks	11 (92%)	30
3D Visualisation Technology	8 (67%)	23
Workbooks*	9 (75%)	18
eBooks	8 (67%)	17
TeachMe Anatomy[7]	7 (58%)	14
Screencast Videos*	7 (58%)	13
Lecture Recordings*	6 (50%)	12
Google Searching	6 (50%)	10
Online Quizzing	4 (33%)	8
Facebook	4 (33%)	8
Dissection Videos*	5 (42%)	7
VLE MCQs[8]*	1 (8%)	2
Podcasts	1 (8%)	1

* Instructor-developed resources

The focus group discussions were coded and thematised into the following five overarching themes, and eleven associated sub-themes:

1. *Expectations of TEL*
    i. Aesthetic Design
    ii. Usability
    iii. Accessibility
    iv. Privacy Online
2. *Attitude Towards TEL in Anatomy*
    i. TEL “Bridges a Gap”
    ii. Region-Specific Benefits

[7] Website dedicated to providing anatomy learning content for medical students

[8] Multiple choice questions available via the virtual learning environment

3. *Navigating and Managing TEL Content*
    i. Influence of Time
    ii. Boundary Setting
    iii. Seeking Validation
4. *Social Influence*
    i. Influence of peers
    ii. Influence of Educators
5. *Generational Characteristics*
    i. Learning Behaviours and Preferences
    ii. Digital Competency
    iii. Perceptions of Enhancement to Learning

This list represents the organisation of the presentation of the findings, where the five overarching themes are presented across the following five sub-sections.

6.3.1 Expectations of TEL Resources

The first theme that was identified in the focus groups was participant expectations of TEL. This theme is defined as participants expectations on the aesthetic design, usability and accessibility of a resource. Expectations of TEL resources was one of the largest themes with all 12 participants providing a total of 76 related comments. It was evident throughout discussions that this overarching theme could be divided into four sub-themes: (i) Aesthetic Design (N = 11; 47 comments); (ii) Usability (N = 6; 11 comments); (iii) Accessibility (N = 6; 10 comments) and; (iv) Privacy Online (N = 4; 8 comments).

Aesthetic Design

The first sub-theme, aesthetic design, was one of the most pertinent findings and relates to the subjective judgements made by participants on both the visual and auditory aesthetics of the resource. For most participants, expectations regarding the aesthetic design of a resource were high:

> *"I think for me it's just pictures… I'm learning anatomy, I want to be able to look at it whilst I listen to you talking. So if they have no nice diagrams, I'm like 'nah… skip'." [FG1, P1]*

Nearly all of the participants (N = 11; 47 comments) described selecting a resource based upon how visually appealing they find it. This judgement was evident from participants who commented on visual aspects of resources such as the use of colour, labels and imagery, as well as the clarity and overall layout (N = 9).

> *“A website has got to look nice. I know it sounds silly, but if it looks like it was built in Windows 1998, then I’m just not going to use it [laughs].” [FG2, P1]*

For almost half of the participants (N = 5), the judgement they made on TEL resources went beyond aesthetic appeal. These participants described a perceived lack of effort on the part of the resource developer, with some going as far to say that while an older website may be the best learning resource, if it they perceive it as desultory in design, they will likely not attempt to use it.

> *“You just think, ‘Oh they haven’t put the effort into making it look nice, it’s probably not going to be good’” [FG2, P4]*

Furthermore, some participants (N = 5) described an aversion to resources that are dense in text, with two participants [FG1, P4; FG2, P4] stating they actively avoid reading when it came to studying anatomy.

> *“If you go on a website and it is just full of like loads of text and loads of massive words, I’ll just be like ‘no’ [hand gesture]” [FG1, P1]*

The drive to avoid excessive effort continued to be expressed by participants when describing the process of deciding upon which online video to use. Firstly, there seemed to be a general consensus among participants (N = 9) that the optimum length of a video is 10-15 minutes, with anything shorter perceived to have insufficient detail, and anything longer perceived to be excessive. For a few participants (N = 3), the exception to this rule was when the video was provided by an educator:

> *“I think that the exception to that is [educator]’s own videos on YouTube. If they are longer then I’ll watch them because I know it’s probably what I should be watching.” [FG3, P4]*

Secondly, when determining which online videos they are willing to engage with, half of the participants (N = 6) also described making a judgement on auditory aesthetics. For some participants (N = 3), this was expressed as frustration with narration that was perceived to be slow and tedious, while one participant [FG3, P1] described avoiding narrators that spoke too quickly. For others (N = 3), comments regarding auditory aesthetics were associated with difficulty understanding the accent of the narrator.

> *“It sounds bad, but if they have a really strong accent that’s hard to understand… It’s really hard to take in the information so I just watch a different video.” [FG2, P2]*

It is evident that participants make judgements about the quality of the TEL resources they are presented with based upon how aesthetically pleasing they find it. Colour, layout, volume of text and narration all play a significant role in determining participants perceptions and use of TEL resources for studying anatomy.

Usability

During discussions around resource design, a number of participants (N = 6; 11 comments) commented on the perceived usability of some resources. These comments were predominantly related to 3D visualisation technologies and the VLE. Since 3D visualisation technologies were not provided by the institution and therefore not a prescribed learning resource, the default position for participants who found a 3D model difficult to use was they simply wouldn’t use it (N = 3).

> *“Some of the 3D models I’ve tried to use before were almost like completely not user-friendly so I was like, ‘well, I just won’t use that’.” [FG1, P3]*

The discussions around usability of 3D visualisation technologies was found to be closely related to perceived digital competence which is discussed in more detail under the theme *Generational Characteristics* (section 6.3.5).

With regards to the VLE, participants described difficulties in finding the resources made available to them by the institution. Participants found sourcing information on the VLE to be a convoluted process, with three participants specifically describing it as a “maze” [FG1, P1; FG1, P2; FG3, P2]. This was a commonly cited issue by participants (N = 6), with notable verbal and non-verbal agreeance from all participants in all of the focus groups.

> *“I waste a lot of time just finding all the [VLE] resources, and then making a checklist, and then I’m like, ‘okay, finally, I can study’.” [FG3, P4]*

It is notable that discussions related to resource usability were focused on resources that participants’ deemed difficult to use, as opposed to those they found easy to use. Within this sub-theme it was also evident there is a much higher expectation that a resource should be easy to use for resources deemed mandatory for successful completion of the course (i.e. the VLE), as compared to those viewed as supplementary or non-mandatory.

Accessibility

Participants' descriptions of their experiences navigating the VLE also reflected the third sub-theme, accessibility. These comments were related to frustration regarding the disparity in the location of resources from one topic to the next (N = 3), with two participants suggesting there should be more support from the institution. However, other than an expectation regarding timely access to lecture slides (N = 2), the topic of accessibility with regards to resources provided by the University of Leeds was scantly described.

> *"When a lecturer doesn't put the slides on beforehand then everyone moans [P3: yeah!] and when they walk into the lecture theatre everyone is like 'oh… it's them!'" [FG3, P1]*

Conversely, accessibility of resources from external providers was a slightly greater issue for some of the participants (N = 5), particularly with regards to financial cost. This was not a particularly pertinent problem for participants, with comments arising sporadically and without much discussion. It was evident however, for those who raised the issue of financial costs, that this played a role in their expectations of the resources quality. Comments were mostly related to 3D visualisation technologies (N = 3), with free mobile applications perceived as ineffective learning resources, while relatively more expensive applications such as Complete Anatomy[9] were perceived to be much higher quality. Furthermore, discussions related to anatomy textbooks revealed that several participants (N = 5) used the e-textbooks provided by the University of Leeds library, citing the benefit of not needing to purchase an expensive anatomy textbook to support their studies:

> *"One of the recommended neuro textbooks, it's free online on the library. It's good because I don't have to buy it, and I don't have to carry it home, so that's quite helpful." [FG3, P2]*

Discussions related to perceived accessibility of resources were minimal highlighting that this may not be a pertinent issue for participants. Despite this, it is evident that financial capability does play a role in determining which resources the participants engage with while studying anatomy.

[9] 3D digital representation the human body available on mobile applications or on desktop

Privacy Online

The final sub-theme within the overarching theme of *Expectations of TEL* was privacy online. This topic did not arise naturally throughout the discussions, however, in order to better understand the results of the pilot survey the topic was prompted by the lead moderator. Responses from participants revealed a relaxed attitude towards personal data online, with four participants stating they would be happy to share their email address with an online resource provider in order to access their content:

> *“I think we are very used to signing up to shopping and ticket sites, getting the emails and then unsubscribing, it’s not something that I ever necessarily worry about.” [FG1, P1]*

Participants described using their university email, personal email and Facebook accounts to sign up to a variety of sites, including anatomy learning resources such as the BioDigital Human[10]. An exception to this generally relaxed stance arose when discussing the Year 2 MBChB Anatomy Facebook page hosted by an anatomy educator from the University of Leeds. Nearly all participants (N = 11) stated they had not commented or asked a question via the Anatomy Facebook page, with some (N = 4) describing it as an unnecessary exposure of their personal lives. Furthermore, there were concerns around the possibility of being judged by both their anatomy educator and their peers:

> *“It kind of feels like a funny platform to do it on. Like, it’s not yourself at medical school, it’s yourself in your personal life and I don’t like to mix what I use to find out about parties with my revision or with contacting my lecturers… I don’t think it’s always appropriate.” [FG1, P3]*

In this final sub-theme, it was evident that privacy online is not a particularly pertinent issue for participants, with concerns only arising following prompting from the moderator. Nevertheless, the concerns raised were associated with the Anatomy Facebook page which the majority of participants avoided using, therefore explaining why these issues may not have been considered prior to prompting.

In summary, the overarching theme of *Expectations of TEL* demonstrates that participants hold particularly high expectations with regards to the aesthetic design of a resource, with some admitting to being discouraged by resources that appear text-heavy, badly narrated or appearing ‘out of date’. The expectations surrounding aesthetic design appear more pertinent

[10] Freely available web-based resource offering a 3D digital representation of the human body

when compared with the sub-themes of usability, accessibility and privacy online, as evidenced by the associated number and nature of comments.

6.3.2 Attitude Towards Technology in Anatomy

While the first theme addressed participants expectations of TEL resources in anatomy education, the second theme that was identified in all three focus groups was related to the participants attitude towards technology within anatomy, with 10 participants providing a total of 38 comments. It was evident throughout discussions that this overarching theme could be divided into two sub-themes: (i) TEL "Bridges a Gap" (N = 9; 24 comments) and; (ii) Region-Specific Benefits (N = 6; 12 comments).

TEL "Bridges a Gap"

The first sub-theme was related to participants' views on technology bridging the gap between knowledge gained through face to face instruction, and the actual knowledge required to understand the relevant content. For some participants (N = 4), this 'gap' was a perceived lack of time in the anatomy laboratory with educators.

> *"I think if we didn't have the technology, we'd need more time in the dissection room with demonstrators. So, that's where technology sort of bridges that gap between having more time in the classroom and still learning it properly." [FG2, P1]*

While this group of participants were explicit in the necessity to supplement a perceived lack of contact time, a much larger group of participants (N = 9) implicitly described means through which TEL resources help to bridge this gap. Firstly, a small majority of participants (N = 7) described the benefit of repeatability by being able to listen back to lectures. For some, this was beneficial in allowing them to work at their own pace, while for others, an important benefit of lecture recordings was a reduced sense of anxiety during class time. As one participant commented:

> *"Learning in the lecture is less stressful than the traditional 'this is the topic, this is an hour on it'. You can sit there for the whole hour, and if you just want to zone out then it's easy because you know it's being recorded. Having that is completely priceless, it's incredible." [FG3, P1]*

The benefit of repeatability was demonstrated further by participants who described using YouTube videos in a similar manner. These online videos are utilised to supplement the educators lecture recordings, with one participant describing them as being "*like another* *teacher*" [FG2, P4]. This theme was evident from the majority of participants (N = 8) who described seeking online videos for alternative explanations of difficult concepts:

> *"It's like having a personal tutor sitting opposite you telling you what you need to know." [FG2, P1]*

Whether participants were explicit or implicit about technology bridging a gap between knowledge gained during contact time with educators and the actual knowledge required, it is evident that TEL resources are important to students in supplementing their face to face curriculum. By providing increased repeatability and flexibility with learning materials, this perceived lack of contact time is being supported by TEL resources, particularly online videos.

Region-Specific Benefits

The second sub-theme within *Attitudes Towards Technology in Anatomy* is related to the benefits of certain TEL resources more than others for specific anatomical regions of the body. This was discussed by half of participants (N = 6) who described strategically using different learning approaches depending on which region they were currently learning. In all cases, the example used was a comparison of musculoskeletal (MSK) anatomy with neuroanatomy, topics the Year 2 cohort were currently engaged in as part of the Control and Movement module (section 5.2). Generally, participants described MSK as simply requiring memorisation, as opposed to neuroanatomy which was described as more conceptual in nature and therefore requiring increased learning effort.

> *"With neuroanatomy, I find it harder to get my head around. Whereas limbs, I feel like it's just learning, so I don't watch those lectures again. Watching a neuro lecture is different, I need to like understand it, if that makes sense?" [FG2, P4]*

Several participants (N = 5) described specific TEL resources which were preferred for each region, such as 3D visualisation technologies for MSK and textbooks for neuroanatomy. Moreover, when utilising the same resource for both topics, for example YouTube, the learning behaviours described for each region varied. Some participants (N = 3) described seeking multiple videos with varied and alternative explanations of the same neuroanatomy concept, compared with MSK where just one or two videos would suffice.

Furthermore, the visual nature of anatomy was often cited as the reason for enjoying the subject so much, with some participants (N = 4) stating they wished they could spend more time learning it, while others (N = 2) described it as 'positive procrastination' from learning content they perceived to be less enjoyable.

> *"Seeing the videos and seeing the muscles, like it's not a horrible way to learn. I think it does make it so much more engaging than just sat, very isolated, reading a textbook." [FG1, P1]*

To summarise, the overarching theme of *Attitudes Towards Technology in Anatomy*, participants revealed positive affective attitudes towards technology and highlighted some of the benefits of TEL specific to the subject of anatomy.

6.3.3 Navigating and Managing TEL Use

It was evident early in the discussions that employing methods to navigate and manage TEL use was a necessary part of the process of learning anatomy for the participants. This was, in part, due to the interminable number of TEL resources available to students engaged within the anatomy curriculum. For some (N = 5), it was evident that the number of anatomy TEL resources on offer was sometimes overwhelming or stressful:

> *"I think it's a lot. It's overwhelming, especially with YouTube videos and websites and stuff. There are so many resources, it's really difficult to know which ones to use." [FG1, P4]*

The majority of participants (N = 11) provided a total of 60 comments related to methods they employ in order to deal with the large volume of information and associated TEL resources available to them. These comments fell into three main sub-themes: (1) Influence of Time (N = 9; 19 comments); (2) Boundary Setting (N = 9; 29 comments) and; (3) Seeking Validation (N = 8; 12 comments).

Influence of Time

The majority of participants (N = 9) made reference to the ongoing time constraints they faced as a medical student, such as the difficulty of juggling anatomy along with other modules in the curriculum:

> *"Time is such a biggie. I've got to remember there are so many other things in that exam and I can't afford to spend 4 hours looking through a textbook to find information on one artery in the whole body" [FG3, P1]*

There was a general perception from participants around a lack of time in the curriculum to learn material sufficiently. For this reason, many participants (N = 8) cited this as one of the main reasons they were not willing to explore or engage with TEL resources outside of those provided by the University of Leeds. For many participants (N = 7), doing so was deemed to be a potential waste of time and source of stress:

"I don't have the time to go out and watch 100 videos and go 'that was the best video for this area'." [FG3, P3]

Furthermore, for many participants, time efficiency was seen as one of the major benefits to using TEL resources over traditional resources such as textbooks. Many of the focus group discussions turned to comparisons of TEL and textbooks, with TEL resources perceived to be more efficient. For example, in an exchange between all of the participants in FG2, there was a collective agreement that completing the anatomy workbooks without the internet would take up to four times as long. Similarly, a small number of participants (N = 3) referred to the length of time it takes to source information from a large anatomy atlas compared to a Google search on their mobile device. The perception that TEL affords improved time efficiency was also evident from participants (N = 2) who attributed their progress to date solely to the use of TEL resources such as YouTube videos:

"If I couldn't use YouTube videos all year, I don't think I'd be at the same point that I am now." [FG1, P1]

In addition, participants cited other benefits technology affords them with regards to time efficiency, such as the ability to easily return to resources to pick up where they left off (N = 2) and using features of technology to speed up the learning process (N = 3), for example, listening back to lectures at two times speed. In addition, participants commented that they could maximise their learning time by repeatedly returning to the same YouTube channels as opposed to spending time looking for new ones (N = 3).

"There might be other ones [videos] out there that are better than what I'm using but that takes time" [FG1, P2]

It is evident that perceived time constraints has impacted upon the participants perceptions of the resources available to them and therefore, their willingness to engage with them. This links closely to the following sub-theme of Boundary Setting, with participants generally avoiding resources from external providers for fear of wasting time searching for appropriate resources and a concern over the trustworthiness of the content.

Boundary Setting

In this sub-theme, boundary setting is defined as the measures taken to manage the number and type of resources the students engaged with based upon the content they believed to be relevant. This was deemed necessary by participants due to the disparity between the level of anatomical detail they are required to learn as part of the MBChB programme at Leeds, and the possible extent of the complexity of the human body. As one participant put it:

> *“I think with anatomy, more than anything else, there’s infinite amounts that you can learn… it’s difficult to know how much we need to know.” [FG2, P4]*

This view of the subject of anatomy being ‘endless’ was one of the main reasons for the need to set a boundary around the content and resources the participants engaged with. For many participants (N = 9), anatomy workbooks provided by the module leader, were described as a baseline from which all other learning would take place. This was evidenced clearly in both the first and second focus groups, with participants focusing on the difficulty of knowing when to “*draw a line*” [FG1, P2] in their learning.

> *"I can get distracted by all these vessels that are actually quite insignificant clinically, and the workbooks always bring you back to where you’re supposed to be at. So, I think they’re good, like a railway line to go along.” [FG2, P3]*

Perceptions of other resources provided by the University of Leeds were similar, with the majority of participants (N = 8) describing institutionally provided resources as a priority over those from external providers. Indeed, as discussions within the focus groups shifted from the familiarity of the institutional resources, to resources that were less familiar and offered by external providers, there was an evident lack of trust associated with these resources. As a result, the theme of boundary setting was further emphasised by participants (N = 5) who described avoiding unfamiliar resources due to a lack of trust in the content or the creator. In these instances, it appeared that the default position for participants was to simply avoid unfamiliar resources.

> *“I find it difficult to know what technology to trust. There’s all these amazing websites but I just think, ‘they might be incorrect’. That’s why I prefer to use university stuff because then you know at least it’s all the correct information.” [FG1, P4]*

Nevertheless, exceptions were made for some participants (N = 3) when they felt they had learnt the content sufficiently from institutional resources in order to make an informed decision about the content of externally provided resources:

> *“After I’ve done the workbooks, after I’ve done the MCQs, after I’ve looked at the screencasts is when I would go look at the YouTube videos cause I don’t kind of want to start with that and it not be what we need. So I do use it [YouTube] but not like a first one’” [FG3, P3]*

By adhering to the structure and guidance set out in the workbooks and seeking resources that align to those workbooks, participants demonstrated implementing methods of navigating and managing TEL resource content. This was achieved by setting a boundary between the resources they were and were not willing to engage with as part of their learning process. For the majority of participants in this study, this was primarily achieved by prioritising institutional resources.

Seeking Validation

Despite the clear prioritisation of institutional resources, participants were also keen to acknowledge the benefits of having access to such a wide variety of sources of anatomical learning material online. As one participant commented:

> *"With the internet and technology you can use so many different resources and it's all in one place. That's something you're never going to get no matter how many libraries you go to." [FG1, P2]*

While the variety and choice of resources online was described as a benefit of using technology to learn anatomy, participants described taking measures to validate or double check information found from a learning resource that was not provided by the University of Leeds. The perceived need to validate unfamiliar resources was largely driven by concerns over learning information or anatomical variants that were irrelevant or incorrect according to the University of Leeds anatomy assessment:

> *"Every uni has a slightly different curriculum, and… I don't want to learn more than we have to" [FG3, P3]*

The majority of participants (N = 8) made reference to using multiple sources of information as a means of double checking and cross-referencing information they were unsure about. When prompted for the reason behind this, many (N = 6) described using a single resource as an unnecessary risk. Participants acknowledged that one of the perceived benefits of using the internet was the ability to seek out a variety of explanations from a variety of sources. For some participants (N = 4), this was important when utilising externally provided resources as a means of ensuring the resources content matched the material they had been taught:

> *"With websites you can have like 10 tabs open at once on the same thing and just keep on flicking in between them to see if they are all saying the same thing. And then, some will have different information, some will have the same and you kind of filter it that way I think." [FG2, P3]*

While participants acknowledged the necessity to employ a variety of resources to maintain their engagement and motivation in the subject, the scepticism regarding externally provided resources was evident. Taking measures to ensure that a resource's content was applicable and relevant to the context of the University of Leeds anatomy curriculum was clearly of importance to participants. For the most part, this was achieved by prioritising resources provided by the institution, using those resources to inform the usefulness of externally provided resources and then double checking and cross-referencing the content of external resources to ensure the information was correct and applicable.

6.3.4 Social Influence

As established in the preceding section, participants described methods of validating the content and context of externally provided resources. Another method used by students in validating resources was to seek recommendations from peers and educators. Resources deemed to generate success for others, or mentioned by educators, were viewed as more trustworthy and valid. Nevertheless, while peers and educators played an important role in the validation of TEL resources, their role extended beyond this characteristic. For this reason, the fourth theme identified in the focus groups was *Social Influence* (N = 11; 37 comments), where the influence of peers (N = 8; 15 comments) and the influence of educators (N = 9; 22 comments) were both explored.

Influence of Peers

During discussions related to how the participants decided which resources to use, more than half (N = 8) referred to the influence of their peers and older medical students. For many (N = 5), establishing the kind of experiences that other medical students have had with a TEL resource was important in determining their perceived value of that resource for their own learning.

> *"You'd probably trust it [a resource] coming from an older medical student because you know that they've done it and they've got through it and it worked for them" [FG1, P4]*

The concept of seeking TEL resources that had been *"tried and tested"* [FG1, P2] by other medical students was prominent. For some (N = 5), actively seeking out recommendations from others allowed them to circumvent the process of searching and finding appropriate resources for themselves. This was raised in all three of the focus groups with participants emphasising that sharing resources, such as YouTube videos, among groups of friends was their main method of finding new learning resources:

> *"I'd like someone to tell me about a resource. Like, I don't want to have to go hunting for them myself [laughs]" [FG1, P3]*

> *"We link each other to videos and that's mainly how I use YouTube. It's less I just type a word in and see what comes up because then… you have to sift through a lot of stuff that's maybe not relevant or not at the right level." [FG3, P3]*

While the majority of participants that discussed the importance of peer recommendations did so in a positive light, others (N = 3) highlighted that peer influence was not always beneficial. One participant attributed copying their peers as the main reason for failing their Year 1 anatomy assessments, resulting in anxiety associated with listening to other medical students. Conversely, following success in anatomy, attributed to their own personal learning routine, two participants described trusting their own judgement above those of their peers. For all three participants, this evident process of self-reflection had resulted in greater levels of confidence in their learning process, making clear they had found a repository of resources and a learning routine that works well for them, therefore, negating the need to rely on others:

> *"I'd say I tend to not do the same things as my friends. I think I do things differently from other people. It's been a lot of trial and error working it out but a lot of the time what other people do doesn't work for me." [FG3, P2]*

It was evident that for some, sharing resources with friends and seeking recommendations was important, while for others, confidence in their individual learning routine meant they were less likely to take recommendations that deviated from their own methods. While this divide in opinion from participants was clear with regards to peer influence, discussions related to the influence of anatomy educators appeared significantly more consistent.

Influence of Educators

The majority of participants (N = 9) were in consensus when discussing the influence of their anatomy educators. At the time of the focus groups, there were two educators responsible for the anatomy component of the Control and Movement module. Educator A was the module lead and was responsible for delivering neuroanatomy teaching, and was also responsible for all anatomy content in the Year 1 Body Systems module. Educator B was responsible for teaching musculoskeletal anatomy.

The influence of the educator manifested in a number of ways. Firstly, this was demonstrated by participants who took both direct and indirect recommendations of TEL resources from educators. Reference to direct recommendations were both reflective and hypothetical. Several participants (N = 5) reflected on their motivation and engagement with Educator A's YouTube channel because it was a recommended learning resource and developed by the individual responsible for writing their assessment. Other participants (N = 3) made more hypothetical comments regarding recommendations from educators. For example:

> *"If [Educator A] was to say an app is really good, I almost definitely would try it. I wouldn't necessarily like it, but I would definitely try it." [FG2, P4]*

Moreover, discussions in both FG1 and FG2 revealed participants had also taken indirect recommendations from Educator B. The example used in both focus groups was the incorporation of images from the externally provided TeachMe Anatomy website in the educator’s workbooks and lecture slides. While this web resource was not explicitly recommended as part of the Year 2 anatomy curriculum, participants took the educator’s use of these images as an endorsement of the websites trustworthiness.

> *“[Educator] always takes pictures from TeachMe Anatomy so I’m like ‘that must be really legit [sic], I’ll go and have a look at those’.” [FG2, P3]*

Secondly, a small majority of participants (N = 7) described varying the types of TEL resources they used dependent upon educator-specific teaching style. In the majority of instances (N = 5), these comments were with regards to lecture slide design and the subsequent use of lecture recordings on the VLE. During comments comparing the two anatomy educators, it became evident that Educator A’s use of minimal text on a small number of slides resulted in participants describing the necessity to listen back to those lectures more so than felt necessary for Educator B’s content.

> *“I wouldn’t use lecture capture for [Educator B], [P3: ‘Me neither’], but I would use it for [Educator A] [P1: ‘Definitely’]. Because [Educator B] writes a lot on the slides so [they] give you all the information already written down, whereas [Educator A] says a lot of the information so it’s good to go back and hear it again.” [FG2, P4]*

Teaching style was also cited as a factor that contributed towards the participants’ sense of engagement within anatomy. A number of participants (N = 4) compared Educator A, their main anatomy educator, with educators from other modules such as Clinical Pathology (CP). In these instances, it was clear that students enjoyed learning anatomy more than many of their other subjects and this was largely attributed to the teaching style of Educator A. In comparison, educators from the CP module, and to a certain extent Educator B, were viewed as more ‘traditional’ lecturers.

> *“I think because [Educator A] has a new way of doing things that no one else does, you kind of go in expecting to do quite well in that lecture. Whereas if it was a CP lecturer… and they’ve got a 96-slide lecture. I’ll just be thinking: ‘At what point am I going to give up on this?” [FG1, P2]*

For three participants, the impact of teaching style extended beyond face to face instruction when they described actively seeking videos online that resembled the teaching style of Educator A. For example:

> *“I look for YouTube videos where they draw, just like [Educator A]’s… it just fits my way of learning [P2 agreeing]. I can sit there and read an entire textbook on*

> *it and I would not understand it in the way that [Educator A] does it in 10 minutes drawing it." [FG1, P4]*

Thirdly, for nearly half of the participants (N = 5), the association between the anatomy educators and their responsibility for assessment content was explicitly referred to as an important factor in determining which TEL resources to use. This was primarily in relation to prioritising the resources provided by the educators as they were guaranteed to cover examinable material:

> *"Last year I watched [Educator A]'s videos because that's what we were meant to know. And how [they] taught it, [they're] obviously writing the exam questions so that's helpful" [FG3, P3]*

> *"There is so much variation in terms of anatomy, I just want to learn the version of anatomy that [Educator A] wants us to know" [FG2, P1]*

Finally, the power and influence afforded to the educators was evident in the type of language used by some participants (N = 5). The most common example of this was the belief that the educators had knowledge that extended beyond any learning resource the participants might use, including textbooks. Two participants [FG1, P1; FG2, P4] referred to educator-developed resources as a *"bible"*, while in another example, one participant [FG3, P3] admitted they had only used paper-based resources when studying neuroanatomy. When prompted for the reason behind this, they stated that Educator A had not recommended any online resources and therefore had assumed that there were no neuroanatomy TEL resources suitable for their needs.

> *"I just generally go off what [Educator A] says, 'cause [sic] I feel like he knows the most about it than any of the textbooks do." [FG3, P1]*

In summary, the findings from this theme have highlighted the degree to which participants look to others when deciding upon which TEL resources are most appropriate for their learning needs. While there was diversity in opinions regarding the helpfulness of peer recommendations, there appeared to be more of a shared consensus of opinions with regards to their educators. Firstly, participants sought direct and indirect recommendations from educators. Secondly, the educators' specific teaching styles had an influence on which TEL resources participants used and on their sense of engagement within anatomy. Thirdly, the educators' responsibility in creating and marking the anatomy assessment was explicitly referred to as a factor influencing which TEL resources the participants prioritise. Finally, the power and influence of educators was evident in the often profound language the participants used to describe them.

6.3.5 Generational Characteristics

The final theme identified throughout the focus groups was related to the generational characteristics of participants when describing their use and preferences for TEL resources. Data coded within this theme was associated with either the affirmation or contradiction of the assumptions so often made about those belonging to the millennial or net generation (section 2.2). This theme was apparent in all 12 participants, providing a total of 86 comments. The three underlying sub-themes within the overarching theme of Generational Characteristics were: (1) Learning Behaviours and Preferences (N = 12; 27 comments); (2) Digital Competency (N = 10; 13 comments) and; (3) Perceptions of Enhancement to Learning (N = 12; 46 comments).

Learning Behaviours and Preferences

It was evident in all focus groups that participants demonstrated a range of preferences in their use of learning resources. During discussions related to learning approaches with TEL, participants demonstrated varying degrees of affinity towards technology. For instance, those who appeared to demonstrate greater affinity towards technology highlighted a number of innovative learning behaviours such as watching YouTube videos while at the gym (N = 2), listening to podcasts while driving (N = 1), or linking e-textbooks to a large screen television (N = 2). Moreover, six participants described a sense of reliance on technology for studying anatomy, with particularly emotive comments arising when discussions turned to a hypothetical learning environment in which they did not have access to technology. In these instances, participants expressed concern that learning via paper-based textbooks would require a significant increase in effort and energy (N = 3), or that they simply would not enjoy learning the subject as much (N = 4).

> *"I would have to spend hours every evening just pouring over textbooks and things… It would be so dry" [FG2, P2]*

However, discussions comparing TEL and paper-based resources also highlighted a number of participants with a lower affinity towards technology, with several expressing negative opinions regarding technology (N = 5). In all cases, the comparison given was e-textbooks versus paper textbooks with participants describing a preference for paper textbooks. The tactile nature of learning with a physical textbook and a disdain for reading on a screen were the reasons consistently provided for this preference.

> *"…'cause [sic] it's like the tactileness of it as well. The fact that you are holding it in your hands, you are like 'yes, I am very engaged with this'." [FG2, P3]*

While initial analysis of participants’ behaviours and preferences seemed to split the group into those who preferred TEL versus those who preferred paper-based, analysis of comments from each individual participant revealed the complexity of these preferences. This was evidenced by multiple conflicting comments from participants. For example, one of the participants most vocal about their dislike of certain TEL resources such as e-textbooks also commented on the positive impact using technologies such as YouTube videos had on their motivation to learn. Similarly, one of the participants most vocal about their positive views and extensive use of TEL resources commented:

> *“I don’t think that we should replace anything with technology. The thought of everything being online… I don’t like the idea of it.” [FG1, P1]*

The diversity of preferences and behaviours with regards to TEL resource use in anatomy highlights that learning approaches are dependent upon many contextual factors. It also demonstrates that the characteristics often assigned to the generation these participants belong to is not applicable for all individuals, in all contexts or across all resources.

Digital Competency

The second sub-theme within *Generational Characteristics* was related to the participants comments regarding their perceived digital competency. This topic did not arise naturally in any of the focus groups, however, in order to develop an understanding of the pilot survey results, prompts from the moderator encouraged participants to discuss their perceived ability to use TEL resources. These prompts led to the majority of participants (N = 10) revealing they felt they did not have any notable issues in using TEL resources for learning anatomy:

> *“Like, can I use a computer?... I think I’m fine [laughs]” [FG2, P4]*

Several participants (N = 7) attributed their comfort with technology to their upbringing and previous exposure to technology. Experience with commercial online services, and several years using web resources in school, had allowed participants to feel they had developed a good understanding of how to use any online resource (N = 5). Participants were comfortable using the resources available to them and, by explicitly referring to their generational group, assumed that their peers would likely feel the same way.

> *“With computer skills, our generation are technology savvy enough, even if we don’t know something, we can figure it out cause we kind of know the ways.” [FG2, P3]*

Nevertheless, for a small number of participants (N = 3), the assumptions associated with their generational group had appeared to work against them.

> *"I don't feel like we've been given any help with 3D stuff. It's a bit of a wing it situation. You are kind of assumed… as a teenager you've got the experience to use technology. You know, 'you people are just expected to be good with computers, expected to be good at software!'" [FG3, P1]*

However, further analysis of these comments revealed they were explicitly related to 3D visualisation technologies, a resource not provided by the university at the time. As highlighted in *Expectations of TEL* (section 6.3.1), participants did express negative perceptions of the usability of such resources. Moreover, while this subset of participants expressed concerns about the assumption they could use TEL effectively, two participants commented they would seek support from peers when using a resource they were unsure about as they assumed their peers would have the skills to utilise the resource effectively.

It may be concluded that the majority of participants were comfortable using technology and felt digitally competent. This was justified with reference to the alignment with the assumptions made about their generation and by linking their comfort with years of experience with TEL from school. The clear exception to this was in relation to 3D visualisation technologies which highlights a disparity between this type of resource and other, more traditional TEL resources such as videos and webpages.

Perceptions of Enhancement to Learning

The final sub-theme was based almost exclusively on the final question given to the participants in each of the focus groups. This question asked: *"What does technology enhanced learning mean to you?"*, and was included to determine the perceived 'enhancement' the participants believed they may be gaining from the use of technology in anatomy. Several participants (N = 5) acknowledged that technology enhanced their engagement and motivation with the course, as well as the repeatability, flexibility and time efficiency of using resources such as lecture recordings and online videos.

> *"I wouldn't understand anatomy as well as I do without technology. I need to be able to revisit things and having someone say exactly the same thing over and over again is a really good tool." [FG3, P1]*

Many of the comments were associated with a sense of increased understanding of course content, improved time management and the increased number of options of learning resources to choose from. This commentary summarised and re-emphasised the previous discussions within the focus groups, particularly those regarding participants expectations of and attitudes towards technology (section 6.3.1 and 6.3.2).

Nevertheless, in all three focus groups, the predominant response to the final question was a shared view among participants (N = 9) that their learning was, in fact, not enhanced by technology. This viewpoint was justified by participants for the simple reason they had been using TEL throughout the entirety of their education and therefore did not feel a sense of enhancement. This rhetoric appeared unprompted in all three focus groups with participants describing the incorporation of technologies such as the VLE, Google searches, YouTube and online webpages as normal aspects of their learning routines:

> *"It's funny to think about, like when you said, 'what does technology enhanced learning mean to you?' because actually, all of my learning my entire life has been technology enhanced, there's never been a part of my education that I haven't used it. It's not really technology enhanced learning, it is just how I learn." [FG1, P3]*

These participants acknowledged that what may have been defined as 'technology enhanced learning' in the past, is now *"just part and parcel"* [FG2, P3] of normal learning for them. While this sentiment was explicitly referred to in response to the final question from the moderator, further analysis revealed evidence of this mindset throughout each of the focus groups. For example, some expressed uncertainty about what constituted the term 'technology' (N = 4):

> *"Just… you mean like lectures on the VLE and stuff? Lectures… is, is that technology?" [FG2, P4]*

> *"Do e-textbooks count?" [FG3, P2]*

Further discussion around 'technology enhanced learning' revealed that for some participants (N = 4), the term conjures images of VR headsets and immersive technologies. This group of participants had an awareness of these novel resources within anatomy education but in all instances, had not experienced their use. This highlights that for some, the term infers something other than their everyday encounters with technology.

> *"When I think of technology enhanced learning, I don't really think of the slides, or lecture capture or eBooks or even, like, YouTube… I just take them as part of my learning routine. When you're saying enhanced, it sounds like something extra that I may want to look at." [FG3, P4]*

In summary, the theme of *Generational Characteristics*, has demonstrated that participants are comfortable using TEL for studying anatomy. This comfort level is commonly attributed to previous experience with TEL and a sense of familiarity with resources such as the VLE and other online webpages. Furthermore, it is apparent participant perceptions of technology are variable between student’s with varying degrees of affinity towards technology, as well as within an individual depending upon the resource in question and a number of other contextual factors. Finally, for participants, the use of most TEL resources appears to have become normalised, where learning anatomy for them involves a variety of both technology-based and paper-based resources.

6.4 Discussion

In the previous chapter, the pilot survey revealed that *affective attitude towards TEL*, *perceived digital competency* and *perceived efficiency* were important factors. The findings from the focus group confirms that attitude towards TEL plays a role in influencing students’ perceptions and use of TEL in anatomy, with participants describing both positive and negative attitudes. In addition, the degree to which attitude towards TEL plays a role may be dependent upon a number of variables such as the anatomical region, the type of TEL resource, who has recommended it and previous experience with technology. With regard to Factor 1 from the pilot survey and the conceptual framework, the findings from the focus groups confirm affective attitude towards TEL influences student perceptions and use of TEL for studying anatomy.

Factor 2 from the pilot survey, *perceived digital competency*, arose during the focus groups following prompts from the moderator. The findings confirm the conceptual framework in that perceived digital competence is likely determined by an individual’s previous experience with TEL and the facilitating conditions surrounding the resource. Despite this, consideration must be given to the lack of natural discussion on the topic. Indeed, subsequent comments from participants appeared to reveal no pertinent issues with digital competency. However, comments prior to prompting from the moderator may suggest otherwise. For instance, opening multiple internet tabs to cross-check information or avoiding searching for material online for fear of learning something incorrectly, suggests an inability or lack of confidence in critically analysing and evaluating information sources (Lankshear and Knobel, 2008). This finding is interesting as it suggests participants do not actively consider their digital skills to be problematic, even when prompted. As such, it may be concluded that *perceived* digital competency does not play as large a role in influencing students perceptions of TEL as the pilot survey results indicated. The exception to this finding was related to 3D visualisation technologies which are somewhat unique to anatomy education and require knowledge associated with panning, zooming and manipulating 3D objects on a monoscopic screen (Lewis et al., 2014). This not only requires students to engage with unfamiliar software interfaces, it also requires application of spatial knowledge and understanding (Nguyen et al., 2014; Berney et al., 2014; Yammine and Violato, 2015). Furthermore, the clear preference for institutionally-provided resources and lack of guidance from educators regarding 3D visualisation technologies has also likely played a role in this exception to perceived digital competency.

Moreover, the findings from the focus groups highlight that the *perceived efficiency* (Factor 3) of a resource does influence students' perceptions and use of it. In the pilot survey, the relationship between the items loading was unclear and not easily mapped to existing theories or frameworks. However, the focus groups have demonstrated that efficiency and enjoyment are closely linked with one another. Participants described frustration with narration of videos and with webpages that were text-heavy and time-consuming. They also described feeling more motivated and engaged with resources that were 'clean', 'concise' and visually appealing. These findings are likely linked to the cognitive load experienced by students engaging with these resources however, further to this, the emotive nature of comments associated with time efficiency suggests TEL resource use is also driven by the high-stakes nature of assessment.

The fervency of comments associated with efficiency, and the high expectations presented by students were somewhat surprising given that these factors influencing the use of TEL have not previously been reported within anatomy education literature. This may be due to TEL evaluation articles focusing on evaluating a single TEL intervention as opposed to a more generalised evaluation of TEL, as in the present study. Therefore, those reporting on student expectations of TEL have largely focused on evaluating the extent to which a resource met prior expectations (e.g. Tworek et al., 2013; Doubleday and Wille, 2014; Ocak and Topal, 2015), without measuring what those prior expectations were. Furthermore, while instructional design, usability and curriculum design were accounted for within the conceptual framework, the topic of efficiency was not fully realised. The findings from Chapter 5 and 6 add additional insight into the degree to which factors such as time efficiency and aesthetic appeal of resources are playing a role in influencing student perceptions and use of TEL.

Finally, despite evident enhancements to learning such as improved flexibility, accessibility, enjoyment and efficiency, the majority of participants felt this was simply what was to be expected from learning anatomy within a HE setting. The comments associated with technology being 'part and parcel' of the learning experience suggests that participants feel a sense of normality, and even mundanity, with the TEL resources available to them, while new technologies (such as VR and AR) elicit a sense of novelty and inaccessibility which are more akin to the participants' own definition of 'technology enhanced learning'. This attitude appears to align with assumptions made about the millennial and net generation, that is, they have an innate digital literacy and preference to learn using technology (Sharpe et al., 2010; White and Le Cornu, 2011; Hopkins et al., 2018). However, it may be more likely that this attitude is a reflection of the normalisation of the TEL resources actually used by participants, such as lecture recordings, videos, webpages and eBooks, while engaged within a multi-modal anatomy curriculum at the University of Leeds. Investigation into the attitudes of students from other institutions in a variety of contexts would provide an improved understanding whether this attitude is generational or contextual.

6.5 Conclusion

This chapter has described the findings from the qualitative stage of this exploratory mixed methods study. In line with RQ4(a), this chapter has presented the five overarching themes and associated sub-themes developed from focus group data. Within these themes, additional insights into the factors influencing the perceptions and use of TEL were identified beyond those established by both the conceptual framework and the three emergent factors of the pilot survey. These include the influence of resource design, time, anatomical region, credibility, assessment and social influence from educators and peers.

In line with RQ4(b), the findings from this qualitative inquiry have established that Factor 1 and 3 (*affective attitude towards TEL* and *perceived efficiency*) from the pilot survey are supported, while the influence of Factor 2 (*perceived digital competency*) is not as prominent as the pilot survey results suggested. Furthermore, this chapter has provided additional insight into students perceptions of TEL at the University of Leeds (RQ3), however, this data has been collected from a sample of participants belonging to a larger cohort of medical students. Therefore, in order to determine the generalisability of these results within the wider cohort, a second large-scale survey was required. As such, the following chapter will describe the triangulation of data from both the pilot survey and focus groups for the development of the refined Anatomy TEL Utility scale.

Chapter 7

Refining the Anatomy TEL Utility Scale: Data Triangulation

7.1 Introduction

The previous two chapters described the sequential development and analysis of the Anatomy TEL Utility pilot survey scale and focus groups, respectively. In this final quantitative stage of this mixed methods study, RQ3 and RQ4 continue to be addressed, as well as the sub-question RQ4(c): "In what way do the results of a newly developed survey relate to the findings from the pilot survey and qualitative inquiry?".

The chapter begins by describing the process of data triangulation and subsequent development of the refined Anatomy TEL Utility scale. To achieve this, each individual survey item from the pilot survey was critically analysed in light of the quantitative and qualitative findings from this study so far. The chapter continues by detailing the process of data collection and analysis of the new Anatomy TEL Utility scale with Year 2 MBChB students. From here, the results of this new scale are explored in detail, firstly examining the results from factor analysis, followed by an account of the relationships existing between factor scores, assessment scores, gender and resource preference. Finally, this chapter ends with a discussion of the findings within the context of the current study and summary of the results. Discussion of the findings from this chapter within the context of the wider literature is conducted within Chapter 8.

7.2 Methods

The final stage of this exploratory sequential mixed methods study sought to triangulate the data gathered from the pilot survey and focus groups. The resulting Anatomy TEL Utility scale was deployed to Year 2 MBChB students at the University of Leeds to determine students perceptions of TEL and the factors that may influence such perceptions.

7.2.1 Triangulation and Survey Refinement

As described in the preceding chapters, the data from the pilot survey and the focus groups were analysed sequentially. By carrying out data analysis at different stages, the results from both methods were connected to one another, but not 'merged' as in other mixed methods research designs (Creswell and Plano Clark, 2011). In this study, inferences were drawn from the quantitative and qualitative data independently and, in this chapter, meta-inferences are drawn from a larger interpretation across all findings (Teddlie and Tashakkori, 2009).

Analysis of the pilot survey data revealed a 3-factor structure. While the items loading within Factor 1 (*affective attitude towards*) were logical and aligned with existing literature, Factor 2 (*perceived digital competency*) and Factor 3 (*perceived efficiency*) were explored in more detail in the focus groups. Analysis of the focus group data revealed that student perceptions of their own competence in using a resource was not a major factor influencing use of TEL, therefore suggesting that Factor 2 played a more minor role than the pilot survey results initially demonstrated. Furthermore, the focus groups revealed that students were influenced by the perceived efficiency of a resource by giving conscious consideration to the resource design and the potential cost in time. In addition, analysis of the focus group data revealed other important factors playing a role in students' perception and use of TEL. These include the influence of anatomical region, trustworthiness, assessment and influence of educators and peers.

In light of these findings, the process of data triangulation and refinement of the survey scale involved critical analysis of each survey item from the pilot survey. This allowed, on an item to item basis, for decisions to be made on the outcome of each survey item determined by meta-inferences drawn from the quantitative and qualitative findings so far. Each of the 30 items developed for the pilot survey were analysed and one of the following actions was taken in order to refine the scale: (1) removed – there was neither a quantitative or qualitative justification for retaining the item within the scale; (2) retained – there was both quantitative and qualitative justification to retain the item as is; (3) modified – the item wording was modified to reflect new information developed from focus group findings, generating one or more new items and; (4) added – where items were not included in the pilot survey but were uncovered in the qualitative findings. In total, 11 items were removed, 11 items were retained, 8 items were modified and 6 items were added. The actions taken for each individual survey item are detailed in Appendix 9, and an example of this workflow for determining each of the above actions is demonstrated in Table 8. For each item the relevant quantitative and qualitative justifications are displayed.

Table 8: Example workflow demonstrating the process of data triangulation

Original Survey Item	Quantitative Findings	Qualitative Findings	Action	New Survey Item
I am concerned about my privacy when using the TEL resources available to me	Item does not correlate with any other item in the scale. Internal consistency of overall scale would increase from α=.763 to α=.776 if removed.	FGs highlighted that privacy online was not a major concern when selecting TEL resources. The exception to this was in relation to Facebook, however, this only arose when prompted. For this reason, the item could be interpreted as being ambiguous.	Removed	*Not applicable*
TEL resources improve my ability to visualise where anatomical structures are located within the body	Correlates highly with other items. Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.784 to α=.735 from factor 2 if removed.	Several references during FGs regarding the need for imagery and videos to support the development of 3D understanding of the body.	Retained	TEL resources improve my ability to visualise where anatomical structures are located within the body
TEL resources make my learning less efficient	Correlates highly with other items. Internal consistency would decrease from α=.811 to α=.748 from factor 3 if deleted.	General perception that TEL is more 'efficient' than traditional resources. However, the concept 'efficiency' was mostly discussed in relation to time. The word 'effective' is distinct from time and encapsulates this item more clearly in accordance with the FG data.	Modified	I believe it is more effective to learn anatomy with TEL resources compared to paper-based resources
Not applicable	*Not applicable*	Resource design and aesthetics were repeatedly discussed by students as something that would influence their decision to use the resource or not. (e.g. Avoiding those with distracting colours or with lots of text).	Added	I prefer to use TEL resources that I find visually appealing

FG = Focus Groups

7.2.2 Development of Survey Scale

Following triangulation of the relevant quantitative and qualitative data for each survey item, a new 28-item Anatomy TEL Utility scale was developed. The refined survey items were scrutinised to ensure each item was composed based on best practice for developing survey items (DeVellis, 1991; Dillman et al., 2014). The new Anatomy TEL Utility scale was then embedded into the same format used for the pilot survey (section 5.3.2). This included incorporating simple demographic questions at the beginning and asking students to report their resource preference (i.e. TEL resources or paper-based resources).

Measures were taken to ensure the validity and reliability of the refined Anatomy TEL Utility scale. Content and face validity were achieved through consultation with PhD supervisors, while predictive validity was achieved through correlation coefficients to determine the association with assessment scores and respondent demographics. As with the pilot survey, the construct validity of the refined scale was achieved using exploratory factor analysis (EFA). In order to achieve parallel forms reliability, three separate versions of the survey instrument were created, each entirely identical except for the order in which the items appeared. Finally, to measure the internal consistency of the items within the refined scale, Cronbach's coefficient alpha (Cronbach, 1951) was employed to determine the extent to which the items within the scale and sub-scales were measuring the same underlying construct.

7.2.3 Data Collection Procedure

Following completion of the development stage of the survey, the new Anatomy TEL Utility scale was distributed to Year 2 MBChB students from the consecutive cohort to the participants in the pilot survey and focus groups. All aspects of data collection were identical to those described in section 5.3.3, including the timing of distribution (January 2019) and the use of hard copy surveys. The final version of the Anatomy TEL Utility scale administered to students is provided in Appendix 10.

7.2.4 Statistical Analysis of Survey Data

The results from the new Anatomy TEL Utility scale were analysed using an identical procedure to that of the pilot survey. As outlined in section 5.3.3, analysis of the survey scale involved, firstly, descriptive statistics for gender and reported resource use followed by EFA. As with the pilot survey, the parameters used in determining the emergent factors were: (1) Kaiser's criterion; (2) parallel analysis; (3) factor loading analysis; (4) subjective interpretation, and (5) internal consistency (measured using Cronbach's Alpha).

By summing the scores of the retained items, respondent scores were calculated for the whole survey and for each of the emergent factors. Respondent scores were then used to calculate a mean, median and standard deviation (SD). Normality (Shapiro-Wilk) tests revealed that the distribution of whole survey scores, emergent factor scores and assessment scores were not normally distributed, with P values of <0.01 recorded for all. Since all variables violated the normal distribution, the same non-parametric tests used for the pilot survey were employed to evaluate the relationships of individual factor scores with gender and reported resource use. Associated correlations between factor scores and assessment outcomes were calculated using Spearman Rank Test. Statistical significance was set at 0.05 for all statistical tests.

7.3 Results

7.3.1 Demographics and Completion Rates

During the academic year 2018/19, the Year 2 MBChB cohort consisted of 245 students. Of these, 129 (52.7%) completed the Anatomy TEL Utility scale, with 85 (65.9%) identifying as female and 44 (34.1%) identifying as male. The gender distribution of those who completed the survey did not differ significantly from the MBChB Year 2 cohort (female, 155 [63.3%]; male, 90 [36.7%]; χ^2 (1, n = 245) = 0.254, P = 615). The majority of participants were aged 19, 20 or 21 (27.9%, 28.7% and 9.3% respectively), with 1 student aged 18, and the rest aged between 22 and 40 (13.4%) or did not disclose their age (20.2%). With 65.9% of the sample aged between 19 and 21, and with such a large proportion of missing data, no further analysis of age categories was carried out.

7.3.2 Resource Use Preference

Respondents reported their current proportionate use of TEL resources versus paper-based resources. Table 9 provides a summary of respondents' self-reported resource use by gender. No gender differences were observed between those who preferred paper-based resources (PB) and those who preferred technology-based resources (TEL), χ^2 (1, n = 129) = 0.320, P = 0.571.

Table 9: Summary of reported resource use for males and females

Resource Use Preference	Male N = 44	Female N = 85	Total N = 129
Paper-based resources (%)	15.9%	20.0%	18.6%
Technology-based resources (%)	84.1%	80%	81.4%

7.3.3 Comparison with Pilot Survey Data

The consecutive Year 2 MBChB cohort were recruited to complete the refined Anatomy TEL Utility scale. Homogeneity was found between the two cohorts, with equitable gender distribution χ^2 (1, n = 131) = 0.048, P = 0.826, and no significant difference in reported resource use χ^2 (1, n = 131) = 0.729, P = 0.393.

7.3.4 Exploratory Factor Analysis

Initial analysis of the dataset revealed an adequate KMO measure (0.805) and Bartlett's test of Sphericity, χ^2 (378) = 1485.89, $P < 0.05$, for continuing with factor analysis. Subsequently, EFA revealed an initial 8 factor structure. Each factor had a Kaiser's criterion >1 and together the 8 factors explained 66.46% of the total variance. The internal reliability of the new 28-item scale was calculated as good, with a Cronbach's alpha α = 0.861 recorded. However, this initial output revealed some items did not correlate sufficiently with others in the scale, and factors 6, 7 and 8 all had less than 3 items loading, therefore, further cycles of EFA were required.

The initial analysis revealed that item no.19 did not correlate with any other item and had a low total item correlation (r = .115). Removal of item no.19 resulted in a slightly increased reliability score of α = 0.867. This reduced the factor structure down to 7 factors, however, factors 5 and 7 had less than 3 items loading. Incrementally reducing the number of factors resulted in 3 factors explaining 43.64% of the total variance. However, item no.23 was found not to load onto any factor with a loading value > 0.4, and parallel analysis suggested 4 factors should be retained. Furthermore, there were limited apparent conceptual or theoretical links to real-world settings following subjective analysis, therefore, further EFA cycles were carried out.

This process continued over multiple iterations (see Appendix 11) and resulted in the removal of items 15, 16, 19, 23 and 24 from the scale. All remaining items had a factor loading value > 0.4, with each of the emergent factors demonstrating a minimum of 3 items loading. EFA of the remaining 23 items revealed a 4-factor structure (Table 10), with each factor having a Kaiser's criterion > 1 and collectively accounting for 54.31% of the total variance explained. Analysis of the scree plot, parallel analysis and subjective interpretation of the conceptual nature of the individual items loading onto each factor, led to the 4-factor structure being retained. The internal reliability of the final 23-item scale was calculated as good, with a Cronbach's alpha $\alpha = 0.886$ recorded. The correlation matrix and associated scree plot for the final 23 items is provided in Appendix 12.

Although the internal consistency of the scale and total variance explained increased in later iterations of EFA, this was at the expense of survey items that contributed conceptually to the overall scale. In the interest of reaching a parsimonious output, it was decided that removal of further items would result in minimal statistical improvements and therefore these items should be retained within the scale.

Factor Structure and Correlations

The iterative process of EFA identified a 4-factor structure for representing the constructs that underlie the survey instrument. Each factor accounts for a different construct and is described below with their associated number of loaded survey items, as well as the internal reliability and total variance explained by the factor:

Factor 1: Affective Attitude Towards TEL

Relates to the extent to which the respondents' attitude towards TEL in anatomy influences their perceptions of a resource's utility. This relates to affective measures such as perceived confidence in the subject, motivation to learn and general enjoyment. For example, item no. 11 *"I feel more confident in anatomy when I study using TEL resources"* and item no. 8 "*I believe TEL resources help me to learn anatomy"*. Factor 1 revealed 12 items loading, with 32.2% variance explained and a high internal consistency ($\alpha = 0.850$).

Factor 2: Perceived Effectiveness

Relates to the extent to which the respondent perceives a resource to be effective in achieving outcomes. This relates to the effectiveness of the resource for revision and learning, time efficiency and learning effectiveness. For example, item no. 25 *"I believe TEL resources help me to learn anatomy in less time than paper-based resources"* and item no. 26 *"I believe it is* *more effective to learn anatomy with TEL resources compared to paper-based resources"*. Factor 2 revealed 5 items loading, with 9.1% variance explained and a high internal consistency (α = 0.785).

Factor 3: Resource design

Relates to the extent to which the design of a resource may influence the perceived utility of the resource. This relates to the perceived need for audio-visual elements, support in visualising 3-dimensional structures and the general visual appeal of the resource. For example, item no. 5 *"I prefer to use TEL resources that I find visually appealing"*. Factor 3 revealed 3 items loading, with 6.7% variance explained. Despite the internal consistency (α = 0.626) being below 0.7, deemed to be the minimum value for determining 'good' reliability (Field, 2009), the factor was retained due to subjective interpretability and alignment with views described by participants in the focus groups.

Factor 4: Personal Norms and Social Influence

Relates to the extent to which personal norms and social influence impact upon the perceived utility of a resource. This relates to the impact of the respondent's educator, peers and own individual views of a resource's utility. For example, item no. 22 *"If my friends recommend an anatomy TEL resource, I will definitely use it"*. Factor 4 revealed 3 items loading, with 6.4% variance explained. Despite the internal consistency (α = 0.656) being below 0.7, the factor was retained due to subjective interpretability and alignment with views described by participants in the focus groups.

Emergent Factor Validity

To assess if the individual factors within the Anatomy TEL Utility Scale were related inter-factor correlation was measured. Correlation analysis was performed between the four factors identified (Table 11) and revealed a significant positive relationship between each of the emergent factors.

Table 10: Rotated components matrix of the final 23-item scale

No	Survey Item	Emergent Factor 1	2	3	4
1	I find TEL resources easy to use	.690			
11	I feel more confident in anatomy when I study using TEL resources	.642			
9	Studying anatomy using TEL resources is intellectually stimulating	.638			
13	I do not enjoy learning anatomy using TEL resources (R)	.632			
7	TEL resources do not accommodate my preferred learning method (R)	.617			
28	I believe TEL resources are essential for learning anatomy	.600			
10	TEL resources negatively affect my experience in anatomy (R)	.591			
12	I am motivated to learn when I study using TEL resources	.555			
3	I am confident I know what resources are available to me	.542			
8	I believe TEL resources help me to learn anatomy	.528			
14	TEL resources help me perform better in my anatomy assessments	.477			
4	I am confident I have the digital skills to use TEL resources for learning anatomy	.404			
18	I use TEL resources developed outside my own university to revise for anatomy assessments		.865		
17	I use TEL resources developed outside my own university for learning anatomy		.828		
2	TEL resources are useful for studying anatomy		.547		
25	I believe TEL resources help me to learn anatomy in less time than paper-based resources		.426		
26	I believe it is more effective to learn anatomy with TEL resources compared to paper-based resources		.405		
5	I prefer to use TEL resources that I find visually appealing			.785	
6	I prefer to use TEL resources which have audio / visual elements			.622	
27	TEL resources improve my ability to visualise where anatomical structures are located within the body			.423	
20	When I find a new TEL resource, I will definitely use it				.804
22	If my friends recommend an anatomy TEL resource, I will definitely use it				.700
21	If my teacher recommends an anatomy TEL resource, I will definitely use it				.628
	Internal Consistency (α)	.850	.785	.626	.656

Extraction method: Principal Components Analysis. Rotation method: varimax. Total variance explained = 54.31%. (R) = item was reverse coded. Factor 1 = Affective attitudes towards TEL; Factor 2 = Perceived Effectiveness; Factor 3 = Resource Design; Factor 4 = Personal Norms and Social Influence.

Table 11: Spearman correlations to test for the inter-factor relationships within the Anatomy TEL Utility Scale

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.00	.694**	.563**	.441**
Factor 2		1.00	.533**	.476**
Factor 3			1.00	.518**
Factor 4				1.00

** Correlation is significant at the 0.01 level. Factor 1, Affective attitude towards TEL; Factor 2, Perceived effectiveness; Factor 3, Resource design; Factor 4, Personal norms and social influence.

7.3.5 Factor Scores

Individual scores were assigned to participants for each of the three emergent factors. For Factor 1 *Affective Attitude Towards TEL* (12 items), the possible minimum and maximum scores were 12 and 60; for Factor 2 *Perceived Effectiveness* (5 items), possible scores were between 5 and 25; for Factor 3 *Resource Design* (3 items) and for Factor 4 *Personal Norms and Social Influence* (3 items) possible scores were between 3 and 15. Scores were calculated for the overall survey scale (23 items) to determine the overall perceived utility of TEL, with possible minimum and maximum scores were between 23 and 115.

Analysis of participants' factor scores and respective z-scores revealed three outliers which were removed from further statistical analysis. The average score for participants for the whole Anatomy TEL Utility scale was 94.8 ± 9.2 (82.4% positive perception of TEL utility, n = 126). For the emergent factors average scores were as follows: Factor 1 – 50.5 ± 5.7 (83.4% positive affective attitude); Factor 2 – 20.6 ± 2.9 (82.3% influence of perceived effectiveness); Factor 3 – 13.3 ± 1.5 (88.5% influence of resource design), and; Factor 4 – 10.9 ± 1.9 (72.8% impact of personal norms and social influence).

Comparisons between Gender

A Mann Whitney U test was performed to assess if any differences in emergent factor scores existed between gender. No statistical difference was observed for any of the emergent factors in the survey scale: Factor 1, U = 2026.0, z = 1.246, P = 0.213; Factor 2, U = 1894.5, z = 0.569, P = 0.569; Factor 3, U = 2036.5, z = 1.335, P = 0.182, and; Factor 4, U = 1751.0, z = -0.175,

$P = 0.861$. There was also no significant difference across gender for the overall survey scale, $U = 1543.5$, $z = 0.893$, $P = 0.372$.

Comparisons between Resource Use Preference

A further Mann Whitney U test was performed to assess if any differences in emergent factor scores existed between the PB group, who reported a preference for paper-based resources, and the TEL group, who reported a preference for technology-based resources. No statistical difference was observed for any of the emergent factors in the survey scale: Factor 1, $U = 1344.5$, $z = 1.292$, $P = 0.196$; Factor 2, $U = 1364.5$, $z = 1.425$, $P = 0.154$; Factor 3, $U = 1366.5$, $z = 1.472$, $P = 0.141$, and; Factor 4, $U = 1315.0$, $z = 1.114$, $P = 0.265$. However, scores for the TEL group were statistically significantly higher than those in the PB group for the overall survey scale, $U = 1457.5$, $z = 2.016$, $P = 0.044$.

Comparisons between Resource Use Preference grouped by Gender

A Kruskal-Wallis test was performed to assess if any differences in overall scale or emergent factor scores existed between the PB and TEL groups when grouped by gender. There was no statistically significant difference recorded for the overall scale score: $\chi^2(3) = 7.28$; $P = 0.063$, nor for any of the emergent factors: Factor 1, $\chi^2(3) = 6.70$; $P = 0.082$; Factor 2, $\chi^2(3) = 4.41$; $P = 0.220$; Factor 3, $\chi^2(3) = 4.34$; $P = 0.227$, and; Factor 4, $\chi^2(3) = 1.36$; $P = 0.714$.

Relationship with Assessment Outcomes

Survey respondents' (N = 114[11]) assessment outcomes from their Year 1 Body Systems module end of year exam, an anatomy spot test, and the results from the Gross Anatomy subset of questions in the spot test were collected. No significant correlation was observed between the overall scale and emergent factor scores, with any of the assessment outcomes (Table 12). In addition, a Mann-Whitney U test was performed to determine if any differences were present between reported resource use preference and assessment outcomes (Table 13). No significant differences were observed between the PB group and TEL group for the assessment outcomes for any of the aforementioned examinations.

[11] 12 students from the BSc Clinical Studies programme at Bradford University join the MBChB programme at the University of Leeds in Year 2. Therefore, assessment data from the previous academic year was not available for this group.

Table 12: Spearman correlation between factors and anatomy-specific assessment scores (N = 114[11])

		End of Year Exam	Anatomy Spot Test	Gross Anatomy†
Factor 1 Affective Attitude towards TEL	*r*	-.051	-.138	-.105
	P	.595	.144	.268
Factor 2 Perceived Effectiveness	*r*	-.063	-.051	-.007
	P	.510	.593	.942
Factor 3 Resource Design	*r*	-.013	-.048	-.021
	P	.887	.611	.829
Factor 4 Personal Norms and Social Influence	*r*	-.108	-.138	-.083
	P	.254	.145	.381

r = correlation coefficient; *P* = significance level.
† Results from gross anatomy component of spot test which also includes histology, radiology, and embryology components.

Table 13: Mann-Whitney U test for assessment outcomes for the PB vs TEL groups

	PB Group (n = 19)			**TEL Group** (n = 95)			**Mann-Whitney U**		
	Mean Rank	Median	SD	Mean Rank	Median	SD	*U*	*P*-value	*r*-value
Body Systems	55.33	90.00	14.71	57.32	92.00	12.24	885.0	0.814	0.021
Anatomy Spot Test	59.33	61.00	9.34	56.56	58.00	8.62	813.0	0.742	-0.029
Gross Anatomy	65.67	41.50	5.69	55.36	39.00	6.05	699.0	0.220	-0.109

SD, Standard Deviation. *U*, Mann-Whitney U. *r*, effect size (Z/√N).

7.4 Discussion

In this section, RQ3 and RQ4 are answered by considering the results from the new Anatomy TEL Utility scale with comparison to the previous quantitative and qualitative findings. Consideration of the results of this exploratory mixed methods study within the context of the literature are discussed in the proceeding, final chapter.

7.4.1 Emergent Factors Influencing Perceived Utility of TEL

Four emergent factors were established: (1) *affective attitude towards TEL*; (2) *perceived effectiveness*; (3) *resource design*; (4) *personal norms and social influence*. The largest factor, with 12 items loading, was Factor 1 and included items associated with respondents' perception of how helpful, intellectually stimulating, enjoyable and easy to use TEL resources are for studying anatomy. These concepts not only align with the conceptual framework through links with affective domains such as enjoyment and interest, which are closely associated with an individual's intrinsic motivation (Ajzen and Fishbein, 1980; Eccles, 1983; Ryan and Deci, 2000; Eccles, 2016); they also align with Factor 1 from the pilot survey. A high mean factor score, along with the findings from the focus groups, demonstrates that students at the University of Leeds have a positive affective attitude towards the TEL resources they engage with for anatomy education. Interestingly, item no. 4 *"I am confident I have the digital skills to use TEL resources for learning anatomy"*, also loaded in this factor. While this (modified) item originally loaded with similar items associated with perceived digital competence in the pilot survey, it does also align within the wider concept of intrinsic motivation since a sense of competence and autonomy are two of the three basic needs that may determine an individual's motivation to complete a task (Deci and Ryan, 1985; 2004).

Factor 2, *perceived effectiveness*, reflects the evolution of the concept of efficiency first revealed in the pilot survey as Factor 3, and then further explored in the focus groups. With items such as no.4, *"TEL resources are useful for studying anatomy"* and no. 26 *"I believe it is more effective to learn anatomy with TEL resources compared to paper-based resources"*, changing the factor name from perceived efficiency to perceived effectiveness was appropriate. This factor now reflects a student's perception of the adequacy of a resource to produce an intended or expected outcome. The items loading within this factor also have evident links with perceived cost value. That is, the anticipated costs in time and energy required to engage with a resource. This finding is closely associated with the conceptual framework established in Chapter 3, with particular links to expectancy-value theory (Eccles and Wigfield, 2001; 2002).

Factor 3, *resource design*, is closely associated with the theme of *Expectations of TEL* from the focus group data. With items associated with visual appeal and the need for resources with both audio and visual elements, this factor links closely to principles of multimedia design (Mayer, 2005). The impact of resource design has previously been investigated within anatomy education (e.g. Gould et al., 2008; Fenesi et al., 2017; Wismer et al., 2018), however, the emphasis of these studies have been on assessment outcomes and usability questionnaires following single TEL interventions. These are discussed in more detail in the following chapter, however, it is important to note the lack of studies focusing on student perceptions of resource design and the subsequent impact on engagement. This is evidenced by the fact *resource design* was not found to be a factor influencing perceptions of TEL following analysis of the pilot survey which, following results from the systematic review, was based upon the question themes arising from existing TEL evaluation surveys within anatomy education.

Finally, Factor 4 *personal norms and social influence*, revealed another new factor arising from the refined Anatomy TEL Utility scale. Firstly, addressing the difference between personal norms and social influence. Using definitions presented by Schwartz (1977) and Kallgren et al. (2000), personal norms is defined as the students' internalised expectations regarding their reaction to particular learning behaviours. These expectations are adhered to for personal reasons associated with subjective task-value and perceptions of resource utility; which are closely associated with the previous three factors. In contrast, social influence is the change in attitude or behaviour as a result of a belief or action from peers or instructors (French and Raven, 1960; Fishbein and Ajzen, 1975; Archer et al., 2008). The items associated with both personal norms and social influence correlate highly with one another and conceptually, link closely to the theme of *Social Influence* from the focus groups. As with Factor 3, the influence of others has not previously been addressed in the existing TEL evaluation surveys within anatomy education. However, the addition of both factors emerging from the refined Anatomy TEL Utility scale highlights, not only the importance of these concepts in determining engagement with TEL, but also the benefit of engaging in a mixed methods study.

7.4.2 Relationship between Emergent Factor Scores, Gender, Resource Use and Assessment

Any relationships that exists between the emergent factors, gender, preferred resource use and assessment are likely a complex interplay of many variables, including many outside the measures of this study. Despite this, it is important to determine the strength and direction of the relationship between the measured variables in order to develop a better understanding of the role TEL plays in student learning. However, the results from the refined survey scale did not reveal any significant findings across gender, resource preference and assessment outcomes. The exception to this was a significantly higher overall survey score for students who reported a preference for TEL. While this finding is unsurprising given the purpose of the scale was to gather perceptions of TEL, there were no significant differences between the TEL group and PB group in any of the four emergent factors.

Furthermore, despite the majority of focus groups participants identifying as female, the qualitative findings are somewhat validated given there were no significant differences in gender for any of the emergent factors or the overall survey. Moreover, the lack of any significant correlation between assessment score and resource preference is also encouraging, suggesting again that there is no positive or negative impact for students who engage with TEL resources. Interestingly, despite there being no significant difference between the TEL group and PB group, Table 13 highlights that the effect size increases and the *P*-values are closer to significance the more specific the assessment score is to gross anatomy. This finding is encouraging as it suggests the respondents are considering anatomy-specific TEL resources while completing the survey as opposed to TEL resources available in the wider medical curriculum or beyond.

7.5 Conclusion

This chapter has demonstrated the development of the Anatomy TEL Utility scale, through a robust and transparent data triangulation process. The resulting 23-item survey scale was informed by both the quantitative and qualitative findings from this study so far. Factor analysis revealed four emergent factors: (1) *affective attitude towards TEL*; (2) *perceived effectiveness*; (3) *resource design*; (4) *personal norms and social influence*. In line with the second part of RQ3, no significant differences were found between gender and assessment scores; this result is encouraging as suggests TEL is a relatively neutral educational intervention. The discussion of the findings within the chapter addresses RQ4(c) by comparing the emergent factors with the findings from the previous two chapters. Furthermore, this chapter has continued to address RQ4, *"What factors influence student preferences and use of TEL resources within anatomy education?"* by highlighting the importance of affective attitudes, perceptions of effectiveness, resource design and the influence of others. The following chapter synthesizes the findings from Chapter 4, 5, 6 and 7, and provides a general discussion of these findings in light of the existing literature within this field.

Chapter 8
General Discussion

8.1 Introduction

This thesis has evaluated student perceptions and use of TEL resources within anatomy education through both an outward-facing systematic review of TEL evaluation within anatomy, and an internally-facing mixed methods approach to evaluating medical students' experiences with TEL at the University of Leeds. The purpose of this chapter is to synthesise the findings from each of these phases of the research project in order to draw more comprehensive conclusions and implications for educational practice.

Analysis of the data presented in the preceding four chapters have collectively contributed to six core findings of this thesis. These core findings are supported by minor, yet noteworthy, findings identified by this study and are highlighted alongside the respective core finding below:

Finding 1: **Studies within anatomy education take a predominantly positivist approach to TEL evaluation**

Finding 2: **There is a paucity of studies investigating the experiences of students engaged in active anatomy curricula**

Finding 3: **Students have a positive attitude towards anatomy TEL resources**

i. Students specifically identified an appreciation for the increased flexibility, accessibility, efficiency and enjoyment offered by many TEL resources.

Finding 4: **Students have a preference for institutionally provided resources**

i. Students feel there is an overwhelming number of available TEL resources and not enough time in the curriculum to explore resources in a meaningful manner.
ii. Students are particularly concerned about trusting resources from external providers.
iii. Students place a strong emphasis on utilising resources that will support successful assessment outcomes.

Finding 5: Student perception and use of TEL is influenced by perceived effectiveness, resource design and social influence

i. Perceived effectiveness: associated with how much value students assign to a resource based upon their own personal goals, the area of anatomy they are studying and the amount of time they are willing to spend engaging with it.
ii. Resource design: focus group participants demonstrated particularly emotive responses to TEL resources deemed to be badly designed, with reference to both visual and auditory design.
iii. Social influence: students showcase a socially-driven approach to gathering appropriate TEL resources.

Finding 6: Anatomy educators play a significant role in determining student perceptions and use of TEL resources

i. Students take direct and indirect recommendations from their anatomy educators.
ii. Engagement with educator-developed resources may be dependent upon educator style.
iii. Linked to Finding 4(iii), student preference for educator-developed or educator-recommended resources is driven by the awareness of the educators' role in assessment development.

The systematic literature review revealed Findings 1 and 2, which address RQ1 and RQ2 respectively, and Chapter 4 presented a detailed discussion of these first two findings. As such, the focus of the current chapter is predominantly on Findings 3, 4, 5 and 6 which were established via the three-phase exploratory mixed methods study, detailed in Chapter 5, 6 and 7. Findings 3 and 4 address RQ3, and Finding 5 and 6 address RQ4.

This chapter begins with a general discussion which explicitly addresses the four core findings from RQ3 and RQ4, and situates them within the wider literature. In the second part, the implications of the core findings from this thesis for educational practice are discussed, with particular attention paid to the role of anatomy educators. Finally, the limitations of the project and directions for future research are discussed, before providing a summary and conclusion to the thesis.

8.2 General Discussion

The following section utilises Finding 3, 4, 5 and 6 as subheadings in order to discuss each within the context of the wider literature. The factors influencing perceptions and use of TEL are evidently multi-faceted and variable depending upon individual student characteristics, as well as the type of resource, subject area and time-point within the curriculum. While acknowledging the fluctuating degree to which these factors influence students engagement with TEL, the following discussion describes the various factors as evidenced by the Anatomy TEL Utility scale and supported by the themes established from the focus groups. In addition, by drawing on the relevant theories described in the emergent conceptual framework (Chapter 3), the following section incorporates the findings of this study and presents a new conceptual framework for the factors influencing students engagement with TEL resources.

8.2.1 Students have a Positive Attitude Towards Anatomy TEL Resources

Findings from this study revealed that students at the University of Leeds have a positive attitude towards anatomy TEL resources. Results from both the pilot and refined survey revealed high levels of agreement within the emergent factor *affective attitude towards TEL*. Furthermore, *attitude towards technology in anatomy* was one of the five prominent themes from the focus groups, and demonstrated generally positive views. This supports a large majority of TEL evaluation studies within anatomy education that have reported high levels of student satisfaction (e.g. Kivell et al., 2009; Yammine and Violato, 2015; Alfalah et al., 2018). While not novel, this finding is important because affective attitude can influence an individual's intrinsic motivation to perform a behaviour such as engaging with a TEL resource (Ajzen and Fishbein, 1980; Eccles, 1983; Ryan and Deci, 2000; Eccles, 2016). Students revealed factors that may impact upon their intrinsic motivation that aligned with the three basic psychological needs associated SDT, that is, a need for autonomy, competence and relatedness (Ryan and Deci, 2000; Deci and Ryan, 2004; Ten Cate et al., 2011). Firstly, the need for autonomy is satisfied by the variety and flexibility of resources available for studying anatomy. Students highlighted the benefits of being able to pause and replay videos, as well as being able to *choose* to stop engaging with a face-to-face lecture knowing that it would be available to watch online at a later time. This is concurrent with previous research which has shown that students' place a high value on the flexibility and availability of educational videos (Beale et al., 2014) and lecture recordings for these same reasons (Bacro et al., 2013; Morris et al., 2019).

Secondly, the need for competence (i.e. perceived digital competency) is satisfied by the use of familiar and easy to use resource repositories such as the VLE and YouTube. Within anatomy education literature, digital competence is rarely addressed (e.g. Durham et al, 2008). This may be associated with the assumption that the latest generation of students have an innate digital literacy and preference to learn using technology (Kennedy et al., 2008; Sharpe et al., 2010; White and Le Cornu, 2011; Hopkins et al., 2018). Indeed, recent publications make reference to these assumptions as justification for the inclusion of TEL into anatomy education (e.g. Lazarus et al., 2017; Aktekin et al., 2018). This study found that perceptions of digital competence were generally high which suggests these assumptions may be justified. However, exceptions were evident for some students, particularly in relation to 3D visualisation technologies such as the BioDigital Human. At the University of Leeds, 3D visualisation technologies are utilised by lecturers to support the visualisation of anatomical structures, however at the time of this study, these resources were not embedded into the curriculum beyond this use. Therefore, use of 3D visualisation technology was entirely self-directed and those who did not engage with them cited the lack of guidance from anatomy educators on how to use such resources. This finding supports the argument that while students may be proficient in the use of administrative, social or entertainment technologies, the transfer of these skills into a learning environment is *"neither automatic nor guaranteed"* (Kennedy et al., 2008, p.119). Furthermore, the lack of guidance from educators may be a more prominent issue for those who do not possess sufficiently high enough prior knowledge to guide their own learning within these 3D environments (Kirschner et al., 2006).

Finally, the need for relatedness is satisfied by a sense of community from both peers and older medical students. Participants described the need for resources to be pre-approved by friends, or by students who had previously passed the anatomy assessment. This desire for their own use of TEL resources to be connected to others in this way is closely associated with social learning theory which stipulates that learning behaviours can be driven through the observation or imitation of others (Bandura, 1971). Furthermore, learning behaviours may be driven by the social norms associated with the use of individual resources. An example of this was evident during focus group discussions associated with the dedicated Facebook page hosted by one of the anatomy educators. These discussions highlighted shared concerns about judgement from peers and the unnecessary exposure of their non-professional profiles. These findings are supported by Border et al (2019) who argue that a recent decline in social media engagement within anatomy education may be associated with increased concerns from students about the content of their personal profiles (Iqbal, 2018). Such concerns may be due to a growing number of explicit warnings from medical schools regarding the consequences of unprofessional behaviour online (Jain, 2009). This, along with ongoing negative cultural associations between mental health and the use of social media (Dhir et al., 2018), may have contributed to a shift in the social norms medical students assign to the use of social media within anatomy education.

The need for relatedness was also evidently satisfied for students who shared resources with one another. This allowed students to know they were using the same resources as others which affirmed their own learning behaviours. A pertinent example of this was associated with the use of YouTube for viewing anatomy education videos. All focus group participants demonstrated positive attitudes towards YouTube, highlighting the normative belief that this is an acceptable tool for studying anatomy. This is supported by studies that found medical students often use YouTube as their primary resource for learning and research (Kingsley et al., 2011; Barry et al., 2016; Hulme and Strkalj, 2017). One explanation for this may be the impact of prior experience in determining how students search, find and select resources on the internet (Kirschner and van Merriënboer, 2013), which for many, will be influenced by the exponential increase in the popularity of YouTube for entertainment, education and information seeking in day to day life (Holland, 2016; Curran et al., 2020). Moreover, the self-reported heavy usage of YouTube for learning anatomy within this study is supported by a large volume of literature that has found such resources to be popular within anatomy education (Azer, 2012; Jaffar, 2012; Mukhopadhyay et al., 2014; Raikos and Waidyasekara, 2014; Barry et al., 2016; Sutherland and Jalali, 2017). However, a consistent criticism of video hosting webpages within anatomy education is the considerable lack of peer review and quality control (Raikos and Waidyasekara, 2014; Barry et al., 2016; Curran et al., 2020). Clearly, more research is required in this area to generate validated quality appraisal tools to allow both students and educators to determine the educational quality of the videos they use or recommend.

Finally, it should be noted, Finding 3 (students have a positive attitude towards TEL in anatomy education) was found to be a predominant finding within existing anatomy education literature during the systematic literature review (Chapter 4). However, rarely are these positive attitudes described by more than a percentage of agreement (e.g. Mathiowetz et al., 2016; Fairén González et al., 2017; Chakraborty and Cooperstein, 2018). Where other studies have established that positive attitudes towards TEL exist, this thesis has uncovered some of the reasons *why* these positive attitudes exist. This understanding is expanded further through the discussion of Findings 4, 5 and 6.

8.2.2 Students have a Preference for Institutionally Provided Resources

The aim of this thesis was to understand students experiences with all TEL resources available to them while learning anatomy. A notable finding from the focus groups was a preference for resources provided by the institution or educator, as opposed to the wide range of other resources available online. This finding is supported by previous research that demonstrated students are more motivated by educational material provided by their institution because they can more readily trust the content (Fuller and Joynes, 2015). In the current study, preference for institutionally provided resources was due to several factors including, feeling overwhelmed by the number of resources available online, finding a balance in anatomical knowledge, time available for studying and an evidently assessment driven attitude towards the resources they choose to use.

Firstly, as highlighted by the theme of *navigating and managing TEL use*, students reported feeling overwhelmed by the number of anatomy education resources available online. The increasing variety and number of TEL resources was evidenced by the systematic literature review (Chapter 4) and in the historical review of TEL within anatomy education by Trelease (2016). However, the focus on evidence solely from peer-reviewed articles is a limitation of these two reviews and, as such, the full extent to which anatomy is permeated by TEL resources is not known. It is clear, however, that students found the excessive number of options to be burdensome. This finding somewhat contradicts the earlier discussion related to the students need for autonomy being satisfied by the variety and flexibility of resources. Indeed, in discussing SDT, Ryan and Deci (2006) argue that a *"feeling of choice"* (p.1577) may facilitate intrinsic motivation. Nevertheless, this argument may now be outdated given the increasing number of choices in daily life seen in recent years thanks to developments in online shopping, comparison sites, streaming services and many more (Jeffries, 2015; Göke, 2019). In fact, the finding that students are overwhelmed by the excessive number of options for studying anatomy is supported by O'Carroll et al. (2015) who investigated medical students information seeking behaviour and found that students felt overwhelmed by the numbers of resources and the density of information (O'Carroll et al., 2015). Furthermore, within the wider literature, psychologists argue that too much choice can be burdensome (Iyengar and Lepper, 2001; Schwartz, 2000; Scheibehenne et al., 2010; Inbar et al., 2011). Known as the 'paradox of choice', individuals appreciate freedom to make their own choices, however, the more options they have to choose from, the more frustrating it becomes to make a choice (Schwartz, 2000; Scheibehenne et al., 2010; Kirschner and van Merriënboer, 2013). Furthermore, the paradox of choice argues that the greater the number of options available to an individual, the greater the concern about making sub-optimal decisions (Göke, 2019). This was evidenced by students who described a preference for institutionally provided resources as they were certain it would be helpful to revise for their assessments, compared with the uncertainty that surrounded resources from external providers.

Furthermore, the uncertainty surrounding online resources was largely associated with concerns about utilising resources that would not provide sufficient information, or conversely, would provide *too much* information. Kenwright et al (2016) found similar findings when evaluating student perceptions of a flipped classroom setting. The aforementioned reasons were cited by participants to explain why they were unwilling to engage with externally provided resources; and, similar to comments within the theme of *expectations of TEL*, participants from Kenwright et al.'s study acknowledged that anatomy is a subject learned from early school years through to consultant-level training, therefore, sourcing resources online that were pitched at the level of pre-clinical medicine is an important factor (Kenwright et al., 2016). This was evidenced by students who described a reliance on and preference for lecture recordings and anatomy workbooks from the University of Leeds. This finding suggests that these resources are being used as they were intended to, that is, to scaffold learning and provide guidance to students to support their learning (Vygotsky, 1978; Shabani et al., 2014). Moreover, preferred use of these resources was viewed as the path of least resistance, suggesting an intuitive understanding that resources designed specifically for the Leeds curriculum reduce the strain on working memory imposed by unfamiliar resources (Kirschner et al., 2006).

Viewing these findings through the lens of expectancy-value theory provides further theoretical considerations (Wigfield et al., 2009). The theory assumes that a behaviour is goal-oriented which, as highlighted through multiple comments from the focus groups, largely translated to the goal of passing the end-of-year assessment. This is concurrent with research within anatomy education that found that students perceive the importance of subjects within a medical curriculum based upon the severity in which they are assessed (Bergman et al., 2013). This aligns with other research within anatomy education which found that assessment drives learning behaviour (Wormald et al., 2009). Therefore, according to expectancy-value theory, students decide to engage with one TEL resource over another based upon the expectation that one may support greater assessment outcomes over the other (Wigfield et al., 2009; Partridge et al., 2013). Since the end-of-year assessments are based upon the content taught throughout the term, it is understandable that students have a preference for resources provided by their institution. Moreover, expectancy-value theory stipulates that behaviours are dictated by four types of subjective task-value; interest value, utility value, attainment value and cost value (Eccles and Wigfield, 2001; 2002). The findings from this study revealed subjective interest in a TEL resource is largely dictated by factors described in section 8.2.1, and utility value is directed by the perceived importance of a TEL resource in supporting the achievement of high assessment scores. Moreover, subjective attainment value is dictated by the motivation to confirm one's own knowledge. While this is important for generating links between existing knowledge and new knowledge (Taylor and Hamdy, 2013), it may also have negative consequences for students selection of TEL resources. As argued by Kirschner and Merrienboer (2013), low prior knowledge of a subject may negatively influence student learning behaviours since they do not yet have an understanding of the standards by which their knowledge is judged against. This may result in misguided or counterproductive learning behaviours (Kirschner and van Merriënboer, 2013), further demonstrating the importance of guidance for instruction of novice learners (Kirschner et al., 2006).

Finally, cost value relates to the perceived negatives associated with engaging with a TEL resource. Within the theme of *navigating and managing TEL use*, participant comments revealed that cost value is predominantly associated with time efficiency. Indeed the influence of time efficiency on student perception and use of TEL became increasingly salient with each phase of this study, with associated survey items featuring within the second emergent factor, *perceived effectiveness*. This aligns with multiple studies within medical education which found that time constraints within the curriculum dictate how students engage with TEL resources (Hortsch, 2015; Kenwright et al., 2016; 2018; Holland and Pawlikowska, 2019; Bringman-Rodenbarger and Hortsch, 2020). These findings may be explained by the current approach to medical education, which for many, including the University of Leeds, incorporates anatomy education alongside the study of several other basic sciences, and additional clinical-related subjects such as professionalism, ethics and communication skills (Heylings, 2002; Papa and Vaccarezza, 2013; Hortsch, 2015). The volume of information to be learned by students and resultant time-constraints has implications for time spent exploring different types of TEL resources and strategies for learning (Bringman-Rodenbarger and Hortsch, 2020). This educational environment fosters a situation where students prioritise efficiency in preparing for assessments (MacLean et al., 2011; Hortsch, 2015) and may, in some instances, encourage students to take 'shortcuts' in their learning approach by using technology in a suboptimal manner (Bringman-Rodenbarger and Hortsch, 2020). Instances of this were apparent in comments coded to the theme *generational characteristics,* with participants describing learning in distracting environments such as at the gym or on the bus, or by taking an evidently surface approach to learning (e.g. using 10 internet tabs simultaneously to determine the main learning points). Despite these concerns, the second survey revealed that the majority of students believe learning with TEL is more efficient than paper-based resources, with participants of the focus groups agreeing that they would not feel as confident or proficient in anatomy if they had only accessed paper-based resources.

As pre-clinical medical students, the participants of this study are largely novice anatomy learners. Therefore, their ability to confidently search, find and assess high quality resources online is hampered by a lack of understanding about where to 'draw the line' with their anatomy learning (Kirschner and van Merriënboer, 2013). As such, students seek the comfort and familiarity of resources provided by their institution. This is driven by the high value students assign to institutionally provided resources in supporting them in preparing for assessments and, by being readily available, doing so in a time-efficient manner. The influence of familiarity has recently been demonstrated elsewhere in anatomy education by Bringman-Rodenbarger and Hortsch (2020), who found when students were provided with the same histology content via three different TEL modalities: PowerPoint slides, online website and mobile app, students preferred using PowerPoint slides. The most highly cited reason for selecting this relatively low-tech resource was the familiarity of the format and the perceived ease of access. Reasons cited for avoiding the high-tech resources included a lack of time to dedicate to familiarising themselves with the resource, and being unaware these additional resources existed (Bringman-Rodenbarger and Hortsch, 2020). Since uncertainty is known to be a major cause of emotional stress for medical students (Nevalainen et al., 2010), these findings demonstrate the importance of familiarity and further highlight a reliance on institutionally provided resources.

8.2.3 Student perception and use of TEL is influenced by perceived effectiveness, resource design and social influence

Despite an evident preference for remaining within the 'comfort zone' of institutionally provided resources, students do still engage with resources from external providers. As previously mentioned, students described the use of institutionally provided resources as the path of least resistance which, by proxy, suggests the use of externally provided resources requires a greater level of thought and consideration prior to engaging with them. The three emergent factors from the refined Anatomy TEL Utility scale revealed *perceived effectiveness*, *resource design* and *social influence* to be significant factors influencing student perceptions and use of TEL. These findings are tightly aligned with comments from the focus groups, demonstrating the benefits of this mixed methods study.

Perceived Effectiveness

The first factor, *perceived effectiveness*, is closely associated with both the utility value and time efficiency of a resource, which were discussed in the previous section. However, perceived effectiveness also describes the influence of anatomical region. This was captured within the qualitative sub-theme of *region-specific benefits* which highlighted that students perceptions of resource effectiveness may vary depending upon anatomical region. These findings were most prominently associated with differences between musculoskeletal (MSK) anatomy and neuroanatomy. These differences were evidenced by the perception that 3D visualisation technologies are useful for MSK anatomy, but not for neuroanatomy; and, the use of a single video for MSK anatomy was sufficient compared to neuroanatomy which required multiple videos offering a variety of explanations. A possible explanation for these differences in learning behaviours could lie in the perceptions of the level of difficulty for these topics. Previous studies have found that neuroanatomy is perceived by medical students as being notoriously difficult to learn in comparison to other areas of anatomy (Hall et al., 2018; Javaid et al., 2018). Coined 'neurophobia' (Jozefowicz, 1994), the literature repeatedly cites the perceived complexity of neuroanatomy and a lack of clinical exposure as reasons for this perception from medical students (Jozefowicz, 1994; Hazelton, 2011; Hall et al., 2018; Javaid et al., 2018; Sotgiu et al., 2020). However, there is likely more to the 'perceived complexity' of neuroanatomy than the current literature indicates. This was highlighted by a focus group participant, who suggested that MSK anatomy is *"just learning"* compared with neuroanatomy that requires the learner to *"understand"* it [FG2, P4]. This viewpoint eludes to a difference between concrete and abstract concepts. While seemingly rarely referenced within anatomy education (e.g. Küçük et al., 2016), concrete and abstract concepts are topics of investigation within teacher education (e.g. Swanson and Williams, 2014), sociology (e.g. Steele, 2003) and cognitive neuropsychology (e.g. Wang et al., 2010; Davis et al., 2020). Applying these categorisations to anatomy indicates that MSK anatomy involves learning more concrete concepts due to existing familiarity with structure and function of the limbs, the ability to easily manipulate one's own limbs and, when in the anatomy classroom, the ability to engage in tactile interaction with anatomical models (either cadaveric or plastic). Neuroanatomy, on the other hand, requires learning of more abstract concepts that are less tangible and have significantly less opportunities for meaningful tactile interaction with anatomical models. This supports the differences in learning approaches described by students and highlights a possible reason why the perceived effectiveness of a resource may differ depending upon anatomical region.

Resource Design

The next influencing factor, *resource design*, was largely associated with aesthetic features of the resource such as visual appeal, auditory elements, structure, layout and volume of text. These features of resource design are discussed to varying degrees within anatomy education literature. Firstly, a small number of studies discuss resource design within the context of resource usability, which considers the presentation, accessibility, ease of use and instructional design of a resource (Sandars, 2010). However, the focus of these studies is largely on TEL resources that feature interactive software interfaces such as 3D visualisation technologies (Gould et al., 2008; Van Nuland and Rogers, 2015b; Wismer et al., 2018) and mobile applications (Cornwall and Pollard, 2012). Therefore, it is difficult to draw parallels between resource usability research within anatomy education and the comments from participants of this study, which largely focused on more commonly used resources such as online videos and webpages. Secondly, resource design is considered within the literature through reference to Mayer's cognitive theory of multimedia learning (CTML; Mayer and Moreno, 2003; Mayer, 2005). This theory is particularly relevant to this factor since effectively designed resources have been found to improve students' cognitive engagement with TEL by reducing the cognitive strain imposed by potentially distracting visual or auditory information (Kirschner et al., 2006; Hadie et al., 2018). Focus group comments revealed participants feel more motivated to learn with resources that look good and are easily digestible. This reasoning suggests that students are adept at sourcing learning resources that are designed to reduce cognitive load. For example, when participants described a perceived need for both images and text, a need for resources to be clearly laid out with appropriate labels, and a preference for YouTube video playlists which offer a series of short videos compared to one longer video; they were inadvertently referring to the multimedia, signalling and segmenting principles from CTML, respectively (Mayer, 2005). Furthermore, it is evident that consideration of CTML and other instructional design principles are increasing within anatomy education literature. While not an intended aim of the systematic literature review, post hoc analysis reveals that 23.3% (49 out of 210 studies) evaluating TEL in anatomy make reference to cognitive load and instructional design principles. The vast majority of these were published within the last five years (69.4%; 34 out of 49 studies), and evaluated an instructor-developed resource (57.1%; 28 out of 49 studies). This evidence demonstrates that as TEL is increasingly being employed to support anatomy education, appropriate consideration of instructional design principles is also increasing.

Moreover, some of the most emotive comments expressed by participants were coded to the theme *expectations of TEL.* Here, it was revealed that students utilising externally provided resources perceived resource design to be a direct reflection of the effectiveness and trustworthiness of the resource. This finding, along with other findings from the current study, are supported by Shoufan (2019) who investigated motivators for liking or disliking educational online videos, and found several significant motivators, including: visual presentation, relevant learning content, narration quality, perceived efficiency and interestingness. Furthermore, beyond the visual nature of TEL resources, students also commented on auditory elements of online videos. Comments demonstrated that narration speed and narrator accent play a role in determining perceived effectiveness. This supports recent research within anatomy education which found that narrator voice can have an impact on engagement and sense of satisfaction for students (Weinkle et al., 2019). Weinkle and colleague's study, along with others within wider education literature, show that differences in narrator characteristics have no significant impact on learning outcomes, however, do cause significant differences in *perceived* effectiveness (Mayer et al., 2003; Sanchez and Khan, 2016; Weinkle et al., 2019). While these findings may appear unjust, they highlight the realities of student engagement with TEL and demonstrate areas of instructional design that require consideration.

In addition, comments from participants demonstrated that volume, size and font selection of text within a TEL resource impacts upon the perceived effectiveness of the resource. This finding is closely tied to the perceived cost value of engaging with a resource (Eccles and Wigfield, 2001; 2002), with participants perceiving textbooks or text-heavy webpages as requiring more time and effort compared with resources such as online videos or lecture recordings. This supports the theoretical framework of technology-acceptance, which has previously demonstrated that effort expectancy, along with other relevant factors, influences behavioural intention to engage with a resource (Venkatesh et al., 2003; Venkatesh et al., 2012). In addition, this finding is supported by principles of CTML which, drawing upon dual coding theory (Clark and Paivio, 1991), argues that verbal and visual information require different cognitive processes. Therefore, when used effectively and in conjunction with one another, may reduce the overall cognitive load imposed on a learner (Mayer, 2005; 2010); further highlighting an explanation for students preference for audio-visual resources, over solely visual resources. Furthermore, on the topic of reading to study anatomy, participants described a preference for reading long passages of text on paper as opposed to on a screen. Studies comparing paper-based reading and screen-based reading have found students exhibit a shallower approach to learning when engaging with text on a digital device, compared with reading from a hard-copy (Mangen et al., 2013; Sanchez and Jaeger, 2015; Mangen, 2016; Wolf, 2018). Researchers argue this may be the result of digital devices re-shaping human cognition to now favour 'skim-reading' behaviour, subsequently reducing time for contemplation and consolidation of new information (Liu, 2007; Loh and Kanai, 2016; Wolf, 2018; Lim and Jung, 2019). Comments from the focus groups reinforce this argument as participants described the need for tactile interaction with paper-based resources in order to *feel* more engaged with the material. Mangen et al. (2013) and Wolf (2018) both argue physical, tactile interaction with reading material encourages re-examination of content and improves understanding. Finally, this finding contradicts the assumption that the latest generation of students have an innate preference for learning with technology (Kennedy et al., 2008; Sharpe et al., 2010; White and Le Cornu, 2011; Hopkins et al., 2018).

Within anatomy education literature specifically, evidence of differences in perceptions of screen-based and paper-based reading is best explored by studies investigating the use of eBooks. However, contrary to the above evidence, anatomy eBooks are generally very positively received by students (Stirling and Birt, 2014; Pickering, 2015; Guy et al., 2015; Stewart and Choudhury, 2015), with some reporting a preference for eBooks over traditional textbooks for learning anatomy (Guy et al., 2015; Pickering, 2015; Stewart and Choudhury, 2015). Further contradiction regarding the influence of resource design is evidenced by Fenesi et al (2017) who compared learning outcomes of groups of students exposed to anatomical images of either high or low quality, where quality was determined by the level of adherence to CTML. The findings revealed that image quality had minimal impact upon learning outcomes, which the authors conclude, can support educators by reducing the resource investment required to generate high quality images (Fenesi et al., 2017). However, as concluded by the systematic literature review, the current approach to TEL evaluation within anatomy education literature does not sufficiently evaluate the factors influencing student perceptions of TEL (Chapter 4). Therefore, the current paucity of consideration for contextual variables results in an inability to draw out explanations for these contradictions.

Social Influence

The final emergent factor influencing perceptions and use of TEL is *social influence*. This was specifically related to the influence of peers, including older medical students, and the influence of educators.

The influence of peers was discussed in section 8.2.1 with regard to their role in satisfying students' need for relatedness (Deci and Ryan, 2004; Ten Cate et al., 2011) and for establishing norms associated with different resources. While peers play an important role in supporting this psychological precursor for intrinsic motivation, comments from participants coded to the theme *social influence* revealed peers also play a role in supporting students use of externally provided resources. Participants described evaluating the effectiveness of online resources based upon the reputation of such resources amongst peers. This finding is supported by O'Carroll et al. (2015) who found similar findings when exploring medical students information-seeking behaviours online. In addition, studies investigating why medical students engaged with specific TEL resources found that recommendations from peers played a role in determining learning behaviour (Kenwright et al., 2016; Holland and Pawlikowska, 2019).

Within technology-acceptance literature, social influence features as a construct within the UTAUT model and has been found to have a stronger effect for females, novice learners and under conditions of mandatory use (Venkatesh et al., 2003). While gender differences were not found in this study, participants were pre-clinical medical students, as such, may be described as novice learners in anatomy, required to learn within a high-stakes curriculum, where success in assessments is imperative for progression. Unlike UTAUT, and other technology acceptance models, participants in this study made distinctions between the influence of peers and educators. This was apparent through the descriptions for each, with comments associated with peer to peer influence suggesting it was more discretionary that the influence from educators. This was evident in a small number of focus group participants who found the influence of peers to be stressful and distracting from their perceived successful learning approaches. This finding may be explained by evidence that some social relationships can increase test-anxiety within a high stakes learning environment such as medical education (Henning et al., 2017). Furthermore, the differences in perceptions regarding the influence of peers and educators may be explained by hierarchies of power attributed to both groups (French and Raven, 1960; Elias and Mace, 2005), with educators deemed to have more authority than peers, friends or older medical students. According to French and Raven's (1960) theory of social power, 'power' is directly associated with the construct of social influence, where social influence is the change in attitude or behaviour as a result of a belief or action from another person, and social power is the ability of that other person to instigate such changes (French and Raven, 1960; Simpson et al., 2015). Within sociology, power is described as 'authority' when it is perceived to be legitimate according to a social structure (Bealey and Johnson, 1999). Since educators are subject-matter experts with responsibilities for determining learning content, activities and assessment (Harden and Laidlaw, 2017), legitimate power is clearly afforded to them by the participants of this study. This was evidenced by comments from participants who believed their anatomy educators knew *"more… than any of the textbooks"* [FG3, P1], and instructor-developed resources should be treated like a *"bible"* [FG1, P1; FG2, P4]. Further analysis of participant perceptions of anatomy educators revealed they play a significant function in both explicitly and implicitly influencing students perceptions and use of TEL resources for studying anatomy. So much so, this was identified as an independent and significant finding that is discussed in more detail in the following section.

While section 8.2.2 concluded that students have a preference for remaining within the perceived ‘comfort zone’ of institutionally provided TEL resources, the current section has detailed the manner in which students engage with externally provided resources online. Finding 4 suggests that, while students are engaging with resources online, they do so with caution and are influenced by perceived effectiveness, resource design and social influence. This involves making judgements about the aesthetic design of a resource and whether it is fit for purpose (dependent upon anatomical region), as well as weighing up the cost to time and effort, and by taking on recommendations from peers and educators.

8.2.4 Anatomy Educators Play a Significant Function in determining student perceptions and use of TEL resources

The discussion of Finding 6 focuses exclusively on the influence of anatomy educators on students perceptions and use of TEL. This section discusses both the explicit and implicit influence of educators as evidenced by comments coded to the theme of *social influence* and through the findings discussed in preceding sections. The categorisation of explicit and implicit influence is tied theoretically to subjective norms which can be distinguished into two types (Manning, 2009), where injunctive norms are an individual’s perception of what other people want them to do, and descriptive norms are based on the inferred or observed behaviour of others. Following a meta-analysis, Manning (2009) found that descriptive norms have a stronger relationship with behavioural outcomes as compared to injunctive norms. While investigating the links between explicit (or injunctive) influence and implicit (or descriptive) influence and behavioural outcomes was outside the scope of this investigation, inferences are made that highlight how Manning’s results may be relevant to the influence of anatomy educators on students engagement with TEL.

Explicit Influence of Anatomy Educators

As discussed in the previous section, anatomy educators are inevitably viewed to be in a position of authority, therefore increasing the degree of influence they may be able to exert on students within their course or module (French and Raven, 1960; Hattie, 2003; Simpson et al., 2015). This was evidenced clearly within the focus groups by participants who explicitly described the benefit of having a YouTube channel created by Educator A, who was the individual responsible for writing their assessment questions. This unambiguous link between a preference for educator content and assessment reinforces the notion that assessment drives learning (Wormald et al., 2009). While explicit reference to the importance of the educator has not previously been discussed within anatomy education literature, it has been eluded to. For example, Acosta et al. (2018) used focus groups with optometry students to evaluate an online anatomy resource. Students reported that the online resource alone was not sufficient at achieving learning outcomes, and an educator-guided method for demonstrating salient points was preferred. The authors concluded that, *"there is acceptance of online learning methods but there is still dependence on the educator as the main administrator of their learning"* (Acosta et al., 2018, p.11). Similarly, Johnson et al (2013) investigated student perceptions of learning anatomy using web-based resources and found students perceive educators as having a role in guiding students to reputable and relevant sites (Johnson et al., 2013).

Furthermore, while students agreed that resource design was a particularly important factor in determining their perceptions of a resource, several agreed that exceptions to this applied to resources developed or recommended by their educator; with two students independently stating they would try the resource even if they didn't like it. Upon initial examination, it appears this finding may support Fenesi and colleague's (2017) who, upon finding no significant difference in learning outcomes between students who learnt with either low or high quality images supplied by their educators, concluded that resource investment into the generation of high quality images could be reduced. However, despite extensive reference to cognitive load theory, analysis of the low and high quality images reveals no substantial differences other than slightly increased fidelity in the higher quality images (Fenesi et al., 2017). All relevant principles of multimedia learning, according to CTML, were adhered to in both images subsequently calling into question the authors interpretation of image quality. When medical students learn via resources designed with truly disparate levels of adherence to CTML, those exposed to greater levels of extraneous information consistently perform worse than their counterparts (Levinson et al., 2007; Khalil et al., 2008; Issa et al., 2011; Young et al., 2014). This, along with the finding that students will use a TEL resource if it meets their educational needs, regardless of other factors such as resource design (Chen, 2011), has major implications for instructional design within anatomy education.

Implicit Influence of Anatomy Educators

The findings from this study revealed there to be an implicit, unintentional influence on students use of TEL resources as a direct result of instructional design. This was evidenced by several students who said they used the webpage TeachMe Anatomy because Educator B used images from the site in their lecture slides and, therefore, students perceived it to be an effective resource for learning. Moreover, comments from students revealed learning behaviours with TEL were also dictated by instructional design of lecture slides dependent upon the teaching style of the educators. Students were more likely to listen to lecture recordings for Educator A since they included less information on their slides compared with Educator B. A similar finding was reported by Bacro et al (2013) who found a statistically significant correlation between number of lecture recording views and the lecturer delivering it. However, without qualitative inquiry, the authors failed to determine the reason for this. Instead, based on anecdotal feedback from a single student, they suggested the increased number of views for one lecturer may be due to a fast pace of narration and a need to replay (Bacro et al., 2013). The lack of methodological rigour makes it difficult to draw robust conclusions, however, the findings from the present study may support an alternative explanation – students behaviour was influenced by the instructional design of lectures.

Moreover, distinctions can be made between *instructional* design and *learning* design, where instructional design reflects how the educator designs their teaching content and learning design reflects what the student does in order to acquire knowledge (Laurillard, 2012; Beetham and Sharpe, 2013; Newlin, 2016). In both instances, responsibility lies with either an individual or a team of educators, with learning design dictating which resources students are offered, as well as how and when they are offered (Laurillard, 2012; Harden and Laidlaw, 2017). The importance of learning design in determining student experiences with TEL was highlighted by Paechter et al (2010). Using a mixed methods approach, their primary outcome revealed perceived support from educators significantly influences learning achievements and student satisfaction. In addition, secondary outcomes revealed the coherence of the learning material, the structure of the content and the stimulation of learning motivation, all influenced student perceptions of TEL (Paechter et al., 2010). The factors highlighted by Paechter and colleague's (2010) all contribute to learning design and require the educator to have pedagogical expertise.

Furthermore, both instructional design and learning design are particularly important given that Finding 4 revealed students have a strong preference for institutionally provided resources. Given that educators largely dictate which TEL resources are embedded into the curriculum and which are available as supplementary learning resources, consideration must be given to the resultant student experience (Ellaway and Masters, 2008). While impossible to measure the impact learning design has had on students perception and use of TEL at the University of Leeds, inferences can be made from the findings of the present study. Firstly, students who decided not to use 3D visualisation technologies to supplement their learning cited the lack of guidance from educators, suggesting that since this resource is not embedded within the curriculum they were less willing to engage with it, despite the fact it may be beneficial. Secondly, preference for institutionally provided resources may be driven by the wide range of evidence-based TEL resources available to them and directly aligned to their course content (Bickerdike et al., 2014; Pickering, 2014b; 2014a; 2015; 2017; Swinnerton et al., 2017). Finally, it is evident throughout the preceding findings that assessment drives learning, however it may be pertinent to ask, who is responsible for designing the assessment? At the University of Leeds, anatomy educators play a significant role in determining how and when students are assessed on their anatomy knowledge. This will inevitably have consequences on student learning behaviour and engagement with TEL throughout the programme.

8.3 Implications for Anatomy Education

The findings from this thesis have a number of implications for educational practice. These include: a need for increased focus on 'normalised' TEL resources; consideration of the need for additional guidance, and; consideration of the needs and responsibilities of anatomy educators.

Firstly, the systematic literature review demonstrated the increasing number and variety of TEL resources being evaluated (Chapter 4). However, despite recent increases in the evaluation of particularly novel TEL resources such as VR or AR (Yammine and Violato, 2015), such research findings only benefit a minority of institutions and, therefore, a minority of students. While there may be wide ranging benefits to these new resources, for many institutions, financial limitations mean that students learning is more likely to be supplemented by freely available online webpages and videos (Tekian et al., 2019). Furthermore, it is not cost-effective for educators to *"reinvent the wheel and produce instructional material"* (Harden and Crosby, 2000, p.342) when so many educational resources evidently already exist. This is demonstrated further by the evidence from this study and other similar research, that students already readily engage with resources such as Google, Wikipedia and YouTube (Choi-Lundberg et al., 2015; Barry et al., 2016; Holland and Pawlikowska, 2019; Pascoe, 2020). Therefore, evaluation studies must focus more closely on these 'normalised' TEL resources, by evaluating the quality of existing educational material and the perceptions from both students and educators within a variety of contexts.

Secondly, it is noted that for all resources at the University of Leeds, and most resources evaluated within the literature, technology-enhanced 'learning' is largely self-directed, therefore, what the student actually does is outside the measures of traditional evaluation approaches (Ellaway and Masters, 2008). At present, anatomy TEL evaluation literature focuses largely on single TEL interventions with a focus on cognitive learning gains and student satisfaction (Chapter 4). While these are important for determining the effectiveness of a resource within a specific learning context, there is a paucity of studies evaluating or acknowledging that, for many students, learning anatomy involves navigating and managing large numbers of available resources. Educators can support students by providing appropriate levels of guidance (Kirschner and van Merriënboer, 2013). This is particularly important since evidence suggests that lower performing students (i.e. those who may benefit most from supplementary resources) are less likely to use them (Skinner et al., 2012), therefore, additional signposting may be required to support such groups. Dependent upon the educational level, this guidance may be achieved through the provision of pre-approved webpages or videos. This provides students with a sense of autonomy over which resources they choose to engage with, while reducing the sense of being overwhelmed and uncertain about which resource to choose (O'Carroll et al., 2015; Kenwright et al., 2016). Alternatively, with resources such as 3D visualisation technologies, educators can provide worksheets or tutorials to scaffold the learning process and guide students through the software interface (Lewis et al., 2014; Motsinger, 2020).

Finally, one of the core findings of this thesis revealed anatomy educators have a significant influence, both explicitly and implicitly, on students perceptions and use of TEL. This finding has implications for those currently teaching anatomy. Within medical education, basic science subjects are largely taught by clinicians and researchers with little training in teaching (Clark, 2002). This finding was recently confirmed within anatomy education by a U.S. based study that revealed the majority of educators have a basic science background and have not completed post-doctoral education training (Schaefer et al., 2019). While some educators reportedly view teaching as a low priority compared with competing responsibilities (Regan et al., 2016; van Lankveld et al., 2017), others argue that faculty training for basic science educators could fundamentally improve the level of education provided within medicine (Hopkins et al., 2015; Haramati, 2015; Love et al., 2018; Tekian et al., 2019). Indeed, faculty training is viewed as worthwhile by the majority of anatomy educators (Schaefer et al., 2019), and may benefit the field in a number of ways. Firstly, increased understanding of instructional and learning design principles would support educators in the development of effective learning resources or programmes (Anderson et al., 2019). Secondly, it would increase educator awareness of the influence of their actions on students perceptions and behaviours. While there is a wealth of literature associated with clinical educators as role models (Kim et al., 2007; Harden and Laidlaw, 2017; Slivkoff et al., 2019), some argue that this is applicable to all teachers within medical education (Slivkoff et al., 2019). As stated in a review of social influence within medical education: *"As part of caring for and nurturing the 'whole medical student' we need to consider how loudly our actions, as opposed to our words, speak."* (Wilkes and Raven, 2002, p.487). Finally, training in educational research may significantly improve the current standard of TEL evaluation research within anatomy education. The systematic literature review concluded that approaches to evaluation have a bias towards positivist research approaches. This is likely closely linked to the largely scientific background for educators (Schaefer et al., 2019), where RCT studies and numerical analysis are the norm. However, in the words of William Cameron Bruce, *"not everything that can be counted counts, and not everything that counts can be counted"* (Bruce, 1963, p.13).

8.4 Contributions of the Study

This study enhances the understanding of the lived experiences of students engaged in a multi-modal anatomy curriculum and has uncovered a deeper understanding of the factors influencing students perception and use of TEL. Prior to this study, research had largely focused on measuring student perceptions of single TEL interventions (e.g. Raynor and Iggulden, 2008; Barbeau et al., 2013; Ferrer-Torregrosa et al., 2015; Wismer et al., 2018). More recently, studies have investigated factors influencing students choice of TEL resource (Selvig et al., 2015; Holland and Pawlikowska, 2019; Pickering and Swinnerton, 2019; Bringman-Rodenbarger and Hortsch, 2020), however, these studies focused on resources available to students exclusively within their institution. While the literature reveals the use of TEL is continuously increasing (Trelease, 2016), there is a distinct lack of studies considering the impact of the vast number of resources accessible to students from their institutions and more widely via the internet. By identifying the methods students employ for navigating and managing their use of TEL while engaged within a multi-modal anatomy curriculum, this study has been one of the first attempts to address the paucity of evidence associated with student experiences with TEL. In addition, it has provided valuable insights into the current landscape within anatomy TEL evaluation literature, has generated a methodologically robust survey scale for measuring perceptions of TEL in anatomy, and has shed new light on the role of the anatomy educator in determining students engagement with TEL.

The contributions of this study can be categorised as methodological, theoretical and practical. Firstly, as evidenced by the systematic literature review, research into student perceptions of TEL in anatomy has been largely undertaken by employing quantitative approaches to research. This is mostly in the form of self-developed Likert survey scales that are analysed using simple descriptive statistics (Chapter 4). Therefore, methodologically, using a critical realist paradigm, this study undertook a more comprehensive approach to evaluating student perceptions in line with *Level 1A* of the TELEM. The main output of this process is the Anatomy TEL Utility scale which, following measures of construct validity and triangulation with qualitative data, offers a new tool for measuring students perceptions of the utility of TEL in anatomy. Furthermore, by employing a mixed methods approach, this study has been able to enhance descriptions and depth of understanding beyond that which exists in the literature already (Lavelle et al., 2013). In short, this study has employed a different approach to research than is most commonly utilised within anatomy education and, as such, has uncovered a wide array of findings not previously discussed in the literature.

Theoretically, this study has established a conceptual framework for understanding the factors influencing students perceptions and use of TEL within a multi-modal anatomy curriculum. By drawing on existing theories of self-determination (Deci and Ryan, 2004), expectancy-value (Eccles and Wigfield, 2001; 2002) and cognitive load (Chandler and Sweller, 1991; Mayer, 2005; Plass et al., 2010), this newly developed conceptual framework can support anatomy educators in making informed decisions related to the design, development and dissemination of TEL resources within anatomy curricula. The conceptual framework detailed in Chapter 3 was largely predictive of the outcomes of this research. This is undoubtably due to the vast amount of research existing within the field of technology acceptance and student engagement upon which the current conceptual framework was established. While the majority of constructs, and the relationship between them, are well-established within the wider education literature, this thesis has drawn upon and adapted existing theories for use within anatomy education specifically.

Finally, on a practical level, the findings provide useful insights into the factors influencing students decisions to use, or not to use, TEL resources for studying anatomy. This is particularly important given that failed TEL interventions are less likely to be published (Delgaty et al., 2017), therefore, explanations for these failures may also be lacking. Understanding which factors may improve engagement with TEL, such as resource design, perceived effectiveness and the implicit and explicit influence of peers and educators, can offer educators a range of opportunities to redesign TEL interventions lacking in student engagement. Furthermore, the influence of the educator appears more significant than current literature within the field would suggest. This provides an argument for increased focus on instructional design within TEL evaluation literature and, for increased opportunities for educational training.

8.5 Limitations

There are some inherent limitations associated with this thesis, predominantly related to the methodology employed. Firstly, with regards to the systematic literature review, it is to be expected that, despite a robust search strategy and extensive range of keywords, some studies may have been missed. In an attempt to mitigate this, citation-chaining and manual searching of relevant journal articles were employed. Additionally, it is possible that inconsistencies between the coding of eligible articles was present. The use of the TELEM framework as a benchmarking tool and assessment of inter-rater reliability both attempted to counter this limitation. Moreover, investigation into the quality of included studies using a tool such as the Medical Education Research Study Quality Instrument (MERSQI) would further increase the rigour of the results (Cook and Reed, 2015).

Secondly, with regards to the collection of qualitative data, additional information from focus group participants (e.g. previous experience with TEL in both educational and non-educational settings, additional demographic information, and assessment data) would have provided a greater depth of insight and context to the comments made by participants. This was not performed within this study as the principle aim of the qualitative phase of this exploratory mixed methods study was to provide meaning to the outcomes from the pilot survey. However, additional data could support this further and should be considered in future work. Furthermore, an innate limitation when working with human participants is they cannot be assumed to have complete knowledge about the factors influencing their perceptions and use of TEL for anatomy education, or that their account was not biased by the focus group setting (Stalmeijer et al., 2014). However, care was taken to ensure participants each had a fair opportunity to express opinions and to elaborate on their experiences. In addition, with 12 participants volunteering to participate, three smaller focus groups were chosen over two larger focus groups. This reduced the number of other participants who may influence an individual's response, and offered additional opportunity for constructs to be explored in greater detail. Moreover, the topics uncovered in the focus groups informed the refinement of the Anatomy TEL Utility scale, the results of which revealed four emergent factors that align closely with the focus group findings. Therefore, offering some level of confidence in the generalisability within the wider cohort; although, further work is required to understand this in greater detail.

Thirdly, with regards to the quantitative survey data, it cannot be assumed that all survey respondents have a common interpretation of the survey items. For example, the terms ‘learning’ and ‘teaching’ are not interpreted in the same way, with research showing considerable differences in understanding between students and teachers (Kirkwood and Price, 2013). This inherent limitation of self-report data generates concerns related to the accuracy of the data, with critics arguing that a students’ cognitive ability to comprehend survey items and retrieve accurate responses are often over-estimated by survey designers (Klemenčič and Chirikov, 2015). Furthermore, within educational research in particular, it is postulated that it is not possible to gather an accurate reflection of student experience via survey data when it is the institutions and educators who decide what is measured and what is not. The so-called ‘streetlight effect’ in survey research suggests that researchers tend to give more attention to institutional factors or to areas they believe they will find a positive result (Klemenčič and Chirikov, 2015). Since the pilot survey generated survey items from existing anatomy TEL evaluation surveys established during the systematic literature review, it is likely that this limitation existed in the early stages of this project. However, the inclusion of qualitative data provided insight into the lived experience of students and this data informed the content and wording of all items in the refined Anatomy TEL Utility scale, somewhat mitigating the aforementioned limitation.

Finally, a limitation of this study is selection bias. This manifested itself in a number of ways. Firstly, the voluntary nature of this study suggests it is likely that only those with particularly strong feelings towards TEL would participate. Indeed, the survey data revealed a strong positive response to TEL in anatomy, however, the focus group data uncovered the nuance of these responses suggesting that there is more to ‘satisfaction with TEL’ than first believed. Furthermore, it is noted that the factors influencing students engagement with TEL is likely variable both across different students, with some being more willing to explore externally provided resources than others, and within individual students, dependent upon on the subject area, type of resource, and even time of day. Secondly, the research sample was purposive and limited to two concurrent cohorts of Year 2 MBChB students at the University of Leeds. The anatomy curriculum is perhaps more TEL-heavy in comparison with other similar institutions, therefore, the results of this study are limited to the context of this setting. Moreover, accessibility and concerns around digital competency were not found to be a major influencing factor in determining TEL use and preference within this study. This finding may be a reflection of participant demographics, however, without collecting data regarding socioeconomic background this assumption is unsubstantiated. It remains an important educational consideration when evaluating TEL resources to account for students who do not have access to mobile devices and who are perhaps less familiar with navigating technological environments (Trelease, 2016; Bringman-Rodenbarger and Hortsch, 2020). This is increasingly important given the recent trend from medical schools to increase their intake of students from socially disadvantaged backgrounds through widening participation schemes (Angel and Johnson, 2000; Garlick and Brown, 2008; Boursicot and Roberts, 2009; Curtis et al., 2014; Curtis and Smith, 2020). Finally, both cohorts recruited in this study are composed largely of students identifying as female. Despite this study finding no significant difference between male and female students, research has shown that gender may correlate with approaches to learning (Duff, 2002; Cilliers et al., 2010; Pickering and Swinnerton, 2019), therefore further investigation into possible differences may be warranted.

8.6 Future Directions

There are a number of areas for future research building on the findings from this study. Firstly, now that the factors influencing students perceptions and use of TEL have been established with participants at the University of Leeds, future research should begin by investigating whether these factors are generalisable to medical students from other institutions. Moving forward, a large scale investigation including students from a variety of contexts including educational level (e.g. undergraduate / postgraduate), geographic location and educational programmes (e.g. nursing, dental and allied health profession students), would confirm the temporal stability of the Anatomy TEL Utility scale and allow comparison of different student groups.

Secondly, future work should investigate possible differences in the factors influencing perceptions and use of TEL for students exposed to varying degrees of technology. Students at the University of Leeds have a host of TEL resources provided to them to support their anatomical learning. The factors influencing TEL use for students from resource-light institutions may be subtly different given the inevitable increased reliance on externally provided resources.

Thirdly, the importance of resource design was highlighted by the findings of this research. While reference to instructional design and the impact on cognitive load is being increasingly discussed within anatomy education, future research is required to determine if links exist between the adherence to instructional design principles, and both the quantitative and qualitative outcomes of TEL evaluation research.

Finally, consideration must be given to supporting anatomy educators in understanding the factors influencing students engagement with TEL in order to support the development of pedagogically sound TEL resources, and to improve recommendations to students regarding appropriate externally provided resources. Future work should primarily focus on educator training opportunities in the hope of improving the development and evaluation of TEL resources. Moreover, investing resources into the development of anatomy-specific assessment tools for appraising the educational quality of resources such as YouTube videos or online webpages, would support educators in making appropriate, evidence-based recommendations to students regarding existing resources online. Finally, future research should investigate the relationship between educator actions, such as instructional design of resources or learning design of activities and supplementary resources, and student outcomes such as knowledge gains and perceptions of utility.

8.7 Conclusion

Technology-enhanced learning is widely perceived to be successful in supplementing anatomy education. This perception has been confirmed by a series of meta-analyses which have established a number of conclusions, such as students learning with TEL perform better than those who have limited or no access to TEL, and that greater learning gains are demonstrated when TEL supplements traditional learning as opposed to replacing it (Wilson et al., 2019). These findings provide confidence that the increasingly ubiquitous use of TEL is supporting students learn anatomy. However, there is a scarcity of studies investigating what students think or feel about TEL in anatomy, how students navigate their way through a multi-modal anatomy curriculum and the factors that may influence their decision to engage, or not to engage, with specific TEL resources. Furthermore, more widely within medical education there have previously been calls for increased attention on the experiences of all stakeholders involved in the implementation and use of TEL (Cook, 2009; Ellaway, 2011a; Cook and Ellaway, 2015). Therefore, this thesis set out to investigate the factors influencing student perceptions and use of TEL within anatomy education. As such, the research described throughout this thesis has offered new insights into the current standard of TEL evaluation research with regards to student experiences within anatomy education; and into the various interconnected factors that may impact upon student engagement with a resource.

This thesis is based upon two major research objectives, the first an outward-facing examination of the current landscape of TEL evaluation literature within anatomy education, and the second, a comprehensive institutional study exploring student experiences with TEL and the factors influencing their engagement with such resources. To address the first research objective, an extensive and comprehensive systematic review of the existing literature revealed TEL evaluations are largely focused on gathering evidence of cognitive learning gains and student satisfaction. While this is important in understanding the effectiveness of TEL in a variety of contexts, this outcome-oriented approach to evaluation has been criticised for failing to account for unexpected outcomes, or understanding the reasons behind specific outcomes (Cook, 2009). This finding from the existing literature suggests there is a bias towards positivist approaches to TEL evaluation, a conclusion emphasised when the current approaches to evaluating TEL are compared with those from other disciplines within HE (Lai and Bower, 2019). As such, there is a lack of understanding about the lived experiences of students learning anatomy with a host of both institutionally-provided and externally sourced learning resources. Understanding *why* TEL is successful is important for optimising future development and dissemination of resources to students.

Following on from the findings of the systematic literature review, this thesis reported on the exploratory sequential mixed methods approach undertaken to address the second research objective. Using this extended methodology, the findings from each study iteratively informed the design of the following study. To begin, Chapter 5 presented a number of findings. Firstly, analysis of existing surveys from anatomy TEL evaluation research revealed 21 common themes associated with concepts incorporated into existing survey items. This analysis revealed gaps in the literature associated with important concepts, particularly those associated with possible negative aspects of TEL such as distractions, accessibility and privacy concerns. This is an interesting finding as it suggests the largely self-developed surveys from anatomy TEL literature are currently not taking a holistic approach to evaluation. As a result of this finding, the 30-item Anatomy TEL Utility scale was developed using existing concepts from the literature and additional concepts associated with the emergent conceptual framework. Secondly, the results from the pilot Anatomy TEL Utility scale revealed *affective attitude towards TEL* (Factor 1), *perceived digital competency* (Factor 2) and *perceived efficiency* (Factor 3) to be emergent factors associated with students perceptions of TEL. When considered within the context of the conceptual framework and existing literature, the items correlating within each factor become progressively distant from existing theoretical or conceptual frameworks. As such, these factors were explored in more detail in Chapter 6 via focus groups, with particular emphasis on Factor 2 and 3.

Focus groups with survey respondents revealed a number of additional insights into the factors influencing perceptions and use of TEL. With regards to specifically exploring the findings of the pilot survey, qualitative inquiry established that Factor 1 and 3 (*attitude towards TEL* and *perceived efficiency*) were supported, while the influence of Factor 2 (*perceived digital competency*) was not as prominent as the pilot survey results suggested. Furthermore, Chapter 6 revealed a series of other relevant findings, such as: students make judgements related to resource effectiveness based upon resource design and aesthetic appeal; students believe they are digitally competent and report no issues using the majority of resources, the exception being 3D visualisation technologies; students do not have concerns about privacy online, unless it relates to the exposure of their personal Facebook account, and; anatomy educators play a significant function in determining which resources students engage with or believe to be effective. These findings are important because they highlight a number of factors not previously discussed or investigated to any depth within existing anatomy TEL literature.

In Chapter 7, the findings from Chapter 5 and 6 were triangulated and meta-inferences drawn. In order to carry out a methodical data triangulation process, the survey items included in the pilot Anatomy TEL Utility scale were individually analysed in light of both the quantitative and qualitative findings. The refined survey incorporated items linked to the various factors found to influence perceptions of TEL. Analysis of this final survey revealed four emergent factors: (1) *affective attitude towards TEL*; (2) *perceived effectiveness*; (3) *resource design*; (4) *personal norms and social influence*, each linking closely to the findings from the focus groups. Furthermore, while investigating the relationship that exists between the emergent factors, gender, preferred resource use and assessment, the findings from this study reveal there to be largely no significant relationships between variables. This is encouraging as it suggests TEL is a relatively neutral learning device. That being said, not surprisingly, in both Chapter 5 and 7, survey respondents who noted a preference for TEL over paper-based resources scored significantly higher in their overall survey score compared to those with a preference for paper-based resources. Moreover, Chapter 5 revealed females scored significantly higher than males in Factor 3 *perceived efficiency*. This finding did not translate into differences between gender in any of the factors in Chapter 7, however, the items loading within Factor 3 of the pilot survey were a somewhat surprising finding and were tenuously linked to existing theory suggesting there is limited possible explanation for the differences in gender presented.

The iterative mixed methods approach undertaken for this thesis has provided insights into student perceptions of TEL while engaged in a multi-modal anatomy curriculum. Firstly, students view TEL generally very positively and appreciate the increased flexibility, accessibility, efficiency and enjoyment offered by many resources. Secondly, students revealed a preference for institutionally-provided resources. This appears to be the result of the availability of an overwhelming number of resources to students online, concerns about time efficiency and trust of externally-provided resources, as well as an emphasis on utilising resources to support successful assessment outcomes. Thirdly, students are influenced by resource design with the focus groups revealing particularly emotive reactions towards the resources deemed to be ill-designed and subsequently viewed as ineffective. Fourthly, students are influenced by the perceived effectiveness of a resource. That is, how much value they assign to a resource based upon their short- and long-term goals, the area of anatomy they are studying and the amount of time they are willing to spend engaging with it. Furthermore, students take recommendations from peers and showcased a particularly socially-driven approach to gathering appropriate TEL resources. Finally, it is evident that anatomy educators play a significant role in determining perceptions of and learning behaviours with TEL resources. It is perhaps a given that explicit recommendations from educators will results in student engagement with resources, however, this thesis has shed light on the implicit influence of educators. This finding has implications for both the instructional design of individual resources, including lecture slides, and the design of the learning environment, including the explicit recommendations of TEL resources and the amount of guidance provided to scaffold learning in this environment. Examination of who is teaching anatomy reveals the majority have a basic science background and have not had any educational training. This provides a possible explanation for the bias towards positivist approaches to TEL evaluation found in the systematic review. The conclusions from this finding go as far to suggest that increased educational training for anatomy educators may be the single most desirable improvement to anatomy education.

To conclude, this thesis has engaged in a methodological process not commonly utilised within anatomy education research. As such, this thesis has uncovered additional depth of understanding to the factors that may influence students engagement with anatomy learning resources. Theoretically, this thesis provides an emergent conceptual framework specific to students experiences in navigating and managing a multi-modal learning environment within anatomy education. Practically, these findings can support educators in developing or recommending pedagogically robust, evidenced informed resources. In addition, the insights gained via this methodological approach may inform future research into student experiences in this field. Finally, although this thesis offers just a snapshot in to the experiences of students currently engaged within a multi-modal anatomy curriculum, the findings offer new insight into the previously unknown factors influencing students' engagement with TEL. Student preference and use of TEL is influenced by a number of factors, namely, their affective attitude towards technology, the perceived effectiveness of a resource in supporting their short- and long-term goals in a time efficient manner, the aesthetic design of a resource and, perhaps most importantly, the influence of peers and educators in both implicitly and explicitly recommending resources. Knowledge of these factors can support anatomy educators in understanding how students engage with learning resources, and opens the door to a host of new avenues of research into the experiences of students learning anatomy.

References

Abu-Al-Aish, A. and Love, S. 2013. Factors influencing students' acceptance of m-learning: An investigation in higher education. *International Review of Research in Open and Distance Learning*. **14**(5), pp.82–107.

Acosta, M.L. Sisley, A. Ross, J. Brailsford, I. Bhargava, A. Jacobs, R. and Anstice, N. 2018. Student acceptance of e-learning methods in the laboratory class in Optometry. *PLoS ONE*. **13**(12), pp.1–15.

Adamczyk, C. Holzer, M. Putz, R. and Fischer, M.R. 2009. Student learning preferences and the impact of a multimedia learning tool in the dissection course at the University of Munich. *Annals of Anatomy*. **191**(4), pp.339–348.

Ahmad, M. Sleiman, N.H. Thomas, M. Kashani, N. and Ditmyer, M.M. 2016. Use of High-Definition Audiovisual Technology in a Gross Anatomy Laboratory: Effect on Dental Students' Learning Outcomes and Satisfaction. *Journal of Dental Education*. **80**(2), pp.128–132.

Ajzen, I. and Fishbein, M. 1980. *Understanding attitudes and predicting social behaviour*. New Jersey: Prentice Hall.

Aktekin, N.Ç. Çelebi, H. and Aktekin, M. 2018. Let's kahoot! Anatomy. *International Journal of Morphology*. **36**(2), pp.716–721.

Al-Neklawy, A.F. 2017. Online Embryology teaching using learning management systems appears to be a successful additional learning tool among Egyptian medical students. *Annals of Anatomy*. **214**, pp.9–14.

Alderman, L. Towers, S. and Bannah, S. 2012. Student feedback systems in higher education: A focused literature review and environmental scan. *Quality in Higher Education*. **18**(3), pp.261–280.

Alexander, C.J. Crescini, W.M. Juskewitch, J.E. Lachman, N. and Pawlina, W. 2009. Assessing the integration of audience response system technology in teaching of anatomical sciences. *Anatomical Sciences Education*. **2**(4), pp.160–6.

Alfalah, S.F.M. Falah, J.F.M. Alfalah, T. Elfalah, M. Muhaidat, N. and Falah, O. 2018. A comparative study between a virtual reality heart anatomy system and traditional medical teaching modalities. *Virtual Reality*. **13**(1), pp.1–6.

Allen, E.B. Walls, R.T. and Reilly, F.D. 2008. Effects of interactive instructional techniques in a web-based peripheral nervous system component for human anatomy. *Medical Teacher*. **30**(1), pp.40–47.

Allen, L.K. Eagleson, R. and de Ribaupierre, S. 2016. Evaluation of an online three-dimensional interactive resource for undergraduate neuroanatomy education. *Anatomical Sciences*

Education. **9**(5), pp.431–9.

Amrein, A.L. and Berliner, D.C. 2003. *The Effects of High-Stakes Testing on Student Motivation and Learning*. Washington: EBSCO publishing.

Anderson, M.C. Love, L.M. and Haggar, F.L. 2019. Looking Beyond the Physician Educator: the Evolving Roles of Instructional Designers in Medical Education. *Medical Science Educator*. **29**(2), pp.507–513.

Anderson, P. Chapman, P. Ma, M. and Rea, P. 2013. Real-time medical visualization of human head and neck anatomy and its applications for dental training and simulation. *Current Medical Imaging Reviews*.

Ang, E.T. Yip, G. Lim, E. and Hian, C. 2014. Learning undergraduate human anatomy–reflections on undergraduate preferences in Singapore: a pilot study. *Journal of the National University of Singapore Teaching Academy*. **4**(1), pp.36–52.

Angel, C. and Johnson, A. 2000. Broadening access to undergraduate medical education. *British Medical Journal*. **321**(7269), pp.1136–1138.

Anwar, K. Sajid, M.R. Cahusac, P. Shaikh, A.A. Elgammal, A. Alshedoukhy, A. and Kashir, J. 2017. Can Facebook pages be a mode of blended learning to supplement in-class teaching in Saudi Arabia? *Advances in Physiology Education*. **41**(3), pp.472–477.

Archer, M. Decoteau, C. Gorski, P. Little, D. Porpora, D. Rutzou, T. Smith, C. Steinmetz, G. and Vandenberghe, F. 2016. What is Critical Realism? *Perspectives*. **38**(2), pp.4–9.

Archer, R. Elder, W. Hustedde, C. Milam, A. and Joyce, J. 2008. The theory of planned behaviour in medical education: A model for integrating professionalism training. *Medical Education*. **42**(8), pp.771–777.

Arkorful, V. and Abaidoo, N. 2014. The role of e-learning, the advantages and disadvantages of its adoption in Higher Education. *International Journal of Education and Research*. **2**, pp.397-410

Armitage, C.J. and Conner, M. 2001. Efficacy of the Theory of Planned Behaviour: A meta-analytic review. *The British Psychological Society.* **40**(4), pp.471-499

Artino, A.R. La Rochelle, J.S. Dezee, K.J. and Gehlbach, H. 2014. Developing questionnaires for educational research: AMEE Guide No. 87. *Medical Teacher*. **36**(6), pp.463–74.

Attardi, S.M. Choi, S. Barnett, J. and Rogers, K.A. 2016. Mixed methods student evaluation of an online systemic human anatomy course with laboratory. *Anatomical Sciences Education*. **9**(3), pp.272–285.

Attardi, S.M. and Rogers, K.A. 2015. Design and implementation of an online systemic human anatomy course with laboratory. *Anatomical Sciences Education*. **8**(1), pp.53–62.

Attwell, G. and Hughes, J. 2010. *Pedagogic approaches to using technology for learning: Literature review.* Pontydysgu: Lifelong Learning UK.

Azer, S.A. 2012. Can 'YouTube' help students in learning surface anatomy? *Surgical and Radiologic Anatomy*. **34**, pp.465–468.

Azer, S.A. 2013. The place of surface anatomy in the medical literature and undergraduate anatomy textbooks. *Anatomical Sciences Education*. **6**(6), pp.415–432.

Backhouse, S. Taylor, D. and Armitage, J.A. 2018. Is This Mine to Keep? Three-dimensional printing enables active, personalized learning in anatomy. *Anatomical Sciences Education*. **12**(5), pp.518-528.

Bacro, T.R.H. Gebregziabher, M. and Ariail, J. 2013. Lecture recording system in anatomy: possible benefit to auditory learners. *Anatomical Sciences Education*. **6**(6), pp.376–84.

Bacro, T.R.H. Gebregziabher, M. and Fitzharris, T.P. 2010. Evaluation of a lecture recording system in a medical curriculum. *Anatomical Sciences Education*. **3**(6), pp.300–308.

Bandura, A. 1986. *Social foundations of thought and action: A social cognitive theory.* New Jersey: Prentice-Hall.

Bandura, A. 1971. *Social Learning Theory*. New York City: General Learning Press.

Barbeau, M.L. Johnson, M. Gibson, C. and Rogers, K.A. 2013. The development and assessment of an online microscopic anatomy laboratory course. *Anatomical Sciences Education*. **6**(4), pp.246–256.

Barmaki, R. Yu, K. Pearlman, R. Shingles, R. Bork, F. Osgood, G.M. and Navab, N. 2019. Enhancement of Anatomical Education Using Augmented Reality: An Empirical Study of Body Painting. *Anatomical Sciences Education*. **12**(6), pp.599-609.

Barry, D.S. Marzouk, F. Chulak-Oglu, K. Bennett, D. Tierney, P. and O'Keeffe, G.W. 2016. Anatomy education for the YouTube generation. *Anatomical Sciences Education*. **9**(1), pp.90-96.

Battulga, B. Konishi, T. and Moriguchi, H. 2012. The effectiveness of an interactive 3-dimensional computer graphics model for medical education abstract background methods development of the interactive 3DCG model. *Interactive journal of medical research*. **1**(2), pp.1–11.

Bauer, A. Neog, D.R. Dicko, A.-H.H. Pai, D.K. Faure, F. Palombi, O. and Troccaz, J. 2017. Anatomical augmented reality with 3D commodity tracking and image-space alignment. *Computers and Graphics*. **69**, pp.140–153.

Beale, E.G. Tarwater, P.M. and Lee, V.H. 2014. A retrospective look at replacing face-to-face embryology instruction with online lectures in a human anatomy course. *Anatomical Sciences Education*. **7**(3), pp.234–41.

Bealey, F. and Johnson, A.G. 1999. *The Blackwell dictionary of political science: a user's guide to* *its terms.* Oxford: Blackwell Publishers.

Beetham, H. and Sharpe, R. 2013. *Rethinking pedagogy for a digital age: Designing for 21st century learning.* 2nd ed. New York: Routledge.

Beetham, H. and White, D. 2013. *Students' expectations and experiences of the digital environment*. Bristol: JISC.

Bergman, E.M. De Bruin, A. Herrler, A. Verheijen, I. Scherpbier, A.J. and Van Der Vleuten, C. 2013. Students' perceptions of anatomy across the undergraduate problem-based learning medical curriculum: a phenomenographical study*. BMC Medical Education*. **13**, article no: 152 [no pagination].

Bice, M.R. Carey, J. Brown, G.A. and Adkins, M. 2016. The Use of Mobile Application to Enhance Learning of the Skeletal System in Introductory Anatomy and Physiology Students. *The International Journal of Kinesiology in Higher Education*. **27**(1), pp.16–22.

Bickerdike, S. Whittle, S.R. and Pickering, J.D. 2014. Do lecture audio-recordings support engagement and flexible learning? *Medical Education*. **48**(5), pp.522–523.

Bogacki, R.E. Best, A. and Abbey, L.M. 2004. Equivalence study of a dental anatomy computer-assisted learning program. *Journal of Dental Education*. **68**(8), pp.867–871.

Border, S. Hennessy, C. and Pickering, J. 2019. The Rapidly Changing Landscape of Student Social Media Use in Anatomy Education. *Anatomical Sciences Education*. **12**(5), pp.577-579.

Borges, N.J. Manuel, R.S. Elam, C.L. and Jones, B.J. 2010. Differences in motives between Millennial and Generation X medical students. *Medical Education*. **44**, pp.570–576.

Boursicot, K. and Roberts, T. 2009. Widening participation in medical education: Challenging elitism and exclusion. *Higher Education Policy*. **22**, pp.19–36.

Braun, M.W. and Kearns, K.D. 2008. Improved learning efficiency and increased student collaboration through use of virtual microscopy in the teaching of human pathology. *Anatomical Sciences Education*. **1**(6), pp.240–246.

Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*. **3**(2), pp.77–101.

Brewer, D.N. Wilson, T.D. Eagleson, R. and De Ribaupierre, S. 2012. Evaluation of Neuroanatomical Training Using a 3D Visual Reality Model. *Studies in Health Technology and Informatics*. **173**, pp.85–91.

Bricken, M. 1991. Virtual Reality Learning Environments: Potentials and Challenges. *Computer Graphics*. **25**(3), pp.178–184.

Bringman-Rodenbarger, L. and Hortsch, M. 2020. How students choose E-learning resources: The importance of ease, familiarity, and convenience. *FASEB BioAdvances*. **2**(5), pp.286–295.

Brown, G.A. Bice, M.R. Shaw, B.S. and Shaw, I. 2015. Online quizzes promote inconsistent improvements on in-class test performance in introductory anatomy and physiology. *Advances in Physiology Education*. **39**(2), pp.63–66.

Brown, M.E.L. and Dueñas, A.N. 2020. A Medical Science Educator's Guide to Selecting a Research Paradigm: Building a Basis for Better Research. *Medical Science Educator*. **30**, pp.545–553.

Brown, P.M. Hamilton, N.M. and Denison, A.R. 2012. A novel 3D stereoscopic anatomy tutorial. *The clinical teacher*. **9**(1), pp.50–53.

Bruce, W.C. 1963. *Informal sociology: a causal introduction to sociological thinking*. New York City: Random House.

Bryner, B.S. Saddawi-Konefka, D. and Gest, T.R. 2008. The impact of interactive, computerised educational modules on preclinical medical education. *Anatomical Sciences Education*. **1**(6), pp.247–251.

Burgoon, J.M. Meece, J.L. and Granger, N.A. 2012. Self-efficacy's influence on student academic achievement in the medical anatomy curriculum. *Anatomical Sciences Education*. **5**(5), pp.249–255.

Cai, B. Rajendran, K. Bay, B.H. Lee, J. and Yen, C.C. 2019. The effects of a functional three-dimensional (3D) printed knee joint simulator in improving anatomical spatial knowledge. *Anatomical Sciences Education*. **12**(6), pp.610–618.

Carmichael, S.W. and Pawlina, W. 2000. Animated PowerPoint as a tool to teach anatomy. *Anatomical Record, Part B: The New Anatomist*. **261**(2), pp.83–88.

Chakraborty, T.R. and Cooperstein, D.F. 2018. Exploring anatomy and physiology using iPad applications. *Anatomical Sciences Education*. **11**(4), pp.336–345.

Chan, I. D'Eon, M. Haggag, H. and Burbridge, B. 2015. The effectiveness of learning anatomy and medical imaging using the anatomage table compared with prosections. *In*: *Joint Congress on Medical Imaging and Radiation Sciences*. Montreal, QC.

Chandler, P. and Sweller, J. 1991. Cognitive Load Theory and the Formation of Instruction. *Cognition and Instruction*. **8**(4), pp.293–332.

Chen, J.L. 2011. The effects of education compatibility and technological expectancy on e-learning acceptance. *Computers and Education*. **57**(2), pp.1501–1511.

Chen, S. Pan, Z. Wu, Y. Gu, Z. Li, M. Liang, Z. Zhu, H. Yao, Y. Shui, W. Shen, Z. Zhao, J. and Pan, H. 2017. The role of three-dimensional printed models of skull in anatomy education: A randomized controlled trail. *Scientific Reports*. **7**(1), p.575.

Cheng, X. Ka Ho Lee, K. Chang, E.Y. and Yang, X. 2017. The "flipped classroom" approach: Stimulating positive learning attitudes and improving mastery of histology among medical students. *Anatomical Sciences Education*. **10**(4), pp.317–327.

Chimmalgi, M. 2019. Interactive Lecture in the Dissection Hall: Transforming Passive Lecture into a Dynamic Learning Experience. *Anatomical Sciences Education*. **12**(2), pp.191–199.

Choi-Lundberg, D.L. Cuellar, W.A. and Williams, A.M.M. 2016. Online dissection audio-visual resources for human anatomy: Undergraduate medical students' usage and learning outcomes. *Anatomical Sciences Education*. **9**(6), pp.545–554.

Choi-Lundberg, D.L. Low, T.F. Patman, P. Turner, P. and Sinha, S.N. 2015. Medical student preferences for self-directed study resources in gross anatomy. *Anatomical Sciences Education*. **9**(2), pp.150–160.

Choi, K.S. Chan, S.T. Leung, C.H.M. and Chui, Y.P. 2017. Stereoscopic three-dimensional visualization for immersive and intuitive anatomy learning. In: *Proceedings IEEE Eighth International Conference on Technology for Education (T4E), 2-4 Dec 2016, Mumbai.* IEEE. pp.184–187.

Chopra, J. Rani, A. Verma, R.K. Tomar, S. and Manik, P. 2017. Impact of use of audio-visual aid on dissection hall teaching. *Journal of Dental and Medical Sciences*. **16**(6), pp.109–113.

Chopra, J. Rani, Anita, Rani, Archana and Verma, R.K. 2012. Traditional versus computer assisted teaching of human osteology : a randomized control trial study. *Indian Journal of Basic and Applied Medical Research*. **5**(2), pp.370–374.

Choudhury, B. and Gouldsborough, I. 2012. The use of electronic media to develop transferable skills in science students studying anatomy. *Anatomical Sciences Education*. **5**(3), pp.125–131.

Choudhury, B. Gouldsborough, I. and Gabriel, S. 2010. Use of interactive sessions and e-learning in teaching anatomy to first-year optometry students. *Anatomical Sciences Education*. **3**(1), pp.39–45.

Chow, W.S. and Shi, S. 2014. Investigating students' satisfaction and continuance intention toward e-learning: An extension of the expectation–confirmation model. *Social and Behavioral Sciences*. **141**, pp.1145–1149.

Cilliers, F.J. Schuwirth, L.W. Adendorff, H.J. Herman, N. and van der Vleuten, C.P. 2010. The mechanism of impact of summative assessment on medical students' learning. *Advances in Health Sciences Education*. **15**(5), pp.695–715.

Clark, D. 2002. Psychological myths in e-learning. *Medical Teacher*. **24**(6), pp.598–604.

Clark, J.M. and Paivio, A. 1991. Dual Coding Theory and Education. *Educational Psychology Review*. **3**(3), pp.149–210.

Clarke, V. and Braun, V. 2018. Using thematic analysis in counselling and psychotherapy research: A critical reflection. *Counselling and Psychotherapy Research*. **18**(2), pp.107–110.

Cleland, J. and Durning, S.J. 2015. *Researching medical education*. Chichester: Wiley Blackwell.

Clunie, L. Morris, N.P. Joynes, V.C.T. and Pickering, J.D. 2018. How comprehensive are research studies investigating the efficacy of technology-enhanced learning resources in anatomy education? A systematic review. *Anatomical Sciences Education*. **11**(3), pp.303–319.

Codd, A.M. and Choudhury, B. 2011. Virtual reality anatomy: is it comparable with traditional methods in the teaching of human forearm musculoskeletal anatomy? *Anatomical Sciences Education*. **4**(3), pp.119–125.

Coe, R. 1999. *A manifesto for evidence-based education.* [Online]. [Accessed 6 November 2017]. Available from: http://www.cem.org/attachments/ebe/manifesto-for-ebe.pdf.

Cook, D. a. Garside, S. Levinson, A.J. Dupras, D.M. and Montori, V.M. 2010. What do we mean by web-based learning? A systematic review of the variability of interventions. *Medical Education*. **44**(8), pp.765–774.

Cook, D.A. 2009. The failure of e-learning research to inform educational practice, and what we can do about it. *Medical Teacher*. **31**(2), pp.158–162.

Cook, D.A. 2010. Twelve tips for evaluating educational programs. *Medical Teacher*. **32**(4), pp.296–301.

Cook, D.A. and Ellaway, R.H. 2015. Evaluating technology-enhanced learning: A comprehensive framework. *Medical Teacher*. **37**(10), pp.961–970.

Cook, D.A. Levinson, A.J. Garside, S. Dupras, D.M. Erwin, P.J. and Montori, V.M. 2008. Internet-based learning in the health professions. *Journal of American Medical Association*. **300**(10), pp.1181–1196.

Cook, D.A. and Reed, D.A. 2015. Appraising the Quality of Medical Education Research Methods. *Academic Medicine*. **90**(8), pp.1067–1076.

Cook, D.A. and West, C.P. 2012. Conducting systematic reviews in medical education: a stepwise approach. *Medical Education*. **46**(10), pp.943–952.

Cooper, G. Barkatsas, T. and Strathdee, R. 2016. The theory of planned behaviour (TPB) in educational research using structural equation modelling (SEM). In: Barkastsas, T. and Bertram, A. eds. *Global Learning in the 21st Century*. Rotterdam: SensePublishers, pp.139–162.

Cornwall, J. and Pollard, M.F. 2012. Evaluation of free i-applications for tertiary level gross anatomy education. *The Australasian medical journal*. **5**(4), p.239.

Corton, M.M. McIntire, D.D. Wai, C.Y. Ling, F.W. and Wendel Jr. G.D. 2006. A comparison of an interactive computer-based method with a conventional reading approach for learning pelvic anatomy. *American Journal of Obstetrics and Gynecology*. **195**(5), pp.1438–1443.

Craig, R.J. and Amernic, J.H. 2006. PowerPoint presentation technology and the dynamics of teaching. *Innovative Higher Education*. **31**(3), pp.147–160.

Creswell, J.W. Fetters, M.D. and Ivankova, N. V 2004. Designing a mixed methods study in primary care. *Annals of family medicine*. **2**(1), pp.7–12.

Creswell, J.W. and Plano Clark, V.L. 2011. *Designing and conducting mixed methods research*. 3rd ed. Thousand Oaks: SAGE Publications, Inc.

Creswell, J.W. and Poth, C.N. 2017. *Qualitative inquiry and research design: choosing among five approaches.* 4th ed. Thousand Oaks: SAGE Publications, Inc.

Cronbach, L.J. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika*. **16**(3), pp.297–334.

Cui, D. Wilson, T.D. Rockhold, R.W. Lehman, M.N. and Lynch, J.C. 2017. Evaluation of the effectiveness of 3D vascular stereoscopic models in anatomy instruction for first year medical students. *Anatomical Sciences Education*. **10**(1), pp.34–45.

Curran, V. Simmons, K. Matthews, L. Fleet, L. Gustafson, D.L. Fairbridge, N.A. and Xu, X. 2020. [Pre-print]. YouTube as an educational resource in medical education: A scoping review. *Medical Science Educator*.

Curtis, S. Blundell, C. Platz, C. and Turner, L. 2014. Successfully widening access to medicine. Part 2: Curriculum design and student progression. *Journal of the Royal Society of Medicine*. **107**(10), pp.393–397.

Curtis, S. and Smith, D. 2020. A comparison of undergraduate outcomes for students from gateway courses and standard entry medicine courses. *BMC Medical Education*. **20**, article no: 4 [no pagination]

Das, S. and Mitchell, P. 2013. Comparison of three aids for teaching lumbar surgical anatomy. *British Journal of Neurosurgery*. **27**(4), pp.475–478.

Davis, C.P. Altmann, G.T.M. and Yee, E. 2020. Situational systematicity: A role for schema in understanding the differences between abstract and concrete concepts. *Cognitive Neuropsychology* . **37**(1–2), pp.142–153.

Davis, F.D. 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *Management Information Systems Quarterly*. **13**(3), pp.319–340.

Day, L.J. 2018. A gross anatomy flipped classroom effects performance, retention, and higher-level thinking in lower performing students. *Anatomical Sciences Education*. **11**(6), pp.565–574.

Deci, E.L. and Ryan, R.M. 2004. *Handbook of self-determination research*. Rochester: University of Rochester Press.

Deci, E.L. and Ryan, R.M. 1985. *Intrinsic Motivation and Self-Determination in Human Behavior.*

Boston: Springer International Publishing.

Delgaty, L. Fisher, J. and Thomson, R. 2017. The ‘dark side’ of technology in medical education. *MedEdPublish*. **6**(2). [Online]. [Accessed 2 July 2019]. Available from: https://www.mededpublish.org/manuscripts/978/v1.

Devitt, P. and Palmer, E. 1999. Computer-aided learning: An overvalued educational resource? *Medical Education*. **33**(2), pp.136–139.

Dhir, A. Yossatorn, Y. Kaur, P. and Chen, S. 2018. Online social media fatigue and psychological wellbeing—A study of compulsive use, fear of missing out, fatigue, anxiety and depression. *International Journal of Information Management*. **40**, pp.141–152.

DiLullo, C. McGee, P. and Kriebel, R. 2011. Demystifying the millennial student: a reassessment in measures of character and engagement in professional education. *Anatomical Sciences Education*. **4**(4), pp.214–226.

Dimitrov, D.M. and Rumrill, P.D. 2003. Pretest-posttest designs and measurement of change. *Work*. **20**, pp.159–165.

Dixon, N.M. 1990. The relationship between trainee responses on participant reaction forms and posttest scores. *Human Resource Development Quarterly*. **1**(2), pp.129–137.

Dixson, M.D. 2015. Measuring student engagement in the online course: the online student engagement scale (OSE). *Online Learning Journal*. **19**(4), pp.1–13.

Donnelly, L. Patten, D. White, P. and Finn, G. 2009. Virtual human dissector as a learning tool for studying cross-sectional anatomy. *Medical Teacher*. **31**(6), pp.553–555.

Doubleday, A.F. and Wille, S.J. 2014. We are what we do: Examining learner-generated content in the anatomy laboratory through the lens of activity theory. *Anatomical Sciences Education*. **7**(5), pp.361–369.

Duff, A. 2002. Approaches to learning: Factor invariance across gender. *Personality and Individual Differences*. **33**(6), pp.997–1010.

Dunleavy, G. Nikolaou, C.K. Nifakos, S. Atun, R. Law, G.C.Y. and Tudor Car, L. 2019. Mobile digital education for health professions: systematic review and meta-analysis by the digital health education collaboration. *Journal of medical Internet research*. **21**(2), p.e12937.

Durham, J.A. Brettell, S. Summerside, C. and McHanwell, S. 2009. Evaluation of a virtual anatomy course for clinical undergraduates. *European Journal of Dental Education*. **13**(2), pp.100–109.

Eccles, J. 1983. Expectancies, Values and Academic Behaviours. In: Spence, J. T. ed. *Achievement and Achievement Motives*. New York: W.H. Freeman and Company, pp.75–138.

Eccles, J.S. 2016. Engagement: Where to next? *Learning and Instruction*. **43**, pp.71–75.

Eccles, J.S. and Wigfield, A. 2001. Academic Achievement Motivation, Development of. In: Smelser, N.J. and Baltes, P.B. eds. *International Encyclopedia of the Social and Behavioral Sciences*. 2nd ed. Elsevier Inc. pp.20–25.

Eccles, J.S. and Wigfield, A. 2002. Motivational Beliefs, Values and Goals. *Annual Review of Psychology*. **53**(1), pp.109-132.

Ekstrand, C. Jamal, A. Nguyen, R. Kudryk, A. Mann, J. and Mendez, I. 2018. Immersive and interactive virtual reality to improve learning and retention of neuroanatomy in medical students: a randomized controlled study. *Canadian Medical Association Journal open*. **6**(1), p.e103.

Elias, S.M. and Mace, B.L. 2005. Social Power in the Classroom: Student Attributions for Compliance. *Journal of Applied Social Psychology*. **35**(8), pp.1738–1754.

Elizondo-Omaña, R.E. Morales-Gómez, J.A. Guzmán, S.L. Hernández, I.L. Ibarra, R.P. Vilchez, F.C. 2004. Traditional teaching supported by computer-assisted learning for macroscopic anatomy. *Anatomical Record, Part B: The New Anatomist*. **278**(1), pp.18–22.

Ellaway, R. 2011a. E-learning: Is the revolution over? *Medical Teacher*. **33**(4), pp.297–302.

Ellaway, R. 2011b. Reflecting on multimedia design principles in medical education. *Medical Education*. **45**(8), pp.766–767.

Ellaway, R. and Masters, K. 2008. AMEE Guide 32: e-Learning in medical education. Part 1: Learning, teaching and assessment. *Medical Teacher* . **30**(5), pp.455–473.

Ernst, R.D. Sarai, P. Nishino, T. Collins, T. Oto, A. Hernandez, A. Walser, E.M. and Chaljub, G. 2003. Transition from film to electronic media in the first-year medical school gross anatomy lab. *Journal of Digital Imaging*. **16**(4), pp.337–340.

Estai, M. and Bunt, S. 2016. Best teaching practices in anatomy education: A critical review. *Annals of Anatomy*. **208**, pp.151–157.

Evans, D.J.R. 2011. Using embryology screencasts: A useful addition to the student learning experience? *Anatomical Sciences Education*. **4**(2), pp.57–63.

Fairén González, M. Farrés, M. Moyes Ardiaca, J. and Insa, E. 2017. Virtual Reality to teach anatomy. In: *Annual Conference of the European Association for Computer Graphics. "Eurographics 2017: education papers".* Lyon: European Association for Computer Graphics, pp.51–58.

Farah, C.S. and Maybury, T.S. 2009. Implementing digital technology to enhance student learning of pathology. *European Journal of Dental Education*. **13**(3), pp.172–178.

Farah, C.S and Maybury, T.S. 2009. The e-evolution of microscopy in dental education. *Journal of Dental Education*. **73**(8), pp.942–949.

De Faria, J.W. V, Teixeira, M.J. and Figueiredo, E.G. 2016. Virtual and stereoscopic anatomy: when virtual reality meets medical education. *Journal of Neurosurgery*. pp.1–7.

Fenesi, B. Mackinnon, C. Cheng, L. Kim, J.A. and Wainman, B.C. 2017. The effect of image quality, repeated study, and assessment method on anatomy learning. *Anatomical Sciences Education*. **10**(3), pp.249–261.

Fergusson, S.J. Aka, J.J. Hennessy, C.M. Wilson, A.J. Parson, S.H. Harrison, E.M. Finn, G.M. and Gillingwater, T.H. 2018. Examining the impact of audience response systems on student performance in anatomy education: A randomised controlled trial. *Scottish Medical Journal*. **63**(1), pp.16–21.

Ferrer-Torregrosa, J. Torralba, J. Jimenez, M.A. García, S. and Barcia, J.M. 2015. ARBOOK: Development and Assessment of a Tool Based on Augmented Reality for Anatomy. *Journal of Science Education and Technology*. **24**(1), pp.119–124.

Field, A. 2009. *Discovering Statistics Using SPSS*. London: Sage Publications Ltd.

Field, S. 2009. Tomorrow's doctors. *British Medical Journal*. **339**, p.b2696.

Finn, G.M. and McLachlan, J.C. 2010. A qualitative study of student responses to body painting. *Anatomical Sciences Education*. **3**(1), pp.33–38.

Fishbein, M. and Ajzen, I. 1975. *Belief, attitude, intention, and behavior: an introduction to theory and research*. Reading: Addison-Wesley.

Fitz-Gibbon, C.T. 1984. Meta-analysis: an explication. *British Educational Research Journal*. **10**(2), pp.135–144.

Fitz-Gibbon, C.T. 1985. The Implications of Meta-analysis for Educational Research. *British Educational Research Journal*. **11**(1), pp.45–49.

Fleagle, T.R. Borcherding, N.C. Harris, J. and Hoffmann, D.S. 2018. Application of flipped classroom pedagogy to the human gross anatomy laboratory: Student preferences and learning outcomes. *Anatomical Sciences Education*. **11**(4), pp.385–396.

Foreman, K.B. Morton, D.A. Musolino, G.M. and Albertine, K.H. 2005. Design and utility of a web-based computer-assisted instructional tool for neuroanatomy self-study and review for physical and occupational therapy graduate students. *Anatomical Record, Part B: The New Anatomist.* **285**(1), pp.26–31.

Fredricks, J.A. Blumenfeld, P.C. and Paris, A.H. 2004. School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*. **74**(1), pp.59–109.

French, J.R.P. and Raven, B. 1960. The bases for social power. In Cartwright, D. and Zander, A. eds, *Group Dynamics: Research and Theory*. New York: Harper and Row, pp.259–269.

Fuller, R. and Joynes, V. 2015. Enhancement or replacement? Understanding how legitimised use of mobile learning resources is shaping how healthcare students are learning. *Journal of the European Association for Health Information and Libraries.* **11**(2), pp.7–10.

Gagne, R.M. Wager, W.W. Golas, K.C. Keller, J.M. and Russell, J.D. 2005. Principles of instructional design, 5th edition. *Performance Improvement*. **44**(2), pp.44–46.

Garas, M. Vaccarezza, M. Newland, G. McVay-Doornbusch, K. and Hasani, J. 2018. 3D-Printed specimens as a valuable tool in anatomy education: A pilot study. *Annals of Anatomy*. **219**, pp.57–64.

Garlick, P.B. and Brown, G. 2008. Widening participation in medicine. *British Medical Journal*. **336**(111), pp.1111–1113.

Gazave, C.M. and R. Hatcher, A. 2017. Evaluating the Use of Second Life ™ for Virtual Team-Based Learning in an Online Undergraduate Anatomy Course. *Medical Science Educator*. **27**(2), pp.217–227.

Ghosh, S.K. 2017. Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anatomical Sciences Education*. **10**(3), pp.286–299.

Gibson, L.A. and Sodeman, W.A. 2014. Millennials and Technology : Addressing the Communication Gap in Education and Practice. *Organization Development Journal*. **32**(4), pp.1–14.

Gie Yong, A. and Pearce, S. 2013. A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis. *Tutorials in Quantitative Methods for Psychology*. **9**(2), pp.79–94.

Göke, N. 2019. *Why having too many choices is a bad thing.* [Online]. [Accessed 29 July 2019]. Available from: https://www.fastcompany.com/90366816/why-having-too-many-choices-is-a-bad-thing.

Gopal, T. Herron, S.S. Mohn, R.S. Hartsell, T. Jawor, J.M. and Blickenstaff, J.C. 2010. Effect of an interactive web-based instruction in the performance of undergraduate anatomy and physiology lab students. *Computers and Education*. **55**(2), pp.500–512.

Gould, D.J. Terrell, M.A. and Fleming, J. 2008. A usability study of users' perceptions toward a multimedia computer-assisted learning tool for neuroanatomy. *Anatomical Sciences Education*. **1**(4), pp.175–183.

Granger, N.A. Calleson, D.C. Henson, O.W. Juliano, E. Wineski, L. Mcdaniel, M.D. and Burgoon, J.M. 2006. Use of web-based materials to enhance anatomy instruction in the health sciences. *Anatomical Record, Part B: The New Anatomist*. **289**(4), pp.121–127.

Granger, N.A. and Calleson, D. 2007. The impact of alternating dissection on student performance in a medical anatomy course: are dissection videos an effective substitute for actual dissection? *Clinical Anatomy*. **20**(3), pp.315–321.

Green, R.A. and Whitburn, L.Y. 2016. Impact of introduction of blended learning in gross anatomy on student outcomes. *Anatomical Sciences Education*. **9**(5), pp.422–430.

Green, R.A, Farchione, D. Hughes, D.L. and Chan, S.-P.P. 2014. Participation in asynchronous online discussion forums does improve student learning of gross anatomy. *Anatomical Sciences Education*. **7**(1), pp.71–6.

Green, R.A. and Hughes, D.L. 2013. Student outcomes associated with use of asynchronous online discussion forums in gross anatomy teaching. *Anatomical Sciences Education*. **6**(2), pp.101–6.

Green, R.A. Whitburn, L.Y. Zacharias, A. Byrne, G. and Hughes, D.L. 2018. The relationship between student engagement with online content and achievement in a blended learning anatomy course. *Anatomical Sciences Education*. **11**(5), pp.471–477.

Green, S.M. Weaver, M. Voegeli, D. Fitzsimmons, D. Knowles, J. Harrison, M. and Shephard, K. 2006. The development and evaluation of the use of a virtual learning environment (Blackboard 5) to support the learning of pre-qualifying nursing students undertaking a human anatomy and physiology module. *Nurse Education Today*. **26**(5), pp.388–395.

Greene, S.J. 2018. The use and effectiveness of interactive progressive drawing in anatomy education. *Anatomical Sciences Education*. **11**(5), pp.445–460.

Greene, S.J. 2019. The Use of Anatomical Dissection Videos in Medical Education. *Anatomical Sciences Education*. **13**(1), pp.48–58.

Griksaitis, M.J. Sawdon, M.A. and Finn, G.M. 2012. Ultrasound and cadaveric prosections as methods for teaching cardiac anatomy: a comparative study. *Anatomical Sciences Education*. **5**(1), pp.20–26.

Gross, M.M. Wright, M.C. and Anderson, O.S. 2017. Effects of image-based and text-based active learning exercises on student examination performance in a musculoskeletal anatomy course. *Anatomical Sciences Education*. **10**(5), pp.444–455.

Guerri-Guttenberg, R. 2008. Web-based method for motivating 18-year-old anatomy students. *Medical Education*. **42**(11), p.1119.

Guimarães, B. Dourado, L. Tsisar, S. Diniz, J.M. Madeira, M.D. and Ferreira, M.A. 2017. Rethinking Anatomy: How to Overcome Challenges of Medical Education's Evolution. *Acta Médica Portuguesa*. **30**(2), pp.134–140.

Guimarães, B. Firmino-Machado, J. Tsisar, S. Viana, B. Pinto-Sousa, M. Vieira-Marques, P. Cruz-Correia, R. and Ferreira, M.A. 2019. The Role of Anatomy Computer-Assisted Learning on Spatial Abilities of Medical Students. *Anatomical Sciences Education*. **12**(2), pp.138–153.

Guy, R. Pisani, H.R. Rich, P. Leahy, C. Mandarano, G. and Molyneux, T. 2015. Less is more: development and evaluation of an interactive e-atlas to support anatomy learning. *Anatomical Sciences Education*. **8**(2), pp.126–132.

Hackett, M. and Proctor, M. 2018. The effect of autostereoscopic holograms on anatomical knowledge: a randomised trial. *Medical Education*. **52**(11), pp.1147–1155.

Hadadgar, A. Changiz, T. Masiello, I. Dehghani, Z. Mirshahzadeh, N. and Zary, N. 2016. Applicability of the theory of planned behavior in explaining the general practitioners eLearning use in continuing medical education. *BMC Medical Education*. **16**, article no: 215 [no pagination]

Hadie, S.N.H. Hassan, A. Ismail, Z.I.M. Ismail, H.N. Talip, S.B. and Rahim, A.F.A. 2018. Empowering students' minds through a cognitive load theory-based lecture model: A metacognitive approach. *Innovations in Education and Teaching International*. **55**(4), pp.398–407.

Hake, R.R. 1998. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*. **66**(1), pp.64–74.

Hall, S. Stephens, J. Parton, W. Myers, M. Harrison, C. Elmansouri, A. Lowry, A. and Border, S. 2018. Identifying Medical Student Perceptions on the Difficulty of Learning Different Topics of the Undergraduate Anatomy Curriculum. *Medical Science Educator*. **28**(3), pp.469–472.

Hallgren, R.C. Parkhurst, P.E. Monson, C.L. and Crewe, N.M. 2002. An interactive, web-based tool for learning anatomic landmarks. *Academic Medicine*. **77**(3), pp.263–265.

Han, H. Kosaka, J. Chon, S.-C. Itokazu, M. and Kubo, A. 2017. Responses of Korean physical therapy students after practice with a virtual anatomical system in Japan. *Journal of physical therapy science*. **29**(10), pp.1749–1752.

Haramati, A. 2015. Educating the Educators. *Academic Medicine*. **90**(2), pp.133–135.

Harden, R.M. and Crosby, J. 2000. AMEE guide no 20: The good teacher is more than a lecturer - The twelve roles of the teacher. *Medical Teacher*. **22**(4), pp.334–347.

Harden, R.M. and Laidlaw, J.M. 2017. *Essential Skills for a Medical Teacher: An Introduction to Teaching and Learning in Medicine.* 2nd ed. Edinburgh: Elsevier.

Hargittai, E. 2003. The digital divide and what to do about it. New economy handbook, 2003. pp.821-839.

Harris, T. Leaven, T. Heidger, P.M. Kreiter, C. Duncan, J. and Dick, F. 2001. Comparison of a virtual microscope laboratory to a regular microscope laboratory for teaching histology. *Anatomical Record, Part B: The New Anatomist*. **265**(1), pp.10–14.

Hattie, J. 2003. Teachers make a difference: What is the research evidence? In: *Building Teacher Quality: What Does The Research Tell Us? October, 2003. Melbourne.* Camberwell: Australian Council for Educational Research (ACER) Research Conference Archive, pp.1–17.

Hazelkorn, E. 2007. The impact of league tables and ranking systems on Higher Education decision making. *Higher Education Management and Policy*. **19**(2), pp.1–24.

Hazelton, L. 2011. Changing concepts of neuroanatomy teaching in medical education. *Teaching and Learning in Medicine*. **23**(4), pp.359–364.

Heidger, P.M. Dee, F. Consoer, D. Leaven, T. Duncan, J. and Kreiter, C. 2002. Integrated approach to teaching and testing in histology with real and virtual imaging. *Anatomical Record, Part B: The New Anatomist*. **269**(2), pp.107–112.

Heineke, W. and Blasi, L. 2001. *Methods of evaluating educational technology*. Greenwich: Information Age.

Helle, L. Nivala, M. and Kronqvist, P. 2013. More technology, better learning resources, better learning? Lessons from adopting virtual microscopy in undergraduate medical education. *Anatomical Sciences Education*. **6**(2), pp.73–80.

Helle, L. Nivala, M. Kronqvist, P. Gegenfurtner, A. Björk, P. and Säljö, R. 2011. Traditional microscopy instruction versus process- oriented virtual microscopy instruction : a naturalistic experiment with control group. In: *The 10th European Congress on Telepathology and 4th International Congress on Virtual Microscopy*. Vilnius: BioMed Central Ltd, pp.1–9.

Hennessy, C.M. Kirkpatrick, E. Smith, C.F. and Border, S. 2016. Social media and anatomy education: Using twitter to enhance the student learning experience in anatomy. *Anatomical Sciences Education*. **9**(6), pp.505–515.

Henning, M.A. Krägeloh, C.U. Booth, R. Hill, E.M. Chen, J. and Webster, C.S. 2017. Biomedical Students in their First Year of Study: Factors Explaining Performance in a High Stakes Examination. *Medical Science Educator*. **27**(4), pp.633–643.

Henson, R.K. and Roberts, J.K. 2006. Use of exploratory factor analysis in published research. *Educational and Psychological Measurement*. **66**(3), pp.393–416.

Heylings, D.J.A. 2002. Anatomy 1999-2000: the curriculum, who teaches it and how? *Medical Education*. **36**(8), pp.702–710.

Hidi, S. and Renninger, K.A. 2006. The four-phase model of interest development. *Educational Psychologist*. **41**(2), pp.111–127.

Higazi, T.B. 2011. Use of interactive live digital imaging to enhance histology learning in introductory level anatomy and physiology classes. *Anatomical Sciences Education*. **4**(2), pp.78–83.

Hill, C. and Lawton, W. 2018. Universities, the digital divide and global inequality. *Journal of higher education policy and management*. **40**(6), pp.598-610.

Hill, R.J. Fishbein, M. and Ajzen, I. 2006. Belief, attitude, intention and behavior: an introduction to theory and research. *Contemporary Sociology*. **6**(2), p.244.

Hisley, K.C. Anderson, L.D. Smith, S.E. Kavic, S.M. and Tracy, J.K. 2008. Coupled physical and digital cadaver dissection followed by a visual test protocol provides insights into the nature of anatomical knowledge and its evaluation. *Anatomical Sciences Education*. **1**(1), pp.27–40.

Holland, J.C. and Pawlikowska, T. 2019. Learning cardiac embryology-which resources do students use, and why? *Medical Science Educator*. **29**, pp.1051–1060.

Holland, J.C. and Pawlikowska, T. 2018. Undergraduate medical students' usage and perceptions of anatomical case-based learning: comparison of facilitated small group discussions and elearning resources. *Anatomical Sciences Education*. **12**(3), pp.245–256.

Holland, M. 2016. How YouTube developed into a successful platform for user-generated content. *Journal of Undergraduate Research in Communications*. **7**(1), pp.53–64.

Holton, E.F. 1996. The flawed four-level evaluation model. *Human Resource Development Quarterly*. **7**(1), pp.5–21.

Hopkins, L. Hampton, B.S. Abbott, J.F. Buery-Joyner, S.D. Craig, L.B. Dalrymple, J.L. Forstein, D.A. Graziano, S.C. McKenzie, M.L. Pradham, A. Wolf, A. and Page-Ramsey, S.M. 2018. To the point: Medical education, technology, and the millennial learner. *American Journal of Obstetrics and Gynecology*. **218**(2), pp.188–192.

Hopkins, R. Pratt, D. Bowen, J.L. and Regehr, G. 2015. Integrating basic science without integrating basic scientists: Reconsidering the place of individual teachers in curriculum reform. *Academic Medicine*. **90**(2), pp.149–153.

Hopkins, R. Regehr, G. and Wilson, T.D. 2011. Exploring the changing learning environment of the gross anatomy lab. *Academic Medicine*. **86**(7), pp.883–888.

Hortsch, M. 2015. 'How we learn may not always be good for us' – Do new electronic teaching approaches always result in better learning outcomes? *Medical Teacher*. **37**(6), pp.507–509.

Hoyek, N. Collet, C. Di Rienzo, F. De Almeida, M. and Guillot, A. 2014. Effectiveness of three-dimensional digital animation in teaching human anatomy in an authentic classroom context. *Anatomical Sciences Education*. **7**(6), pp.430–437.

Hoyt, A. McNulty, J.A. Gruener, G. Chandrasekhar, A. Espiritu, B. Ensminger, D. Price Jr. R. Naheedy, R. Price, R. and Naheedy, R. 2010. An audience response system may influence student performance on anatomy examination questions. *Anatomical Sciences Education*. **3**(6), pp.295–299.

Hu, A. Wilson, T. Ladak, H. Haase, and Fung, K. 2010. Three-dimensional educational computer model of the larynx: Voicing a new direction. *Archives of Otolaryngology – Head and Neck Surgery*. **135**(7), pp.677–681.

Huffman, S. 2018. The digital divide revisited: What is next?. Education. **138**(3), pp.239-246.

Hulme, A. and Strkalj, G. 2017. Videos in anatomy education: History, present usage and future prospects. *International Journal of Morphology*. **35**(4), pp.1540–1546.

Husmann, P.R. O'Loughlin, V.D. and Braun, M.W. 2009. Quantitative and qualitative changes in teaching histology by means of virtual microscopy in an introductory course in human anatomy. *Anatomical Sciences Education*. **2**(5), pp.218–226.

Inbar, Y. Botti, S. and Hanko, K. 2011. Decision speed and choice regret: When haste feels like waste. *Journal of Experimental Social Psychology*. **47**(3), pp.533–540.

Inuwa, I.M. Al Rawahy, M. Taranikanti, V. and Habbal, O. 2011. Anatomy 'steeplechase' online: necessity sometimes is the catalyst for innovation. *Anatomical Sciences Education*. **4**(2), pp.115–8.

Inwood, M.J. and Ahmad, J. 2005. Development of instructional, interactive, multimedia anatomy dissection software: a student-led initiative. *Clinical Anatomy*. **18**(8), pp.613–617.

Iqbal, N. 2018. *Generation Z: 'We have more to do than drink and take drugs'*. [Online]. [Accessed 10 May 2019]. Available from: https://www.theguardian.com/society/2018/jul/21/generation-z-has-different-attitudes-says-a-new-report.

Issa, N. Schuller, M. Santacaterina, S. Shapiro, M. Wang, E. Mayer, R.E. and Darosa, D.A. 2011. Applying multimedia design principles enhances learning in medical education. *Medical Education*. **45**(8), pp.818–826.

Iyengar, S.S. and Lepper, M.R. 2001. When choice is demotivating: Can one desire too much of a good thing? *Journal of Personality and Social Psychology.* **79**(6, pp.995–1006

Jaffar, A.A. 2014. Exploring the use of a facebook page in anatomy education. *Anatomical Sciences Education*. **7**(3), pp.199–208.

Jaffar, A.A. 2012. YouTube: An emerging tool in anatomy education. *Anatomical Sciences Education*. **5**(3), pp.158–64.

Jain, S.H. 2009. Practicing medicine in the age of Facebook. *New England Journal of Medicine*. **361**(7), pp.649–651.

Jamil, Z. Saeed, A.A. Madhani, S. Baig, S. Cheema, Z. and Fatima, S.S. 2018. Three-dimensional visualization software assists learning in students with diverse spatial intelligence in medical education. *Anatomical Sciences Education*. **12**(5), pp.550–560.

Javadian, P. and Shobeiri, S. 2016. Comparison of dissection-based vs. internet-based pelvic anatomy education for 3rd year medical students. *Journal of Education Technology in Health Sciences*. **3**(2), pp.38–41.

Javaid, M.A. Chakraborty, S. Cryan, J.F. Schellekens, H. and Toulouse, A. 2018. Understanding neurophobia: Reasons behind impaired understanding and learning of neuroanatomy in cross-disciplinary healthcare students. *Anatomical Sciences Education*. **11**(1), pp.81–93.

Jeffries, S. 2015. *Why too much choice is stressing us out.* [Online]. [Accessed 29 July 2019]. Available from: https://www.theguardian.com/lifeandstyle/2015/oct/21/choice-stressing-us-out-dating-partners-monopolies.

Johnson, I.P. Palmer, E. Burton, J. and Brockhouse, M. 2013. Online learning resources in anatomy: What do students think? *Clinical Anatomy*. **26**(5), pp.556–563.

Jones, T.L. Baxter, M. and Khanduja, V. 2013. A quick guide to survey research. *Annals of the Royal College of Surgeons of England*. **95**(1), pp.5–7.

Joo, Y.J. Park, S. and Shin, E.K. 2017. Students' expectation, satisfaction, and continuance intention to use digital textbooks. *Computers in Human Behavior*. **69**, pp.83–90.

Jozefowicz, R.F. 1994. Neurophobia: The fear of neurology among medical students. *Archives of Neurology*. **51**(4), pp.328–329.

Kahu, E.R. 2013. Framing student engagement in higher education. *Studies in Higher Education*. **38**(5), pp.758–773.

Kallgren, C.A. Reno, R.R. and Cialdini, R.B. 2000. A focus theory of normative conduct: when norms do and do not affect behavior. *Personality and Social Psychology Bulletin.* **26**(8), pp.1002–1012.

Keedy, A.W. Durack, J.C. Sandhu, P. Chen, E.M. O'Sullivan, P.S. and Breiman, R.S. 2011. Comparison of traditional methods with 3D computer models in the instruction of hepatobiliary anatomy. *Anatomical Sciences Education*. **4**(2), pp.84–91.

Kelc, R. 2012. Zygote Body: A new interactive 3-dimensional didactical tool for teaching anatomy. *WebmedCentral ANATOMY*. **3**(1), pp.1–10.

Kennedy, G.E. Judd, T.S. Churchward, A. Gray, K. and Krause, K.L. 2008. First year students' experiences with technology: Are they really digital natives? *Australasian Journal of Educational Technology*. **24**(1), pp.108–122.

Kenwright, D. Dai, W. and Grainger, R. 2018. Why students choose or don't choose to use an online pathology museum. *Medical Science Educator*. **28**, pp.295–302.

Kenwright, D. Osborne, E. Dai, W. and Grainger, R. 2016. Drivers of openness to online and flipped learning in medical education. *MedEdPublish*. **5**(2). [online]. [Accessed 2 April 2018]. Available at: https://www.mededpublish.org/manuscripts/537.

Khalil, M.K. Mansour, M.M. and Wilhite, D.R. 2010. Evaluation of cognitive loads imposed by traditional paper-based and innovative computer-based instructional strategies. *Journal of Veterinary Medical Education*. **37**(4), pp.353–357.

Khalil, M.K. Nelson, L.D. and Kibble, J.D. 2010. The use of self-learning modules to facilitate learning of basic science concepts in an integrated medical curriculum. *Anatomical Sciences Education*. **3**(5), pp.219–226.

Khalil, M.K. Paas, F. Johnson, T.E. and Payer, A.F. 2005. Design of interactive and dynamic anatomical visualizations: the implication of cognitive load theory. *Anatomical Record, Part B: The New Anatomist*. **286**(1), pp.15–20.

Khalil, M.K. Paas, F. Johnson, T.E. Su, Y.K. and Payer, A.F. 2008. Effects of instructional strategies using cross sections on the recognition of anatomical structures in correlated CT and MR images. *Anatomical Sciences Education*. **1**(2), pp.75–83.

Khalil, M.K. Williams, S.E. and Gregory Hawkins, H. 2018. Learning and study strategies correlate with medical students' performance in anatomical sciences. *Anatomical Sciences Education*. **11**(3), pp.236–242.

Khot, Z. Quinlan, K. Norman, G.R. and Wainman, B. 2013. The relative effectiveness of computer-based and traditional resources for education in anatomy. *Anatomical Sciences Education*. **6**(4), pp.211–215.

Kim, H.J. Hong, A.J. and Song, H.D. 2018. The relationships of family, perceived digital competence and attitude, and learning agility in sustainable student engagement in higher education. *Sustainability*. **10**(12), p.4635.

Kim, J. Choi, C. De, S. and Srinivasan, M.A. 2007. Virtual surgery simulation for medical training using multi-resolution organ models. *The International Journal Of Medical Robotics and Computer Assisted Surgery*. **3**(2), pp.149–158.

Kingsley, K. V. Galbraith, G.M. Herring, M. Stowers, E. Stewart, T. and Kingsley, K. V. 2011. Why not just Google it? An assessment of information literacy skills in a biomedical science curriculum. *BMC Medical Education*. **11**, article no: 17 [no pagination]

Kirkpatrick, D.L. 1994. *Evaluating training programs: The four levels*. San Francisco: Berrett-Koehlar.

Kirkpatrick, D.L. 2010. *The new world kirkpatrick model.* [Accessed 4 October 2016]. Available from: http://www.kirkpatrickpartners.com/OurPhilosophy/TheNewWorldKirkpatrickModel

Kirkwood, A. and Price, L. 2013. Examining some assumptions and limitations of research on the effects of emerging technologies for teaching and learning in higher education. *British Journal of Educational Technology*. **44**(4), pp.536–543.

Kirkwood, A. and Price, L. 2014. Technology-enhanced learning and teaching in higher education: what is 'enhanced' and how do we know? A critical literature review. *Learning, Media and Technology*. **39**(1), pp.6–36.

Kirschner, P. Sweller, J. and Clark, R. 2006. Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential and inquiry-based teaching. *Educational Psychologist*. **41**(2), pp.75–86.

Kirschner, P.A. and De Bruyckere, P. 2017. The myths of the digital native and the multitasker. *Teaching and Teacher Education*. **67**, pp.135–142.

Kirschner, P.A. and van Merriënboer, J.J.G.G. 2013. Do learners really know best? Urban legends in education. *Educational Psychologist*. **48**(3), pp.169–183.

Kivell, T.L. Doyle, S.K. Madden, R.H. Mitchell, T.L. and Sims, E.L. 2009. An interactive method for teaching anatomy of the human eye for medical students in ophthalmology clinical rotations. *Anatomical Sciences Education*. **2**(4), pp.173–178.

Klemenčič, M. and Chirikov, I. 2015. How Do We Know How Students Experience Higher Education? On the Use of Student Surveys. In: Curaj, A. Matei, L. Pricopie, R. Salmi, J. and Scott P. eds. *The European Higher Education Area: Between Critical Reflections and Future Policies*. Cham: Springer International Publishing, pp.361–379.

Knowles, M.S. 1975. *Self-Directed Learning: A Guide for Learners and Teachers*. New York: Association Press.

Krause, K.L. and Coates, H. 2008. Students' engagement in first-year university. *Assessment and Evaluation in Higher Education*. **33**(5), pp.493–505.

Krippendorf, B.B. and Lough, J. 2005. Complete and Rapid Switch From Light Microscopy to Virtual Microscopy for Teaching Medical Histology. *Anatomical Record, Part B: The New Anatomist*. **285**(1), pp.19–25.

Krosnick, J.A. and Presser, S. 2010. Question and Questionnaire Design. In: Marsden, P. and Wright, J. eds. *Handbook of Survey Research*. 2nd ed. Bingley: Emerald Group Publishing.

Krueger, R. 2002. *Designing and Conducting Focus Group Interviews*. Thousand Oaks: Sage Publishing Ltd.

Küçük, S. Kapakin, S. and Göktaş, Y. 2016. Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load. *Anatomical Sciences Education*. **9**(5), pp.411–421.

Kugelmann, D. Stratmann, L. Nühlen, N. Bork, F. Hoffmann, S. Samarbarksh, G. Pferschy, A. von der Heide, A.M. Eimannsberger, A. Fallavollita, P. Navab, N. and Waschke, J. 2018. An Augmented Reality magic mirror as additive teaching device for gross anatomy. *Annals of Anatomy*. **215**, pp.71–77.

Kumar, R.K. Velan, G.M. Korell, S.O. Kandara, M. Dee, F.R. and Wakefield, D. 2004. Virtual microscopy for learning and assessment in pathology. *Journal of Pathology*. **204**(5), pp.613–618.

Kusurkar, R.A. Croiset, G. Mann, K. V. Custers, E. and Ten Cate, O. 2012. Have motivation theories guided the development and reform of medical education curricula? A review of the literature. *Academic Medicine*. **87**(6), pp.735–743.

Lai, C. Wang, Q. and Lei, J. 2012. What factors predict undergraduate students' use of technology for learning? A case from Hong Kong. *Computers and Education*. **59**(2), pp.569–579.

Lai, J.W.M. and Bower, M. 2019. How is the use of technology in education evaluated? A systematic review. *Computers and Education*. **133**(May 2018), pp.27–42.

Langfield, T. Colthorpe, K. and Ainscough, L. 2018. Online instructional anatomy videos: Student usage, self-efficacy, and performance in upper limb regional anatomy assessment. *Anatomical Sciences Education*. **11**(5), pp.461–470.

Lankshear, C. and Knobel, M. 2008. *Digital Literacies—Concepts, Policies and Practices*. New York: Peter Lang Publishing, Inc.

van Lankveld, T. Schoonenboom, J. Kusurkar, R.A. Volman, M. Beishuizen, J. and Croiset, G. 2017. Integrating the teaching role into one's identity: A qualitative study of beginning undergraduate medical teachers. *Advances in Health Sciences Education*. **22**, pp.601–622.

Laurillard, D. 2012. *Teaching as a design science : building pedagogical patterns for learning and technology*. London: Routledge.

Laurillard, D. 2014. *Thinking about blended learning: A paper for the Thinkers in Residence programme Professor of Learning with Digital Technology*. [online]. [Accessed 19 June 2018]. Available at: http://www.ethicalforum.be/sites/default/files/DP_BlendedLearning_Thinking-about_0.pdf

Laurillard, D. Oliver, M. Wasson, B. and Hoppe, U. 2009. Implementing technology-enhanced learning. In: Balacheff, N. Ludvigsen, S. de Jong, T. de, Lazonder, A. Barnes, S. eds. *Technology-Enhanced Learning: Principles and Products*. Rotterdam: Springer International Publishing, pp.289–306.

Lavelle, E. Vuk, J. and Barber, C. 2013. Twelve tips for getting started using mixed methods in medical education research Ellen. *Medical Teacher*. **35**(4), pp.272–276.

Lazarus, L. Sookrajh, R. and Satyapal, K.S. 2017. Tablet technology in medical education in South Africa: A mixed methods study. *British Medical Journal open*. **7**(7), p.e013871.

Lee, J. Lin, L. and Robertson, T. 2012. The impact of media multitasking on learning. *Learning, Media and Technology*. **37**(1), pp.94–104.

Lee, L.M.J. Nagel, R.W. and Gould, D.J. 2012. The educational value of online mastery quizzes in a human anatomy course for first-year dental students. *Journal of Dental Education*. **76**(9), pp.1195–1199.

Legris, P. Ingham, J. and Collerette, P. 2003. Why do people use information technology? A critical review of the technology acceptance model. *Information and Management*. **40**(3), pp.191–204.

Levine, M.G. Stempak, J. Conyers, G. and Walters, J.A. 1999. Implementing and integrating computer-based activities into a problem-based gross anatomy curriculum. *Clinical Anatomy*. **12**(3), pp.191–198.

Levinson, A.J. Weaver, B. Garside, S. McGinn, H. and Norman, G.R. 2007. Virtual reality and brain anatomy: A randomised trial of e-learning instructional designs. *Medical Education*. **41**(5), pp.495–501.

Lewis, T.L. Burnett, B. Tunstall, R.G. and Abrahams, P.H. 2014. Complementing anatomy education using three-dimensional anatomy mobile software applications on tablet computers. *Clinical Anatomy*. **27**(3), pp.313–320.

Li, S. and Zheng, J. 2018. The relationship between self-efficacy and self-regulated learning in one-to-one computing environment: The mediated role of task values. *Asia-Pacific Education Research*. **27**(6), pp.455–463.

Likert, R. 1932. A technique for the measurement of attitudes. *Archives of Psychology*. **22**(140), p.55.

Lim, H.J. and Jung, H. 2019. Factors related to digital reading achievement: A multi-level analysis using international large scale data. *Computers and Education*. **133**, pp.82–93.

Lim, K.H.A. Loo, Z.Y. Goldie, S.J. Adams, J.W. and McMenamin, P.G. 2015. Use of 3D printed models in medical education: A randomized control trial comparing 3D prints versus cadaveric materials for learning external cardiac anatomy. *Anatomical Sciences Education*. **9**(3), pp.213–221.

Limpach, A.L. Bazrafshan, P. Turner, P.D. and Monaghan, M.S. 2008. Effectiveness of human anatomy education for pharmacy students via the internet. *American Journal of Pharmaceutical Education*. **72**(6), p.145.

Lincoln, Y.S. and Guba, E.G. 1985. *Naturalistic inquiry*. Thousand Oaks: Sage Publications Ltd.

Link, T.M. and Marz, R. 2006. Computer literacy and attitudes towards e-learning among first year medical students. *BMC Medical Education*. **6**, article no: 34 [no pagination]

Liu, Q. Peng, W. Zhang, F. Hu, R. Li, Y. and Yan, W. 2016. The effectiveness of blended learning in health professions: systematic review and meta-analysis. *Journal of Medical Internet Research*. **18**(1), p.e2.

Liu, Z. 2007. Reading behavior in the digital environment. *Journal of Documentation*. **61**(6), pp.700–712.

Lloyds Bank. 2019. *UK Consumer Digital Index 2019.* [Online]. [Accessed 3 April 2020]. Available from: https://www.lloydsbank.com/assets/media/pdfs/banking_with_us/whats-happening/lb-consumer-digital-index-2019-report.pdf

Lochner, L. Wieser, H. Waldboth, S. and Mischo-kelling, M. 2016. Combining traditional anatomy lectures with e-learning activities: how do students perceive their learning experience? *International Journal of Medical Education*. **7**, pp.69–74.

Loh, K.K. and Kanai, R. 2016. How Has the Internet Reshaped Human Cognition? *Neuroscientist*.

22(5), pp.506–520.

Lombardi, S.A. Hicks, R.E. Thompson, K. V and Marbach-Ad, G. 2014. Are all hands-on activities equally effective? Effect of using plastic models, organ dissections, and virtual dissections on student learning and perceptions. *Advances in Physiology Education*. **38**(1), pp.80–86.

Lone, M. McKenna, J.P. Cryan, J.F. Vagg, T. Toulouse, A. and Downer, E.J. 2018. Evaluation of an animation tool developed to supplement dental student study of the cranial nerves. *European Journal of Dental Education*. **22**(3), pp.427–437.

Lone, M. Vagg, T. Theocharopoulos, A. Cryan, J.F. Mckenna, J.P. Downer, E.J. and Toulouse, A. 2019. Development and Assessment of a Three-Dimensional Tooth Morphology Quiz for Dental Students. *Anatomical Sciences Education*. **12**(3), pp.284–299.

Love, L.M. Haggar, F.L. McBrien, S.B. Buzalko, R.J. Hartman, T.L. Shope, R.J. and Beck Dallaghan, G.L. 2018. Supporting the Professional Identity of Medical Science Educators: Understanding Faculty Motivations for Quality Improvement in Teaching. *Medical Science Educator*. **28**(4), pp.655–665.

Luursema, J. Vorstenbosch, M. and Kooloos, J. 2017. Stereopsis, visuospatial ability, and virtual reality in anatomy learning. *Anatomy Research International*. **2017**(13), pp.1–7.

Ma, M. Fallavollita, P. Seelbach, I. Von Der Heide, A.M. Euler, E. Waschke, J. and Navab, N. 2015. Personalized augmented reality for anatomy education. *Clinical Anatomy*. **29**(4), pp.446–453.

MacLean, J.E. Scott, K.M. Marshall, T. and Asperen, P. V. 2011. Evaluation of an e-learning teaching resource: What is the medical student perspective? *Focus on Health Professional Education: A Multi-disciplinary Journal*. **13**(2), pp.55–63.

Maggio, M.P. Hariton-Gross, K. and Gluch, J. 2012. The use of independent, interactive media for education in dental morphology. *Journal of Dental Education*. **76**(11), pp.1497–1511.

Mahmud, W. Hyder, O. Butt. J. and Aftab, A. 2011. Dissection videos do not improve anatomy examination scores. *Anatomical Sciences Education*. **4**(1), pp.16–21.

Mangen, A. 2016. The digitization of literary reading. *Orbis Litterarum*. **71**(3), pp.240–262.

Mangen, A. Walgermo, B.R. and Brønnick, K. 2013. Reading linear texts on paper versus computer screen: Effects on reading comprehension. *International Journal of Educational Research*. **58**, pp.61–68.

Manning, M. 2009. The effects of subjective norms on behaviour in the theory of planned behaviour: A meta-analysis. *British Journal of Social Psychology*. **48**(4), pp.649–705.

Maresky, H.S. Oikonomou, A. Ali, I. Ditkofsky, N. Pakkal, M. and Ballyk, B. 2019. Virtual reality and cardiac anatomy: Exploring immersive three-dimensional cardiac imaging, a pilot study in undergraduate medical anatomy education. *Clinical Anatomy*. **32**(2), pp.238–243.

Marks, S. White, D. and Mazdics, M. 2019. Evaluation of a Virtual Reality Nasal Cavity Education Tool. In: *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering. 4–7 December, Wollongong.* New Jersey: Institute of Electrical and Electronics Engineers, pp.193–198.

Mars, M. and McLean, M. 1996. Students' perceptions of a multimedia computer-aided instruction resource in histology. *South African Medical Journal*. **86**(9), pp.1098–1102.

Mathiowetz, V. Yu, C.H. and Quake-Rapp, C. 2016. Comparison of a gross anatomy laboratory to online anatomy software for teaching anatomy. *Anatomical Sciences Education*. **9**(1), pp.52–59.

Maybury, T.S. and Farah, C.S. 2010. Electronic blending in virtual microscopy. *Journal of Learning Design*. **4**(1), pp.41–51.

Mayer, R.E. 2010. Applying the science of learning to medical education. *Medical Education*. **44**(6), pp.543–549.

Mayer, R.E. 2004. Should there be a three-strikes rule against pure discovery learning? *American Psychologist*. **59**(1), pp.14–19.

Mayer, R.E. 2005. *The Cambridge handbook of multimedia learning*. New York: Cambridge University Press.

Mayer, R.E. and Moreno, R. 2003. Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*. **38**(1), pp.43–52.

Mayer, R.E. Sobko, K. and Mautone, P.D. 2003. Social cues in multimedia learning: Role of speaker's voice. *Journal of Educational Psychology*. **95**(2), pp.419–425.

Mayfield, C.H. Ohara, P.T. and O'Sullivan, P.S. 2013. Perceptions of a mobile technology on learning strategies in the anatomy laboratory. *Anatomical Sciences Education*. **6**(2), pp.81–89.

McCready, Z.R. and Jham, B.C. 2013. Dental students' perceptions of the use of digital microscopy as part of an oral pathology curriculum. *J Dent Educ.* **77**(12), pp.1624–1628.

McEvoy, E. Padwick, R. Coey, S. Fielding, D. Gold, P. Harrison, L. Murthy, P. Tan, C. Brydges, S. and Abrahams, P. 2014. Coachpod—students of the 21st century—anatomy on the move. *European Journal of Anatomy*. **18**(2), pp.109–117.

McKeown, P.P. Heylings, D.J.A. Stevenson, M. McKelvey, K.J. Nixon, J.R. and R McCluskey, D. 2003. The impact of curricular change on medical students' knowledge of anatomy. *Medical Education*. **37**(11), pp.954–961.

McLachlan, J.C. and Patten, D. 2006. Anatomy teaching: ghosts of the past, present and future. *Medical Education*. **40**(3), pp.243–253.

McMenamin, P.G. McLachlan, J. Wilson, A. McBride, J.M. Pickering, J.D. Evans, D.J.R. and Winkelmann, A. 2018. Do we really need cadavers anymore to learn anatomy in undergraduate medicine? *Medical Teacher*. **40**(10), pp.1020–1029.

McMenamin, P.G. Quayle, M.R. McHenry, C.R. and Adams, J.W. 2014. The production of anatomical teaching resources using three-dimensional (3D) printing technology. *Anatomical Sciences Education*. **7**(6), pp.479–486.

McNulty, J. a. Sonntag, B. and Sinacore, J.M. 2009. Evaluation of computer-aided instruction in a gross anatomy course: a six-year study. *Anatomical Sciences Education*. **2**(1), pp.2–8.

McNulty, J.A. Halama, J. Dauzvardis, M.F. and Espiritu, B. 2000. Evaluation of web-based computer-aided instruction in a basic science course. *Academic Medicine*. **75**(1), pp.59–65.

McNulty, J.A. Halama, J. and Espiritu, B. 2004. Evaluation of computer-aided instruction in the medical gross anatomy curriculum. *Clinical Anatomy*. **17**(1), pp.73–78.

Meyer, A.J. Stomski, N.J. Innes, S.I. and Armson, A.J. 2015. VARK learning preferences and mobile anatomy software application use in pre-clinical chiropractic students. *Anatomical Sciences Education*. **9**(3), pp.247–254.

Miller, M. 2016. Use of computer-aided holographic models improves performance in a cadaver dissection-based course in gross anatomy. *Clinical Anatomy*. **29**(7), pp.917–924.

Mione, S. Valcke, M. and Cornelissen, M. 2013. Evaluation of virtual microscopy in medical histology teaching. *Anatomical Sciences Education*. **6**(5), pp.307–315.

Mione, S. Valcke, M. and Cornelissen, M. 2015. Remote histology learning from static versus dynamic microscopic images. *Anatomical Sciences Education*. **9**(3), pp.222–230.

Mitrousias, V. Varitimidis, S.E. Hantes, M.E. Malizos, K.N. Arvanitis, D.L. and Zibis, A.H. 2018. Anatomy learning from prosected cadaveric specimens versus three-dimensional software: A comparative study of upper limb anatomy. *Annals of Anatomy*. **218**, pp.156–164.

Mogali, S.R. Vallabhajosyula, R. Ng, C.H. Lim, D. Ang, E.T. and Abrahams, P. 2019. Scan and learn: Quick response code enabled museum for mobile learning of anatomy and pathology. *Anatomical Sciences Education*. **12**(6), pp.664–672.

Mogali, S.R. Yeong, W.Y. Tan, H.K.J. Tan, G.J.S. Abrahams, P.H. Zary, N. Low-Beer, N. and Ferenczi, M.A. 2018. Evaluation by medical students of the educational value of multi-material and multi-colored three-dimensional printed models of the upper limb for anatomical education. *Anatomical Sciences Education*. **11**(1), pp.54–64.

Moorman, S.J. 2006. Prof-in-a-Box: using internet-videoconferencing to assist students in the gross anatomy laboratory. *BMC Medical Education*. **6**, article no: 55 [no pagination]

Moro, C. Štromberga, Z. Raikos, A. and Stirling, A. 2017. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anatomical Sciences Education*.

10(6), pp.549–559.

Morris, N.P. Lambe, J. Ciccone, J. and Swinnerton, B. 2016. Mobile technology: Students perceived benefits of apps for learning neuroanatomy. *Journal of Computer Assisted Learning*. **32**(5), pp.430–442.

Morris, N.P. Swinnerton, B.J. and Coop, T. 2019. Lecture recordings to support learning: A contested space between students and teachers. *Computers and Education*. **140**, article no. 103604 [no pagination]

Motsinger, S.K. 2020. Complete Anatomy. *Journal of the Medical Library Association*. **108**(1), p.155.

Mukhopadhyay, S. Tennant, M. and Kruger, E. 2014. YouTube: A new way of supplementing traditional methods in dental education. *Journal of Dental Education*. **78**(11), pp.1568–1571.

Nevalainen, M.K. Mantyranta, T. and Pitkala, K.H. 2010. Facing uncertainty as a medical student: A qualitative study of their reflective learning diaries and writings on specific themes during the first clinical year. *Patient Education and Counseling*. **78**(2), pp.218–223.

Newlin, A. 2016. *Why We Prefer "Learning Design" Over "Instructional Design"*. [Online]. [Accessed 30 April 2020]. Available from: https://www.smartsparrow.com/2016/07/12/why-we-prefer-learning-design/.

Ngan, O.M.Y. Tang, T.L.H. Chan, A.K.Y. Chen, D.M. and Tang, M.K. 2018. Blended learning in anatomy teaching for non-medical students: An innovative approach to the health professions education. *Health Professions Education*. **4**(2), pp.149–158.

Nicholson, D.T. Chalk, C. Funnell, W.R.J. and Daniel, S.J. 2006. Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model. *Medical Education*. **40**(11), pp.1081–1087.

Nieder, G.L. and Borges, N.J. 2012. An eight-year study of online lecture use in a medical gross anatomy and embryology course. *Anatomical Sciences Education*. **5**(6), pp.311–320.

Nieder, G.L. and Nagy, F. 2002. Analysis of medical students' use of web-based resources for a gross anatomy and embryology course. *Clinical Anatomy*. **15**(6), pp.409–418.

Nieder, G.L. Scott, J.N. and Anderson, M.D. 2000. Using QuickTime virtual reality objects in computer-assisted instruction of gross anatomy: Yorick the VR Skull. *Clinical Anatomy*. **13**(4), pp.287–293.

Noble, H. and Smith, J. 2015. Issues of validity and reliability in qualitative research. *Evidence Based Nursing*. **18**(2), pp.34–35.

O'Byrne, P.J. Patry, A. and Carnegie, J.A. 2008. The development of interactive online learning tools for the study of anatomy. *Medical teacher*. **30**(8), pp.260–271.

O'Carroll, A.M. Westby, E.P. Dooley, J. and Gordon, K.E. 2015. Information-Seeking Behaviors of Medical Students: A Cross-Sectional Web-Based Survey. *Journal of Medical Internet Research*. **1**(1), p.e4.

O'Reilly, M.K. Reese, S. Herlihy, T. Geoghegan, T. Cantwell, C.P. Feeney, R.N.M. and Jones, J.F.X. 2016. Fabrication and assessment of 3D printed anatomical models of the lower limb for anatomical teaching and femoral vessel access training in medicine. *Anatomical Sciences Education*. **9**(1), pp.71–79.

Ocak, M.A. and Topal, A.D. 2015. Blended Learning in Anatomy Education: A Study Investigating Medical Students' Perceptions. *Eurasia Journal of Mathematics, Science and Technology Education*. **11**(3), pp.647–663.

Ogunranti, J.O. 1987. Video technology in integrated anatomy education. *Journal of Educational Television*. **13**(1), pp.63–67.

Ozer, M.A. Govsa, F. and Bati, A.H. 2017. Web-based teaching video packages on anatomical education. *Surgical and Radiologic Anatomy*. **39**(11), pp.1253–1261.

Padilla-Meléndez, A. Del Aguila-Obra, A.R. and Garrido-Moreno, A. 2013. Perceived playfulness, gender differences and technology acceptance model in a blended learning scenario. *Computers and Education*. **63**, pp.306–317.

Paechter, M. Maier, B. and Macher, D. 2010. Students' expectations of, and experiences in e-learning: Their relation to learning achievements and course satisfaction. *Computers and Education*. **54**(1), pp.222–229.

Panadero, E. and Alonso-Tapia, J.J. 2014. How do students self-regulate? Review of Zimmerman's cyclical model of self-regulated learning. *Annals of Psychology*. **30**(2), pp.450–462.

Papa, V. and Vaccarezza, M. 2013. Teaching anatomy in the XXI century: new aspects and pitfalls. *The Scientific World Journal*. **2013**, article no: 310348 [no pagination]

Park, S.Y. 2011. An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Journal of Educational Technology and Society*. **12**, pp.150–162.

Partridge, J. Brustad, R. Stellino, M.B. Partridge, J. Brustad, R. and Stellino, M.B. 2013. Theoretical perspectives : Eccles' expectancy-value theory. *Advance in Sport Psychology*. pp.269–292.

Pascoe, M.A. 2020. Web browsing habits of healthcare professions students in gross anatomy laboratory. *Anatomical Sciences Education*. **13**(4), pp.520–526.

Pascoe, M.A. and Lee, L.M.J. 2017. Incorporation of light field photography into an online anatomy resource does not influence student quiz performance or perceptions of usability. *Medical Science Educator*. **27**(3), pp.465–474.

Patasi, B. Boozary, A. Hincke, M. and Jalali, A. 2009. The utility of podcasts in Web 2.0 human anatomy. *Medical Education*. **43**(11), p.1116.

Patel, S.G. Benninger, B. and Mirjalili, S.A. 2017. Integrating ultrasound into modern medical curricula. *Clinical Anatomy*. **30**(4), pp.452–460.

Patel, S.G. Rosenbaum, B.P. Chark, D.W. and Lambert, H.W. 2006. Design and implementation of a web-based, database-driven histology atlas: Technology at work. *Anatomical Record, Part B: The New Anatomist*. **289**(5), pp.176–183.

Pereira, J.A. Merí, A. Masdeu, C. Molina-Tomás, M.C. and Martinez-Carrio, A. 2004. Using videoclips to improve theoretical anatomy teaching. *European Journal of Anatomy*. **8**(3), pp.143–146.

Pereira, J.A. Pleguezuelos, E. Meri, A. Molina-Ros, A. Molina-Tomas, M.C. and Masdeu, C. 2007. Effectiveness of using blended learning strategies for teaching and learning human anatomy. *Medical Education*. **41**(2), pp.189–195.

Peterson, D.C. and Mlynarczyk, G.S.A. 2016. Analysis of traditional versus three-dimensional augmented curriculum on anatomical learning outcome measures. *Anatomical Sciences Education*. **9**(6), pp.529–536.

Petersson, H. Sinkvist, D. Wang, C. Smedby, Ö. and Smedby, O. 2009. Web-based interactive 3D visualization as a tool for improved anatomy learning. *Anatomical Sciences Education*. **2**(2), pp.61–68.

Petriceks, A.H. Peterson, A.S. Angeles, M. Brown, W.P. and Srivastava, S. 2018. Photogrammetry of human specimens: An innovation in anatomy education. *Journal of Medical Education And Curricular Development*. **5**, pp.1–10.

Pickering, J.D. 2014a. Anatomy drawing screencasts: Enabling flexible learning for medical students. *Anatomical Sciences Education*. **8**(3), pp.249–257.

Pickering, J.D. 2014b. Taking human anatomy drawings for teaching outside the classroom. *Surgical and Radiologic Anatomy*. **36**, pp.953–954.

Pickering, J.D. 2015. Introduction of an anatomy eBook enhances assessment outcomes. *Medical Education*. **49**(5), pp.522–523.

Pickering, J.D. 2017. Measuring learning gain: Comparing anatomy drawing screencasts and paper-based resources. *Anatomical Sciences Education*. **10**(4), pp.307–316.

Pickering, J.D. and Bickerdike, S.R. 2017. Medical student use of Facebook to support preparation for anatomy assessments. *Anatomical Sciences Education*. **10**(3), pp.205–214.

Pickering, J.D. and Joynes, V.C.T. 2016. A holistic model for evaluating the impact of individual technology-enhanced learning resources. *Medical Teacher*. **38**(12), pp.1242–1247.

Pickering, J.D. and Swinnerton, B.J. 2019. Exploring the dimensions of medical student engagement with technology-enhanced learning resources and assessing the impact on assessment outcomes. *Anatomical Sciences Education*. **12**(2), pp.117–128.

Pintrich, P.R. 2000. The Role of Goal Orientation in Self-Regulated Learning In: Boekaerts, M. Zeidner, M. and Pintrich, P.R. eds. *Handbook of Self-Regulation*. San Diego: Academic Press, pp.451–502.

Plass, J.L. Moreno, R. and Brünken, R. 2010. *Cognitive load theory*. New York: Cambridge University Press.

Poushter, J. and Stewart, R. 2016. *Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies* [Online]. [Accessed 26 February 2020]. Available from: https://www.pewresearch.org/global/2016/02/22/smartphone-ownership-and-internet-usage-continues-to-climb-in-emerging-economies/

Prensky, M. 2001. Digital Natives, Digital Immigrants. *On the Horizon.* **9**(5), pp.1–6.

Raikos, A. and Waidyasekara, P. 2014. How useful is YouTube in learning heart anatomy? *Anatomical Sciences Education*. **7**(1), pp.12–18.

Raney, M.A. 2016. Dose- and time-dependent benefits of iPad technology in an undergraduate human anatomy course. *Anatomical Sciences Education*. **9**(4), pp.367–77.

Raynor, M. and Iggulden, H. 2008. Online anatomy and physiology: piloting the use of an anatomy and physiology e-book-VLE hybrid in pre-registration and post-qualifying nursing programmes at the University of Salford. *Health Information and Libraries Journal*. **25**(2), pp.98–105.

Rea, P. and Linn, A. 2017. Creation of E-tutorials to enhance medical student anatomy learning experience using articulate storyline 2. In: Ma, M. and Oikonomou, A. eds. *Serious Games and Edutainment Applications: Volume II.* Cham: Springer International Publishing. pp.203–221.

Reeves, R.E. Aschenbrenner, J.E. Wordinger, R.J. Roque, R.S. and Sheedlo, H.J. 2004. Improved dissection efficiency in the human gross anatomy laboratory by the integration of computers and modern technology. *Clinical Anatomy*. **17**(4), pp.337–344.

Regan, L. Jung, J. and Kelen, G.D. 2016. Educational Value Units. *Academic Medicine*. **91**(12), pp.1642–1646.

Ribeiro, M. Amaral, M. Ribeiro, H. Machado, J. Povo, A. Severo, M. and Ferreira, M.A. 2009. "Virtual quiz": A tool for active learning and assessment in clinical anatomy. In: *1st International Conference on Education and New Learning Technologies, 6-8 July, 2009, Barcelona*. Valencia: International Association of Technology, Education and Development, pp. 5523-5527

Rich, P. and Guy, R. 2013. A 'do-it-yourself' interactive bone structure module: Development and evaluation of an online teaching resource. *Anatomical Sciences Education*. **6**(2), pp.107–113.

Richardson-Hatcher, A. Hazzard, M. and Ramirez-Yanez, G. 2014. The cranial nerve skywalk: A 3D tutorial of cranial nerves in a virtual platform. *Anatomical Sciences Education*. **7**(6), pp.469–478.

Rienties, B. and Toetenel, L. 2016. The impact of learning design on student behaviour, satisfaction and performance: A cross-institutional comparison across 151 modules. *Computers in Human Behavior*. **60**, pp.333–341.

Rinaldi, V.D. Lorr, N.A. and Williams, K. 2017. Evaluating a technology supported interactive response system during the laboratory section of a histology course. *Anatomical Sciences Education*. **10**(4), pp.328–338.

Rizzolo, L.J. Aden, M. and Stewart, W.B. 2002. Correlation of Web usage and exam performance in a human anatomy and development course. *Clinical Anatomy*. **15**(5), pp.351–355.

Rizzolo, L.J. Rando, W.C. O'Brien, M.K. Haims, A.H. Abrahams, J.J. and Stewart, W.B. 2010. Design, implementation, and evaluation of an innovative anatomy course. *Anatomical Sciences Education*. **3**(3), pp.109–120.

Robinson, L. Cotten, S.R. Ono, H. Quan-Haase, A. Mesch, G. Chen, W. Schulz, J. Hale, T.M. and Stern, M.J. 2015. Digital inequalities and why they matter. *Information, communication & society*. **18**(5), pp.569-582.

Rogaten, J. Rienties, B. Sharpe, R. Cross, S. Whitelock, D. Lygo-Baker, S. and Littlejohn, A. 2019. Reviewing affective, behavioural and cognitive learning gains in higher education. *Assessment and Evaluation in Higher Education*. **44**(3), pp.321–337.

Rogers, E.M. 1983. *Diffusion of Innovations*. New York: Free Press.

Rogers, E.M. 2010. *Diffusion of Innovations*. 4th ed. New York: Simon and Schuster.

Rondon, S. Sassi, F.C. and Furquim de Andrade, C.R. 2013. Computer game-based and traditional learning method: a comparison regarding students' knowledge retention. *BMC Medical Education*. **13**, article no. 30 [no pagination]

Rosas, C. Rubí, R. Donoso, M. and Uribe, S. 2012. Dental students' evaluations of an interactive histology software. *Journal of Dental Education*. **76**(11), pp.1491–6.

Ryan, R.M and Deci, E.L. 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being self-determination theory. *American Psychological Association*. **55**(1), pp.68–78.

Ryan, R.M. and Deci, E.L. 2006. Self-regulation and the problem of human autonomy: does psychology need choice, self-determination, and will? *Journal of Personality*. **74**(6), pp.1557–1586.

Saltarelli, A.J. Roseth, C.J. and Saltarelli, W.A. 2014. Human cadavers vs. multimedia simulation: A study of student learning in anatomy. *Anatomical Sciences Education*. **7**(5), pp.331–339.

Sanchez, C.A. and Jaeger, A.J. 2015. If it's hard to read, it changes how long you do it: Reading time as an explanation for perceptual fluency effects on judgement. *Psychonomic Bulletin and Review*. **22**, pp.206–211.

Sanchez, C.A. and Khan, S. 2016. Instructor accents in online education and their effect on learning and attitudes. *Journal of Computer Assisted Learning*. **32**(5), pp.494–502.

Sandars, J. 2010. The importance of usability testing to allow e-learning to reach its potential for medical education. *Education for Primary Care*. **21**(1), pp.6–8.

Sander, B. and Golas, M.M. 2013. HistoViewer: An interactive e-learning platform facilitating group and peer group learning. *Anatomical Sciences Education*. **6**(3), pp.182–190.

Saxena, V. Natarajan, P. O'Sullivan, P.S. and Jain, S. 2008. Effect of the use of instructional anatomy videos on student performance. *Anatomical Sciences Education*. **1**(4), pp.159–165.

Schaefer, A.F. Wilson, A.B. Barger, J.B. Azim, H.M. Brokaw, J.J. and Brooks, W.S. 2019. What Does a Modern Anatomist Look like? Current Trends in the Training of Anatomy Educators. *Anatomical Sciences Education*. **12**(3), pp.225–235.

Scheibehenne, B. Greifeneder, R. and Todd, P.M. 2010. Can there ever be too many options? A meta-analytic review of choice overload. *Journal of Consumer Research*. **37**(3), pp.409–425.

Schunk, D.H. 2014. *Handbook of Self-Regulation of Learning and Performance*. London: Routledge.

Schunk, D.H. 2012. *Learning Theories: An Educational Perspective.* 6th ed. London: Pearson.

Schunk, D.H. 1989. *Social Cognitive Theory and Self-Regulated Learning.* New York: Springer International Publishing.

Schwartz, B. 2000. Self-determination: The tyranny of freedom. *American Psychologist.* **55**(1), pp.79–88.

Scibora, L.M. Mead, T.P. and Larson, C. 2018. The influence of iPads on course performance and student perceptions of learning in human anatomy. *Journal of Teaching and Learning with Technology*. **7**(1), pp.108–124.

Scoville, S.A. and Buskirk, T.D. 2007. Traditional and virtual microscopy compared experimentally in a classroom setting. *Clinical Anatomy*. **20**(5), pp.565–570.

Selvig, D. Holaday, L.W. Purkiss, J. and Hortsch, M. 2015. Correlating students' educational background, study habits, and resource usage with learning success in medical histology. *Anatomical Sciences Education*. **8**(1), pp.1–11.

Selwyn, N. 2016. Digital downsides: exploring university students' negative engagements with digital technology. *Teaching in Higher Education*. **21**(8), pp.1006–1021.

Shabani, K. Khatib, M. and Ebadi, S. 2014. Vygotsky's Zone of Proximal Development: Instructional Implications and Teachers' Professional Development. *English Language Teaching*. **3**(4), pp.237–248.

Sharpe, R. Beetham, H. and De Freitas, S. 2010. *Rethinking learning for a digital age: How learners are shaping their own experiences*. London: Routledge.

Sharpe, R. Benfield, G. Roberts, G. and Francis, R. 2006. The undergraduate experience of blended e-learning. The Higher Education Academy. [online]. [Accessed 30 October 2017]. Available at: https://www.advance-he.ac.uk/knowledge-hub/undergraduate-experience-blended-e-learning

Shenton, A.K. 2004. Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*. **22**(2), pp.63–75.

Shoepe, T.C. Cavedon, D.K. Derian, J.M. Levy, C.S. and Morales, A. 2015. The ATLAS project: The effects of a constructionist digital laboratory project on undergraduate laboratory performance. *Anatomical Sciences Education*. **8**(1), pp.12–20.

Shoufan, A. 2019. What motivates university students to like or dislike an educational online video? A sentimental framework. *Computers and Education*. **134**, pp.132–144.

Silen, C. Wirell, S. Kvist, J. Nylander, E. and Smedby, O. 2008. Advanced 3D visualisation in student-centred medical education. *Medical Teacher*. **30**(5), pp.e115-24.

Simpson, J.A. Farrell, A.K. Oriña, M.M. and Rothman, A.J. 2015. Power and social influence in relationships. In Mikulincer, M. Shaver, P.R. Simpson, J.A. and Dovidio, J.F. eds. *APA handbook of personality and social psychology*. **3**, pp.393–420.

Sivamalai, S. Murthy, S.V. Gupta, T. Sen and Woolley, T. 2011. Teaching pathology via online digital microscopy: Positive learning outcomes for rurally based medical students. *Australian Journal of Rural Health*. **19**(1), pp.45–51.

Skinner, E.A. and Belmont, M.J. 1993. Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology*. **85**(4), pp.571–581.

Skinner, I. Mort, P. Calvo, R. Drury, H. Molina, M.G. and Wales, S. 2012. Some do, some don't: student use of online writing resources In: *23rd Annual Conference of the Australasian Association for Engineering Education, Dec 2012*, *Melbourne.* Victoria: Profession of engineering education: Advancing teaching, research and careers, pp.547–555.

Slivkoff, M.D. Bahner, I. Bonaminio, G. Brenneman, A. Brooks, W.S. Chinn, C. El-Sawi, N. Haight, M. Hurtubise, L. McAuley, R.J. Michaelsen, V. Rowe, R. Vari, R.C. and Yoon, M. 2019. The Role of Basic Science in 21st Century Medical Education. *Medical Science Educator*. **29**(3), pp.881–883.

Smith, C.F. Stabile, I.R. and Finn, G.M. 2018. Pedagogic research in anatomical sciences: A best practice guide. *European Journal of Anatomy*. **22**(3), pp.257–268.

Smith, M.J.H. and Wilkinson, T. 2018. Does a functional prosection provide a more effective method of learning the anatomy of the forearm and hand than a 3D online anatomy resource? *MedEdPublish*. **1**(4), [online]. [Accessed 24 February 2019]. Available at: https://www.mededpublish.org/manuscripts/1923

So, S. Patel, R.M. and Orebaugh, S.L. 2017. Ultrasound imaging in medical student education: Impact on learning anatomy and physical diagnosis. *Anatomical Sciences Education*. **10**(2), pp.176–189.

Soh Said, C. Shamsudin, K. Mailok, R. Johan, R. and Hanaif, H.F. 2016. The Development and Evaluation of a 3D Visualization Tool in Anatomy Education. *Journal of Science, Mathematics and Technology*. **2**, pp.48–56.

Sotgiu, M.A. Mazzarello, V. Bandiera, P. Madeddu, R. Montella, A. and Moxham, B. 2020. Neuroanatomy, the Achille's Heel of Medical Students. A Systematic Analysis of Educational Strategies for the Teaching of Neuroanatomy. *Anatomical Sciences Education*. **13**(1), pp.107–116.

Stalmeijer, R.E. Mcnaughton, N. and Van Mook, W. 2014. Using focus groups in medical education research: AMEE Guide No. 91. *Medical teacher*. **36**(11), pp.923–939.

Steele, T. 2003. Sex, culture, and linguistic relativity: Making abstract concepts concrete. *Teaching Sociology*. **31**(2), pp.212–220.

Stepan, K. Zeiger, J. Hanchuk, S. Del Signore, A. Shrivastava, R. Govindaraj, S. and Iloreta, A. 2017. Immersive virtual reality as a teaching tool for neuroanatomy. *International Forum Of Allergy and Rhinology*.**7**(10), pp.1006–1013.

Stewart, S. and Choudhury, B. 2015. Mobile technology: Creation and use of an iBook to teach the anatomy of the brachial plexus. *Anatomical Sciences Education*. **8**(5), pp.429–437.

Stirling, A. and Birt, J. 2014. An enriched multimedia eBook application to facilitate learning of anatomy. *Anatomical Sciences Education*. **7**(1), pp.19–27.

Strkalj, G. Hulme, A. El-Haddad, J. Luo, K. Crafford, D. and Rampe, M. 2018. Students' perceptions and usage of short anatomy videos: A preliminary study. *International Journal of Morphology*. **36**(2), pp.493–499.

Sugand, K. Abrahams, P. and Khurana, A. 2010. The anatomy of anatomy: A review for its modernization. *Anatomical Sciences Education*. **3**(2), pp.83–93.

Sullivan, G.M. 2011. Getting Off the "Gold Standard": Randomized Controlled Trials and Education Research. *Journal of Graduate Medical Education*. **3**(3), pp.285–289.

Sun, P.C. Tsai, R.J. Finger, G. Chen, Y.Y. and Yeh, D. 2008. What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers* *and Education*. **50**(4), pp.1183–1202.

Sutherland, S. and Jalali, A. 2017. Social media as an open-learning resource in medical education: Current perspectives. *Advances in Medical Education and Practice*. **8**, pp.369–375.

Sutton, J. and Austin, Z. 2015. Qualitative research: Data collection, analysis, and management. *Canadian Journal of Hospital Pharmacy*. **68**(3), pp.226–231.

Svirko, E. and Mellanby, J. 2017. Teaching neuroanatomy using computer-aided learning: what makes for successful outcomes? *Anatomical Sciences Education*. **10**(6), pp.560–569.

Swanson, D. and Williams, J. 2014. Making abstract mathematics concrete in and out of school. *Educational Studies in Mathematics*. **86**, pp.193–209.

Sweller, J. 2003. Evolution of human cognitive architecture. In: Ross, B.H. ed. *The psychology of learning and motivation: Advances in research and theory*. New York: Elsevier, pp.215–266.

Swinnerton, B.J. Morris, N.P. Hotchkiss, S. and Pickering, J.D. 2017. The integration of an anatomy massive open online course (MOOC) into a medical anatomy curriculum. *Anatomical Sciences Education*. **10**(1), pp.53–67.

Tabachnick, B.G. and Fidell, L.S. 2007. *Using multivariate statistics.* 5th ed. Needham Heights: Allyn and Bacon.

Tam, M.D. Hart, A.R. Williams, S. Heylings, D. and Leinster, S. 2009. Is learning anatomy facilitated by computer-aided learning? A review of the literature. *Medical Teacher*. **31**(9), pp.393–396.

Tan, S. Hu, A. Wilson, T. Ladak, H. Haase, P. and Fung, K. 2012. Role of a computer-generated three-dimensional laryngeal model in anatomy teaching for advanced learners. *Journal of Laryngology and Otology*. **126**(4), pp.395–401.

Tavakol, M. and Sandars, J. 2014. Quantitative and qualitative methods in medical education research: AMEE Guide No 90: Part I. *Medical teacher*. **44**(90), pp.1–11.

Taylor, D.C.M. and Hamdy, H. 2013. Adult learning theories: Implications for learning and teaching in medical education: AMEE Guide No. 83. *Medical Teacher*. **35**(11), pp.1561–1572.

Taylor, S. and Todd, P.A. 1995. Understanding Information Technology Usage: A Test of Competing Models. *Information Systems Research*. **6**(2), pp.144–176.

Teddlie, C. and Tashakkori, A. 2009. *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Thousand Oaks: Sage Publications Ltd.

Tekian, A. Harden, R.M. Cook, D.A. Steinert, Y. Hunt, D. and Norcini, J. 2019. Managing the tension: from innovation to application in health professions education. *Medical Teacher*. **42**(3), pp.333–339.

Ten Cate, O.T.J. Kusurkar, R.A. and Williams, G.C. 2011. How self-determination theory can assist our understanding of the teaching and learning processes in medical education. AMEE Guide No. 59. *Medical Teacher*. **33**(12), pp.961–973.

Thompson, A.R. and Lowrie, D.J. 2017. An Evaluation of Outcomes Following the Replacement of Traditional Histology Laboratories with Self-Study Modules. *Anatomical Sciences Education*. **10**(3), pp.276–285.

Thompson, B. 2004. *Exploratory and confirmatory factor analysis: Understanding concepts and applications.* Washington: American Psychological Association.

Tian, Y. Xiao, W. Li, C. Liu, Y. Qin, M. Wu, Y. Xiao, L. and Li, H. 2014. Virtual microscopy system at Chinese medical university: an assisted teaching platform for promoting active learning and problem-solving skills. *BMC Medical Education*. **14**, article no: 74 [no pagination]

Tinsley, H.E. and Tinsley, D.J. 1987. Uses of factor analysis in counseling psychology research. *Journal of Counseling Psychology*. **34**(4), pp.414–424.

Topping, D.B. 2014. Gross anatomy videos: Student satisfaction, usage, and effect on student performance in a condensed curriculum. *Anatomical Sciences Education*. **7**(4), pp.273–279.

Traser, C.J. Hoffman, L. a. Seifert, M.F. and Wilson, A.B. 2015. Investigating the use of quick response codes in the gross anatomy laboratory. *Anatomical Sciences Education*. **8**(5), pp.421–428.

Trelease, R.B. 2016. From chalkboard, slides, and paper to e-learning: How computing technologies have transformed anatomical sciences education. *Anatomical Sciences Education*. **9**(6), pp.583–602.

Triola, M.M. and Holloway, W.J. 2011. Enhanced virtual microscopy for collaborative education. *BMC Medical Education*. **11**, article no. 4 [no pagination]

Tworek, J.K. Jamniczky, H. a. Jacob, C. Hallgrímsson, B. and Wright, B. 2013. The LINDSAY Virtual human project: An immersive approach to anatomy and physiology. *Anatomical Sciences Education*. **6**(1), pp.19–28.

UCISA Digital Education Group 2018. *Technology enhanced learning survey*. Oxford. [online]. [Accessed 12 March 2020]. Available at: https://www.ucisa.ac.uk/en/Resources/2018/Technology-enhanced-learning-survey

Upson-Taboas, C.F. Montoya, R. and O'Loughlin, V.D. 2019. Impact of cardiovascular embryology animations on short-term learning. *Advances in Physiology Education*. **43**(1), pp.55–65.

Van Nuland, S.E. Eagleson, R. and Rogers, K.A. 2016. Educational software usability: Artifact or Design? *Anatomical Sciences Education*. **10**(2), pp.190–199.

Van Nuland, S.E. and Rogers, K.A. 2015a. E-learning, dual-task, and cognitive load: The anatomy of a failed experiment. *Anatomical Sciences Education*. **9**(2), pp.186–196.

Van Nuland, S.E. and Rogers, K.A. 2015b. The anatomy of E-Learning tools: Does software usability influence learning outcomes? *Anatomical Sciences Education*. **9**, pp.378–390.

Venail, F. Deveze, A. Lallemant, B. Guevara, N. and Mondain, M. 2010. Enhancement of temporal bone anatomy learning with computer 3D rendered imaging softwares. *Medical Teacher*. **32**(7), pp.282–288.

Veneri, D.A. and Gannotti, M. 2014. A comparison of student outcomes in a physical therapy neurologic rehabilitation course based on delivery mode: Hybrid vs traditional. *Journal of Allied Health*. **43**(4), pp.75E-81E.

Venkatesh, V. and Davis, F.D. 2000. A theoretical extension of the technology acceptance model: four longitudinal field studies. *Management Science*. **46**(2), pp.186–204.

Venkatesh, V. Morris, M.G. Davis, G.B. and Davis, F.D. 2003. User acceptance of information technology: Toward a unified view. *Management Information Systems Quarterly*. **27**(3), pp.425–478.

Venkatesh, V. Thong, J. and Xu, X. 2012. Consumer acceptance and user of information technology: Extending the unified theory of acceptance and use of technology. *Management Information Systems Quarterly*. **36**(1), pp.157–178.

Venkatiah, J. 2010. Computer-assisted modules to enhance the learning of anatomy by dissection. *Medical Education*. **44**(5), pp.523–524.

Vivek, P.H. Singh, S.N. Mishra, S. and Donavan, T.D. 2017. *Parallel Analysis Engine to Aid in Determining Number of Factors to Retain using R.* [Software]. Available from https://analytics.gonzaga.edu/parallelengine/.

Volery, T. and Lord, D. 2000. Critical success factors in online education. *International Journal of Educational Management*. **14**(5), pp.216–223.

Vygotsky, L. 1978. *Interaction between learning and development*. Cambridge: Harvard University Press.

Wainman, B. Pukas, G. Wolak, L. Zheng, E. and Norman, G. 2018. Virtual unreality–promise vs. performance of technology in anatomy education. *The FASEB Journal*. **32**(1), p.92.

Wait, K.R. Cloud, B. Forster, L. Jones, T.M. Nokleby, J.J. Wolfe, C.R. and Youdas, J.W. 2009. Use of an audience response system during peer teaching among physical therapy students in human gross anatomy: Perceptions of peer teachers and students. *Anatomical Sciences Education*. **2**(6), pp.286–93.

Wallace, S. Clark, M. and White, J. 2012. 'It's on my iPhone': Attitudes to the use of mobile computing devices in medical education, a mixed-methods study. *British Medical Journal Open*. **2**(4), p.e001099.

Wang, J. Conder, J.A. Blitzer, D.N. and Shinkareva, S. V. 2010. Neural representation of abstract and concrete concepts: A meta-analysis of neuroimaging studies. *Human Brain Mapping*. **31**(10), pp.1459–1468.

Wang, Y.S. Wu, M.C. and Wang, H.Y. 2009. Investigating the determinants and age and gender differences in the acceptance of mobile learning. *British Journal of Educational Technology*. **40**(1), pp.92–118.

Wang, Z. Liu, Y. Luo, H. Gao, C. Zhang, J. and Dai, Y. 2017. Is a three-dimensional printing model better than a traditional cardiac model for medical education? A pilot randomized controlled study. *Acta Cardiologica Sinica*. **33**(6), p.664.

Watkins, M.W. 2006. Determining parallel analysis criteria. *Journal of Modern Applied Statistical Methods*. 5(2), pp.344-346.

Weinkle, L.J. Stratford, J.M. and Lee, L.M.J. 2019. Voice in digital education: The impact of instructor's perceived age and gender on student learning and evaluation. *Anatomical Sciences Education*. **13**(1), pp.59–70.

White, D. and Le Cornu, A. 2011. Visitors and residents: A new typology for online engagement. *Educational Research*. **16**(9), pp.183–196.

White, L.J. McGowan, H.W. and McDonald, A.C. 2019. The effect of content delivery style on student performance in anatomy. *Anatomical Sciences Education*. **12**(1), pp.43–51.

Whitely, B.E. 1997. Gender differences in computer-related attitudes and behavior: A meta-analysis. *Computers in Human Behavior*. **13**(1), pp.1–22.

Wiers-Jenssen, J. Stensaker, B. and Grogaard, J.B. 2002. Student Satisfaction: towards an empirical deconstruction of the concept. *Quality in Higher Education*. **8**(2), pp.183–195.

Wigfield, A. 1994. Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review*. **6**(1), pp.49–78.

Wigfield, A. Tonks, S. and Lutz Klauda, S. 2009. Expectancy-Value Theory. In: Wentzel, K. and Meile, D. eds. *Handbook of Motivation at School*. London: Routledge, pp.55–75.

Wilkes, M. and Raven, B. 2002. Understanding Social Influence in Medical Education. *Academic Medicine*. **77**(6), pp.481–488.

Wilkinson, K. and Barter, P. 2016. Do mobile learning devices enhance learning in Higher Education anatomy classrooms? *Journal of Pedagogic Development*. **6**(1), pp.14–23.

Wilson, A.B. Brown, K.M. Misch, J. Miller, C.H. Klein, B.A. Taylor, M.A. Goodwin, M. Boyle, E.K. Hoppe, C. and Lazarus, M.D. 2019. Breaking with tradition: A scoping meta-analysis analyzing the effects of student-centered learning and computer-aided instruction on student performance in anatomy. *Anatomical Sciences Education*. **12**(1), pp.61–73.

Wilson, A.B. Miller, C. Klein, B. Taylor, M. Goodwin, M. Boyle, E. Brown, K. Hoppe, C. and Lazarus,

M. 2018. A meta-analysis of anatomy laboratory pedagogies. Clinical Anatomy. **31**(1), pp.122–133

Wilson, A.B. Taylor, M.A. Klein, B.A. Sugrue, M.K. Whipple, E.C. and Brokaw, J.J. 2016. Meta-analysis and review of learner performance and preference: Virtual versus optical microscopy. *Medical Education*. **50**(4), pp.428–440.

Wismer, A. Reinerman-jones, L. Teo, G. Willis, S. McCracken, K. and Hackett, M. 2018. Assessing performance and usability of 3d visualization technologies for anatomical training. *ModSim 2018*. (17), pp.1–11.

Wolf, M. 2018. *Skim reading is the new normal. The effect on society is profound.* [online]. [Accessed 26 April 2020]. Available at: https://www.theguardian.com/commentisfree/2018/aug/25/skim-reading-new-normal-maryanne-wolf

Wormald, B.W. Schoeman, S. Somasunderam, A. and Penn, M. 2009. Assessment drives learning: An unavoidable truth? *Anatomical Sciences Education*. **2**(5), pp.199–204.

Wright, E.F. and Hendricson, W.D. 2010. Evaluation of a 3-D interactive tooth atlas by dental students in dental anatomy and endodontics courses. *Journal of Dental Education*. **74**(2), pp.110–122.

Wu, J.H. Tennyson, R.D. and Hsia, T.L. 2010. A study of student satisfaction in a blended e-learning system environment. *Computers and Education*. **55**(1), pp.155–164.

Yammine, K. and Violato, C. 2015. A meta-analysis of the educational effectiveness of three-dimensional visualisation technologies in teaching anatomy. *Anatomical Sciences Education*. **8**(6), pp.525–38.

Yao, W.C. Regone, R.M. Huyhn, N. Butler, E.B. and Takashima, M. 2014. Three-dimensional sinus imaging as an adjunct to two-dimensional imaging to accelerate education and improve spatial orientation. *The Laryngoscope*. **124**(3), pp.596–601.

Yardley, S. and Dornan, T. 2012. Kirkpatrick's levels and education 'evidence'. *Medical Education*. **46**(1), pp.97–106.

Yot-Domínguez, C. and Marcelo, C. 2017. University students' self-regulated learning using digital technologies. *International Journal of Educational Technology in Higher Education*. **14**, article no: 38 [no pagination]

Young, J.Q. Van Merrienböer, J. Durning, S. and Ten Cate, O. 2014. Cognitive load theory: Implications for medical education: AMEE Guide No. 86. *Medical teacher*. **36**(5), pp.371–84.

Zaharias, P. and Poylymenakou, A. 2009. Developing a usability evaluation method for e-learning applications: Beyond functional usability. *International Journal of Human-Computer Interaction*. **25**(1), pp.75–98.

Zimmerman, B.J. 1990. Self-Regulated Learning and Academic Achievement: An Overview.

Educational Psychologist. **25**(1), pp.3–17.

Zimmerman, B.J. 2011. Motivational Sources and Outcomes of Self-Regulated Learning and Performance. In: Schunk, D.H. ed. *Handbook of Self-Regulation of Learning and Performance.* London: Routledge, pp.49–64.

Zimmerman, B.J. and Schunk, D.H. 2011. Self-Regulated Learning and Performance. In: *Schunk, D.H. ed. Handbook of Self-Regulation of Learning and Performance.* London: Routledge.

Zureick, A.H. Burk-Rafel, J. Purkiss, J.A. and Hortsch, M. 2018. The Interrupted Learner: How Distractions during Live and Video Lectures Influence Learning Outcomes. *Anatomical Sciences Education*. **11**(4), pp.366–376.

Appendix 1: Details of Articles Included within the Systematic Review

Details of the 210 eligible studies extracted from the systematic review by resource type, with the assigned level of evaluation documented in accordance with the Technology-Enhanced Learning Evaluation Model (TELEM) as a benchmarking tool (Updated from Table 2 in original publication).

		Level on TELEM			
First Author	**Year**	**1a**	**1b**	**2**	**3**
3D Visualisation Technologies					
Alfalah et al	2018	✓			
Allen et al	2016	✓	✓		
Barmaki et al	2019	✓	✓		
Battulga et al	2012	✓			
Braun & Kearns	2008	✓		✓	
Brewer et al	2012	✓	✓		
Brown et al	2012	✓			
Choi et al	2017	✓			
Codd & Choudhury	2011	✓	✓		
Cui et al	2017	✓	✓		
Das & Mitchell	2013		✓		
de Faria et al	2016		✓		
Ekstrand et al	2018	✓	✓		
Farah & Maybury	2009	✓			
Farah & Maybury	2009	✓		✓	
Ferrer-Torregrosa et al	2015	✓		✓	
Hackett & Proctor	2018		✓		
Harris et al	2001	✓			
Heidger et al	2002	✓			
Helle et al	2011	✓	✓		
Helle et al	2013	✓		✓	
Higazi	2011	✓		✓	
Hisley et al	2008		✓		
Hopkins et al	2011	✓	✓		
Hoyek et al	2014	✓		✓	
Hu et al	2010	✓	✓		
Husmann et al	2009	✓		✓	
Keedy et al	2011	✓	✓		
Khot et al	2013		✓		
Krippendorf & Lough	2005	✓		✓	
Kucuk et al	2016	✓	✓		
Kugelmann et al	2018	✓			
Kumar et al	2004	✓			
Levinson et al	2007		✓		
Lone et al	2018	✓	✓	✓	
Ma et al	2015	✓			
Maybury & Farah	2010	✓			
McCready et al	2013	✓			
Miller	2016			✓	
Mione et al	2013		✓		
Mione et al	2015			✓	
Moro et al	2017	✓	✓		
Nicholson et al	2006		✓		
Patel et al	2006	✓			
Petersson et al	2009	✓		✓	
Richardson-Hatcher et al	2014	✓			
Rosas et al	2012	✓			
Sander & Golas	2013	✓			

First Author	Year	1a	1b	2	3
		Level on TELEM			
Scoville & Buskirk	2007	✓		✓	
Silen et al	2008	✓			
Sivamalai et al	2011	✓			
Soh Said et al	2015	✓			
Tan et al	2011	✓	✓		
Thompson & Lowrie	2017	✓		✓	
Tian et al	2014	✓		✓	
Triola & Holloway	2011			✓	
Tworek et al	2013	✓			
Venail et al	2010	✓		✓	
Wainman et al	2018		✓		
Wismer et al	2018	✓	✓		
Wright & Hendricson	2010	✓			
Yao et al	2014	✓			
Commercial Resources					
Ang et al	2014	✓			
Attardi & Rogers	2015			✓	
Donelly et al	2009		✓		
Han et al	2017	✓			
Jamil et al	2018	✓	✓		
Kelc	2012	✓			
Lombardi et al	2014	✓	✓		
Mitrousias et al	2018	✓	✓		
Peterson & Mlynarczyk	2016	✓		✓	
Saltarelli et al	2014			✓	
Swinnerton et al	2016	✓			
Van Nuland & Rogers	2017	✓	✓		
Van Nuland & Rogers	2015		✓		

First Author	Year	1a	1b	2	3
		Level on TELEM			
Educator-Developed Resource					
Acosta et al	2018	✓		✓	
Adamczyk et al	2009	✓		✓	
Ahmad et al	2016	✓		✓	
Aktekin et al	2018	✓			
Al-Neklawy et al	2017	✓			
Alexander et al	2009	✓		✓	
Allen et al	2008	✓		✓	
Attardi et al	2016	✓			
Bacro et al	2013	✓		✓	
Barbeau et al	2013	✓		✓	
Beale et al	2014	✓		✓	
Bogacki et al	2004	✓	✓		
Brown et al	2015			✓	
Bryner et al	2008	✓	✓		
Carmichael & Pawlina	2000	✓			
Cheng et al	2017	✓	✓		
Chimalgi	2019	✓		✓	
Choi-Lundberg et al	2016	✓		✓	
Choi-Lundberg et al	2015	✓			
Chopra et al	2017	✓		✓	
Chopra et al	2012	✓		✓	
Choudhury et al	2010	✓		✓	
Corton et al	2006	✓	✓		
Day	2018			✓	
Devitt & Palmer	1999		✓		
Doubleday & Wille	2014	✓			
Durham et al	2008	✓			

		Level on TELEM			
First Author	**Year**	**1a**	**1b**	**2**	**3**
Elizondo-Omana et al	2004			✓	
Ernst et al	2003	✓			
Evans	2011	✓		✓	
Fergusson et al	2018		✓		
Fleagle et al	2018	✓		✓	
Foreman et al	2005	✓			
Gazave & Hatcher	2017	✓			
Gopal et al	2010		✓		
Granger & Calleson	2007	✓		✓	
Granger et al	2006	✓			
Green et al	2018	✓		✓	
Green et al	2014			✓	
Green et al	2013	✓		✓	
Green & Whitburn	2016	✓		✓	
Green et al	2006	✓		✓	
Greene	2018	✓		✓	
Greene	2019	✓		✓	
Gross et al	2017	✓		✓	
Guerri-Guttenberg	2008	✓		✓	
Guimarães et al	2019			✓	
Guy et al	2015	✓			
Hallgren et al	2002		✓		
Holland & Pawlikowska	2018	✓			
Hoyt et al	2010	✓		✓	
Inwood & Ahmad	2005	✓			
Javadian & Shobeiri	2016			✓	
Johnson et al	2013	✓		✓	
Khalil et al	2010	✓		✓	

		Level on TELEM			
First Author	**Year**	**1a**	**1b**	**2**	**3**
Langfield et al	2018	✓		✓	
Lee et al	2012	✓		✓	
Levine et al	1999	✓			
Limpach et al	2008	✓		✓	
Lochner et al	2016	✓			
Lone et al	2018	✓	✓		
Maggio et al	2012	✓	✓		
Mahmud et al	2011	✓		✓	
Mars & McLean	1996	✓	✓		
Mathiowetz et al	2015	✓		✓	
McNulty et al	2000			✓	
McNulty et al	2004			✓	
McNulty et al	2009	✓		✓	
Moorman et al	2006	✓			
Ngan et al	2018	✓		✓	
Nieder et al	2012			✓	
Nieder et al	2002	✓			
Nieder et al	2000	✓			
O'Byrne et al	2008	✓		✓	
Ocak & Topal	2015	✓			
Ogunranti	1987	✓			
Ozer et al	2017	✓		✓	
Pascoe & Lee	2017	✓	✓		
Patasi et al	2009	✓			
Pereira et al	2004	✓		✓	
Pereira et al	2007	✓		✓	
Pickering & Swinnerton	2019	✓			
Pickering	2014	✓		✓	

		Level on TELEM			
First Author	**Year**	**1a**	**1b**	**2**	**3**
Pickering	2016	✓	✓		
Pickering	2015	✓		✓	
Raynor & Iggulden	2008	✓			
Reeves et al	2004	✓			
Ribeiro et al	2007	✓		✓	
Rich & Guy	2013	✓		✓	
Rinaldi et al	2017	✓		✓	
Rizzolo et al	2010	✓		✓	
Rizzolo et al	2002	✓		✓	
Rondon et al	2013			✓	
Saxena et al	2008	✓		✓	
Stewart & Choudhury	2015	✓	✓		
Stirling & Birt	2014	✓	✓		
Strkalj et al	2018	✓			
Svirko & Mellanby	2017	✓		✓	
Topping	2014	✓		✓	
Upson-Taboas et al	2019	✓	✓		
Veneri & Gannotti	2014	✓		✓	
Venkatiah	2010	✓		✓	
Wait et al	2009	✓			
White et al	2019	✓		✓	
Shoepe et al	2015	✓		✓	
Mobile Devices					
Bice et al	2016	✓		✓	
Chakraborty & Cooperstein	2018	✓		✓	
Lazarus et al	2017	✓			
Mayfield et al	2012	✓			
Meyer et al	2015	✓			

		Level on TELEM			
First Author	**Year**	**1a**	**1b**	**2**	**3**
Mogali et al	2019	✓			
Morris et al	2016	✓		✓	
Raney	2015	✓		✓	
Scibora et al	2018	✓		✓	
Traser	2015	✓		✓	
Wilkinson & Barter	2016	✓		✓	
Purpose Built Hardware					
Backhouse et al	2018	✓			
Cai et al	2019		✓		
Chan et al	2015	✓	✓		
Chen et al	2017	✓	✓		
Fairén González et al	2017	✓			
Garas et al	2018	✓	✓		
Lim et al	2015		✓		
Luursema et al	2017		✓		
Maresky et al	2019	✓	✓		
Marks et al	2019	✓	✓		
Mogali et al	2018	✓			
O'Reilly et al	2016	✓	✓		
Stepan et al	2017	✓	✓		
Wang et al	2017	✓	✓		
Social Media					
Anwar et al	2017	✓		✓	
Hennessy et al	2016	✓		✓	
Jaffar	2012	✓			
Jaffar	2014	✓			
Pickering & Bickerdike	2016	✓		✓	

Appendix 2: Development of the Pilot Anatomy TEL Utility Scale

The following table details the items used in the pilot survey scale. Where applicable, the survey items were developed following thematic analysis of existing surveys within anatomy TEL evaluation literature (cited in column 3) and with reference to the conceptual framework (column 4).

Pilot Survey Item	Question Theme	Citing Literature (Anatomy Education)	Link with Conceptual Framework
I find TEL resources easy to use	Easy to use	(Nieder et al., 2000; Reeves et al., 2004; Inwood and Ahmad, 2005; Foreman et al., 2005; Durham et al., 2009; Husmann et al., 2009; Alexander et al., 2009; Venail et al., 2010; Hu et al., 2010; Battulga et al., 2012; Tan et al., 2012; Kelc, 2012; Stirling and Birt, 2014; Guy et al., 2015)	**Factors influencing affective attitude towards TEL** Items associated with affective engagement such as motivation, autonomy, and subjective interest value. Ryan and Deci (2004); Venkatesh et al. (2003); Hill et al., (2006); Eccles (1983, 2016)
Using TEL resources to study anatomy is frustrating	Frustrating	(Silen et al., 2008; Adamczyk et al., 2009; Choudhury et al., 2010; Hu et al., 2010)	
TEL resources accommodate my preferred learning method	Preferred method	(Khalil, Nelson, et al., 2010; Yao et al., 2014; Stirling and Birt, 2014; Ferrer-Torregrosa et al., 2015; Guy et al., 2015)	
TEL resources are useful for studying anatomy	Useful	(Mars and McLean, 1996; Reeves et al., 2004; Moorman, 2006; Durham et al., 2009; Evans, 2011; Battulga et al., 2012; Maggio et al., 2012; Green and Whitburn, 2016; Hennessy et al., 2016; Morris et al., 2016)	
I believe TEL resources help me to learn anatomy	Help learning	(Mars and McLean, 1996; Braun and Kearns, 2008; Adamczyk et al., 2009; Hu et al., 2010; Maggio et al., 2012; Battulga et al., 2012; Brown et al., 2012; Tan et al., 2012; L.M.J. Lee et al., 2012; Johnson et al., 2013; Rich and Guy, 2013; Yao et al., 2014; Ang et al., 2014; Pickering, 2014b; Stirling and Birt, 2014; Ferrer-Torregrosa et al., 2015; Guy et al., 2015; Morris et al., 2016; Ahmad et al., 2016; Rinaldi et al., 2017; Khalil et al., 2018)	

TEL resources allow me to work at my own pace	Work at own pace	(Hu et al., 2010; Ferrer-Torregrosa et al., 2015; Guy et al., 2015)	**Factors influencing affective attitude towards TEL (Cont'd)**
Studying anatomy using TEL resources is intellectually stimulating	Intellectually stimulating	(Adamczyk et al., 2009; Khalil, Nelson, et al., 2010; Rich and Guy, 2013; Ferrer-Torregrosa et al., 2015; Green and Whitburn, 2016)	
I do not enjoy learning anatomy using TEL resources	Enjoy	(Adamczyk et al., 2009; Wright and Hendricson, 2010; Hu et al., 2010; Choudhury et al., 2010; Morris et al., 2016)	
TEL resources positively affect my experience in anatomy	Positive experience	(Patel et al., 2006; Pickering, 2014b)	
I am motivated to learn when I study using TEL resources	Motivation	(Silen et al., 2008; Adamczyk et al., 2009; Battulga et al., 2012; Ferrer-Torregrosa et al., 2015; Hennessy et al., 2016)	
I feel more confident in anatomy when I study using TEL resources	Confidence	(Patel et al., 2006; Brown et al., 2012; Pickering and Bickerdike, 2017)	
Using TEL resources to study anatomy is not an efficient use of my time	Time efficiency	(Harris et al., 2001; Patel et al., 2006; Braun and Kearns, 2008; Wait et al., 2009; Alexander et al., 2009; Choudhury et al., 2010; Brown et al., 2012; Yao et al., 2014)	**Factors influencing perceived value of TEL** Items associated with subjective value, such as attainment value, utility value and cost value. Eccles (1983, 2016); Hill et al., (2006)
TEL resources make my learning less efficient	Learning efficiency	(Harris et al., 2001; Reeves et al., 2004; Inwood and Ahmad, 2005; Braun and Kearns, 2008; Husmann et al., 2009; Maggio et al., 2012; Battulga et al., 2012; Raney, 2016; Green and Whitburn, 2016; Pickering and Bickerdike, 2017; Khalil et al., 2018)	
I need to use TEL resources to study anatomy in order to score highly in my assessments	TEL required	(Khalil, Nelson, et al., 2010; Stirling and Birt, 2014; Guy et al., 2015; Ahmad et al., 2016)	
I use TEL resources when revising for my anatomy assessments	Use for revising	(Nieder et al., 2000; Foreman et al., 2005; Inwood and Ahmad, 2005; Patel et al., 2006; Wait et al., 2009; Adamczyk et al., 2009; Durham et al., 2009; Alexander et al., 2009; Choudhury et al.,	

		2010; L.M.J. Lee et al., 2012; Ahmad et al., 2016; Thompson and Lowrie, 2017)	**Factors influencing perceived value of TEL (cont'd)**
TEL resources improve my ability to visualise where anatomical structures are located within the body	Ability to visualise 3D	(Nieder et al., 2000; Foreman et al., 2005; Patel et al., 2006; Adamczyk et al., 2009; Venail et al., 2010; Wright and Hendricson, 2010; Hu et al., 2010; Tan et al., 2012; Kelc, 2012; Johnson et al., 2013; Ang et al., 2014; Stirling and Birt, 2014; Guy et al., 2015; Ferrer-Torregrosa et al., 2015; Ahmad et al., 2016; Raney, 2016)	
Learning with TEL resources is more effective than learning face to face with my anatomy teacher(s)	TEL vs F2F	(Hu et al., 2010; Maggio et al., 2012; Kelc, 2012; Brown et al., 2012; Stirling and Birt, 2014; Ferrer-Torregrosa et al., 2015; Guy et al., 2015)	
I know how to strategically use TEL resources in order to perform well in my anatomy assessments	Strategic Use	(Adamczyk et al., 2009; Johnson et al., 2013)	**Factors influencing perceived competence** Items associated with competence, one of the three psychological needs of intrinsic motivation Ryan and Deci (2004)
I have the digital literacy skills to use TEL resources effectively and efficiently	Digital literacy	(Durham et al., 2009; Hu et al., 2010; Stirling and Birt, 2014)	
I am confident I know where to find the TEL resources that are available to me	Knowledge of resources	None	
TEL resources enhance the interaction between students and teachers	Student / teacher interaction	(Reeves et al., 2004; Ahmad et al., 2016)	**Influence of others** Items associated with social norms and relatedness, one of the three psychological needs of intrinsic motivation Ajzen and Fishbein (1980); Armitage and Conner (2001);
I only use TEL resources recommended by my anatomy teachers because they cover material that will be assessed	Teacher Recommended (Assessment)	(Wait et al., 2009; Yao et al., 2014; Rinaldi et al., 2017)	
I only use TEL resources recommended by my anatomy teachers because I do not trust the content of other resources	Teacher Recommended (Trust)	None	

I am influenced by what my classmates are using when choosing which TEL resource to use	Peer Influence	None	Venkatesh et al. (2003); Ryan and Deci (2004)
I am concerned about my privacy when using the TEL resources available to me	Privacy	None	**Influence of possible negatives to TEL** While not referred to within anatomy TEL evaluation surveys, items associated with privacy, distractions and accessibility were included. Wei and Hindman, (2011); Wallace et al. (2012); Lee et al. (2012); Delgaty et al (2017); Zureick et al. (2017)
I am distracted (e.g. by social media / emails) when studying anatomy using TEL resources	Distractions	None	
There are TEL resources I would like to use but I have no access to them	Limited access	None	
I am able to use TEL resources to study anatomy whenever and wherever I want	Flexible access	None	
I can access TEL resources using my mobile device (i.e. mobile phone / tablet)	Mobile device access	None	
I do not use all of the TEL resources available to me	Use all resources	None	

Appendix 3: Ethical Approval

Faculty of Medicine and Health Research Office
School of Medicine Research Ethics Committee (SoMREC)

Room 9.29, level 9
Worsley Building
Clarendon Way
Leeds, LS2 9NL
United Kingdom

✆ +44 (0) 113 343 1642

19 February 2018

Lauren Clunie
PhD Student
School of Medicine
Leeds Institute of Medical Educatoin
Faculty of Medicine and Health
Worsley Building
University of Leeds
Clarendon Way
LEEDS LS2 9NL

Dear Lauren

Ref no: **MREC17-002**

Title: **The Perceived impact of TEL Resources on Successful Learning in Anatomy Education**

Your research application has been reviewed by the School of Medicine Ethics Committee (SoMREC) and we can confirm that ethics approval is granted based on the following documentation received from you.

Document	*Version*	*Date Submitted*
Lauren Clunie Ethics Application_V3	3.0	15/02/2018
Appendix 1 - Permission for Prof Fuller	1.0	08/08/2017
Appendix 2 - Permission from Dr Pickering	1.0	08/08/2017
Appendix 3 - Focus Group Recruitment Email	1.0	08/08/2017
Appendix 4 - Participant Information Sheet	1.0	08/08/2017
Appendix 5 - Focus Group Consent Form	1.0	08/08/2017
Appendix 6 - Flyer for support services	1.0	15/02/2018

Please notify the committee if you intend to make any amendments to the original research ethics application or documentation. All changes must receive ethics approval prior to implementation. Please contact the Faculty Research Ethics Administrator for further information (fmhuniethics@leeds.ac.uk)

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

Appendix 4: Pilot Survey

School of Medicine, Faculty of Medicine and Health

UNIVERSITY OF LEEDS

Technology in Anatomy Questionnaire

Please check the boxes below if you agree with the following statements:

☐ **I agree to my data being used for research purposes**

☐ **I am happy to be contacted regarding my survey responses** (You may be selected to take part in a focus group to help us improve the resources that currently supplement your anatomy curriculum)

Student ID Number: ______________________________

Gender: Male ☐ Female ☐ Prefer not to say ☐ **Age:** ☐

The following questions are related to the technology which is available to you to supplement your anatomy learning. For the purposes of this questionnaire, these resources are described collectively as <u>TEL Resources</u> (Technology Enhanced Learning Resources). These resources are listed below:

- Lecture Recordings
- Lecture Slides on the VLE
- MCQs on VLE
- Dissection Videos
- Anatomy eBooks
- Anatomy MOOCs
- YouTube Videos
- 3D Virtual Models (*e.g. in mobile apps or online*)

When studying anatomy, which of the following statements is true? (Please select one answer)

I only use paper-based resources (*e.g. work/text books*)	I use paper-based resources MORE than TEL resources	I use TEL resources MORE than paper-based resources	I only use TEL resources (*i.e. those listed above*)
☐	☐	☐	☐

Please think about these resources and how you use them to support your <u>anatomy learning specifically</u>.

Below are a number of statements related to the resources listed above.

Please <u>circle</u> whether you agree or disagree with each statement.

Statement	Strongly Disagree		Neutral		Strongly Agree
I find TEL resources easy to use	1	2	3	4	5
Using TEL resources to study anatomy is useful	1	2	3	4	5
I do not enjoy learning anatomy using TEL resources	1	2	3	4	5
Using TEL resources to study anatomy is intellectually stimulating	1	2	3	4	5
Using TEL resources to study anatomy is a challenge	1	2	3	4	5
I would recommend using TEL resources to others studying anatomy	1	2	3	4	5

School of Medicine, Faculty of Medicine and Health

Statement	Strongly Disagree		Neutral		Strongly Agree
I feel more confident in anatomy when I study using TEL resources	1	2	3	4	5
Learning anatomy using TEL resources can be frustrating	1	2	3	4	5
I dislike using TEL resources to study anatomy	1	2	3	4	5
TEL resources positively affects my learning experience in anatomy	1	2	3	4	5
Using TEL resources to study anatomy is not an efficient use of my time	1	2	3	4	5
I use TEL resources to prepare for my anatomy exams	1	2	3	4	5
I am motivated to learn when I study using TEL resources	1	2	3	4	5
My time in the Anatomy Laboratory (Dissection Room) is less worthwhile because I can use TEL resources to study anatomy	1	2	3	4	5
TEL resources accommodate my preferred learning method	1	2	3	4	5
I am uncomfortable using TEL resources to study anatomy	1	2	3	4	5
TEL resources allow me to work at my own pace	1	2	3	4	5
I do not use the TEL resources available to me to search for information	1	2	3	4	5
I do not need TEL resources to help solidify my understanding of the basic concepts in anatomy	1	2	3	4	5
TEL resources improve my ability to visualise where anatomical structures are located within the body	1	2	3	4	5
TEL resources help to reinforce my anatomical knowledge	1	2	3	4	5
My performance in the Anatomy Laboratory (Dissection Room) is enhanced when I have studied with TEL resources	1	2	3	4	5
I believe my learning is less efficient when I study using TEL resources	1	2	3	4	5
TEL resources do not help me improve my learning	1	2	3	4	5
I like to use TEL resources because they can give me feedback on my knowledge and understanding	1	2	3	4	5
The content of the TEL resources available to me is sufficient for my learning	1	2	3	4	5
Studying with TEL resources helps me determine areas where I need more work	1	2	3	4	5
TEL resources are not necessary for me to understand anatomy	1	2	3	4	5

Appendix 5: Exploratory Factor Analysis (EFA) Solutions for Pilot Survey

Total no. of items	Questions Removed	Internal Consistency (α)	KMO	No. with Eigenvalue >1	Factors Forced	Parallel Analysis	Scree plot inflection	Total Variance Explained	Internal Consistency (α) of Emerging Factors				
									1	2	3	4	5
30	-	0.688	0.800	9	0	5	7	64.31	-	-	-	-	-
30	-	0.688	0.800	9	5	5	7	49.46	-	-	-	-	-
29	16	0.763	0.798	8	5	3	6	50.32	-	-	-	-	-
28	16,30	0.776	0.806	8	5	3	6	51.02	-	-	-	-	-
27	16,28,30	0.786	0.807	7	5	3	5	52.07	0.854	0.526	0.724	0.536	0.627
26	16,24,28,30	0.811	0.810	7	5	3	5	53.42	0.854	0.811	0.724	0.536	0.627
26	16,24,28,30	0.811	0.810	7	4	3	5	48.11	0.854	0.510	0.681	0.537	-
25	16,19,24,28,30	0.824	0.822	7	5	3	6	54.04	0.858	0.811	0.621	0.627	0.161
24	16,19,20,24,28,30	0.841	0.830	6	4	3	6	50.34	0.854	0.809	0.435	0.627	-
23	16,19,20,23,24,28,30	0.841	0.842	6	4	3	4	51.14	0.872	0.811	0.572	0.435	-
22	16,19,20,23,24,27,28,30	0.847	0.849	6	4	3	4	52.75	0.858	0.811	0.643	0.435	-
21	16,19,20,21,23,24,27,28,30	0.871	0.853	5	4	3	5	53.60	0.825	0.811	0.718	0.142	-
21	16,19,20,21,23,24,27,28,30	0.871	0.853	5	3	3	5	48.39	0.818	0.811	0.718	-	-
20	16,19,20,21,23,24,25,27,28,30	0.880	0.856	4	3	2	4	50.15	0.817	0.755	0.811	-	-
20	16,19,20,21,23,24,27,28,29,30	0.882	0.857	4	3	2	4	50.35	0.848	0.811	0.718	-	-
19	16,19,20,21,23,24,25,27,28,29,30	0.891	0.861	3	0	2	4	52.17	0.835	0.784	0.811	-	-
18	16,17,19,20,21,23,24,25,27,28,29,30	0.886	0.860	3	0	2	4	53.38	0.824	0.784	0.811	-	-
18	16,18,19,20,21,23,24,25,27,28,29,30	0.893	0.866	3	0	2	4	53.80	0.851	0.767	0.811	-	-

Highlighted iteration = most parsimonious output; KMO = Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy; Internal consistency measured using Cronbach's alpha (α). Note: measures of internal consistency were only gathered when all emerging factors had >3 items loading.

Appendix 6: Focus Group Schedule

Introduction Moderator / Assistant Moderator / Participants

Establish ground rules for participating in focus groups

Ice breaker question – "what is your favourite area of anatomy and why?"

Key Question	Example Prompts
Can you tell me about some of the resources that you use to study anatomy?	Are there any resources you prefer over all others? Are there any resources offered to you by the University of Leeds that you use? Do you use resources that are not provided by the University of Leeds?
Can you tell me what made you choose these resources?	Do you think your friends and peers have an influence? What are you looking for in a resource for it to be worthwhile for you to use? Is there anything that might put you off using a resource? How much of a factor is time when you're looking at resources?
Can you tell me a bit about how you use these resources to revise anatomy?	When you're watching a video do you tend to just watch it all the way through? Why do you think the workbooks are used so heavily? Do you ever find learning with technology is distracting? Do you always go to the same resources when you're revising?
Do you think that you need technology in order to be successful in anatomy?	Do you believe you have the appropriate digital skills for using all technology-based anatomy resources?
What does technology enhanced learning mean to you?	Where is the enhancement coming from with those specific resources?

Summary – summarise the discussion before asking participants to confirm it is an adequate summary.

Final Question – recap the purpose of the study and ask participants if there is anything they'd like to raise, discuss further or elaborate on following the summary.

Appendix 7: Participant Information Sheet

School of Medicine, Faculty of Medicine and Health

UNIVERSITY OF LEEDS

Information Sheet

The Perceived Impact of Technology Enhanced Learning (TEL) Resources on Learning within Anatomy Education

Lead Researcher: Miss Lauren Clunie *Email*: umlccl@leeds.ac.uk

You are being invited to volunteer to take part in a research project. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and to discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like additional information.

What is the purpose of this research?

This study is part of a PhD research project, the aim of which is to gain a deeper understanding of your perceptions of the impact technology enhanced learning (TEL) resources have on your anatomy learning and teaching at the University of Leeds. This study has been approved by the School of Medicine Research Ethics Committee. Reference: MREC17-002.

The data from this study will help to understand the reasons for engagement and motivation to use technology to learn anatomy. The scale and thoroughness of this evaluation of TEL in anatomy education has never been published before in the literature. In particular, evaluating resources through focus groups is not commonly used in this field. Therefore, the hope will be to publish the results at conferences or in academic journals. You will not be identifiable in any reports or publications, and any quotes used will be anonymised.

Why am I being invited?

You recently completed a survey in which you answered questions related to the resources you have access to as part of your anatomy learning. We would like to ask you a few more questions related to the responses you gave during the survey. This will help to provide a better understanding of how TEL might be impacting your learning and what your experiences are of using it to learn and revise.

What do I have to do?

If you decide to participate in this study you will be asked to attend a focus group. This will involve an informal discussion with an anatomy demonstrator (Lauren Clunie) and a handful of your peers. This will last no longer than 60 mins and will be audio-recorded for analysis purposes. All comments made in the focus group will be kept confidential by the lead researcher; however, this cannot be guaranteed for other participants, although it will be requested.

Project title	*Document type*	*Ethics Ref*	*Version*	*Date*
The Perceived Impact of Technology Enhanced Learning (TEL) Resources on Successful Learning in Anatomy Education	Information sheet	MREC17-002	1	04/08/17

School of Medicine, Faculty of Medicine and Health

UNIVERSITY OF LEEDS

Am I obliged to take part?

Participation in this study is completely voluntary and there is no penalty on your studies or work going forward in anatomy or any other part of the MBChB if you choose not to participate. You can withdraw at any time before or during the focus group and you do not have to give a reason. However, due to the interactive nature of a focus group, your responses up until the point of withdrawal will be retained.

Why should I volunteer to take part?

By volunteering to participate you will be providing vital information on the impact of technology on learning, not only to the anatomy team here at Leeds, but also to the wider community of anatomy educators. You will have an opportunity to discuss, with your peers, why you think TEL is good/bad, how you learn using it, what parts of anatomy teaching could be improved and how you believe it impacts on your learning.

How can I volunteer to participate?

If you are interested in participating or have any questions you can email Lauren Clunie (Lead Researcher) at umlccl@leeds.ac.uk. If you decide to take part you will be given this information sheet to keep for your records, and a suitable date and time will be arranged for a focus group session.

Thank you for taking the time to read this information sheet and I am happy to answer any questions relating to the project.

Lead Researcher
Lauren Clunie
PhD Student & Anatomy Demonstrator
9.12 Worsley
Leeds Institute of Medical Education
School of Medicine
umlccl@leeds.ac.uk

PhD Supervisor
Dr James Pickering
9.06 Worsley
Division of Anatomy
Leeds Institute of Medical Education
School of Medicine
james.pickering@leeds.ac.uk

Project title	*Document type*	*Ethics Ref*	*Version*	*Date*
The Perceived Impact of Technology Enhanced Learning (TEL) Resources on Successful Learning in Anatomy Education	Information sheet	MREC17-002	1	04/08/17

Appendix 8: Participant Consent Form

School of Medicine, Faculty of Medicine and Health

UNIVERSITY OF LEEDS

Participant Consent Form

The Perceived Impact of TEL Resources on Successful Learning in Anatomy Education

Lead Researcher: Miss Lauren Clunie *Email*: umlccl@leeds.ac.uk

Please tick the box if you agree with the statement:

1. I confirm that I have read and understood the participant information sheet, dated 1st August 2017. I have had the opportunity to ask questions and I have received contact information for the project. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time before or during the focus group without giving any reason and without there being any negative consequences. I am aware that due to the interactive nature of a focus group, my responses up until the point of withdrawal will be retained. ☐
3. I understand that my responses are anonymous and will be kept confidential. I give permission for members of the research team to have access to my anonymised responses, and to directly quote me. ☐
4. I understand that comments from other participants during the focus group are confidential and should not be discussed outside of the focus group session. ☐
5. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in any research outputs such as reports or publications. ☐
6. I agree for my comments during the focus group to be audio-recorded. ☐
7. I agree for the data collected from me to be stored securely and used in future research. ☐
8. I agree to take part in the above research project. ☐

____________________ __________ ____________________

Name of Participant Date Signature

____________________ __________ ____________________

Lead Researcher Date Signature

Project title	*Document type*	*Version #*	*Date*
The Perceived Impact of TEL Resources on Successful Learning in Anatomy Education	Participant Consent Form (Focus Group)	1	01/08/17

Appendix 9: Details of Data Triangulation Process

This table details, item per item, the process of data triangulation undertaken to determine whether survey items should be removed, retained, modified from the pilot survey, or in some instances, where items should be added. Both quantitative and qualitative justifications are given for each action taken on a survey item. The resultant 28-item survey scale was utilised, the results from which are detailed in Chapter 7.

	Original Survey Item	Quantitative Findings	Qualitative Findings	Action	New Survey Item
16	I do not use all of the TEL resources available to me	Item did not correlate with any other item in the scale. Internal consistency of overall scale increased from α=.730 to α=.763 when removed.	Potentially ambiguous question. Respondents may not be aware of all resources available to them prior to completing the survey.	Removed	*Not applicable*
30	I am concerned about my privacy when using the TEL resources available to me	Item did not correlate with any other item in the scale. Internal consistency of overall scale increased from α=.763 to α=.776 when removed.	FGs highlighted that privacy online was not a major concern when selecting TEL resources. The exception to this was in relation to Facebook, however, this only arose when prompted. For this reason, the item could be interpreted as being ambiguous.	Removed	*Not applicable*
28	Learning with TEL resources is not as effective as learning face to face with my anatomy teacher(s)	Item did not correlate with any other item in the scale. Internal consistency of overall scale increased from α=.776 to α=.786 when removed.	Naturally arising discussion revealed all FG participant emphatically agreed learning face to face is preferable to learning using TEL.	Removed	*Not applicable*
24	There are TEL resources I would like to use to study anatomy but have little or no access to them	Item did not correlate with any other item in the scale. Internal consistency of overall scale increased from α=.786 to α=.811 when removed.	Potentially ambiguous question. Respondents, like some of the FG participants, may consider TEL resources such as VR, while others may consider accessibility issues such as device ownership or financial barriers etc.	Removed	*Not applicable*

	Original Survey Item	Quantitative Findings	Qualitative Findings	Action	New Survey Item
19	I only use TEL resources recommended to me by my anatomy teachers since those resources sufficiently cover the material that will be assessed	Internal consistency of overall scale increased from α=.811 to α=.824 when removed. Only correlated with Q20, another poorly performing item.	FG discussions revealed that both anatomy educators and assessment have a significant influence over perceptions and use of TEL. However, these concepts were not always explicitly linked, as the original survey item would suggest.	Removed	*Not applicable*
20	I only use TEL resources recommended to me by my anatomy teachers because I do not trust the content of other resources	Internal consistency of overall scale increased from α=.824 to α=.841 when removed. Only correlated with Q19, another poorly performing item.	FG discussions revealed that both anatomy educators and lack of trust have a significant influence over perceptions and use of TEL. However, these concepts were not always explicitly linked, as the original survey item would suggest.	Removed	*Not applicable*
23	I can access TEL resources using my mobile device (i.e. mobile phone / tablet)	Internal consistency remained the same when removed, however, only correlated with Q25, another poorly performing item.	The use of mobile devices was not referred to often by FG participants. In addition, issues of accessibility were not found to be a prominent issue for students.	Removed	*Not applicable*
27	TEL resources enhance the interaction between students and teachers	Item did not correlate with any other item in the scale. Internal consistency of overall scale increased from α=.841 to α=.849 when removed.	Potentially ambiguous question. FG discussions associated with the enhancement of interaction between student and educator was vague and lacking in consensus.	Removed	*Not applicable*
21	I am often distracted (e.g. by social media / emails) when studying anatomy using TEL resources	Item did not correlate with any other item in the scale. Internal consistency increased from α=.847 to α=.871 when removed.	When issues associated with distractions while using TEL arose during discussions, students described employing mechanisms to actively prevent distractions interfering with work.	Removed	*Not applicable*

	Original Survey Item	Quantitative Findings	Qualitative Findings	Action		New Survey Item
25	I am able to use TEL resources to study anatomy whenever and wherever I want	Only correlated with Q23, another poorly performing item. Internal consistency of overall scale increased from α=.871 to α=.880 when removed.	FG participants acknowledged the benefits of flexible access to resources; however, several comments associated with the perceived need to study in specific locations (e.g. library) suggests the item may be ambiguous.	Removed		*Not applicable*
29	When choosing which TEL resource to study with, I am influenced by what my classmates are using	Continuously loaded in Factor 1 without fitting conceptually. Internal consistency of overall scale increased from α=.871 to α=.880 when removed.	Recommendations from peers was found to be an influencing factor in determining student perceptions and use of TEL, however, there were differing opinions between FG participants.	Removed		*Not applicable*
1	I find TEL resources easy to use	Internal consistency would decrease from α=.891 to α=.882 for the overall scale, and from α=.784 to α=.714 from factor 2 when removed.	The majority of FG participants found TEL resources easy to use and, cited their regular use of the internet and smart devices as the reason for this. The exception to this was with regard to 3D models, however, these were not the most prominently used resource.	Retained	1	I find TEL resources easy to use
5	TEL resources accommodate my preferred learning method	Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.784 to α=.754 from factor 2 when removed.	In FG discussions, there were several comments related to students' preferred learning method being associated with pictures, animations and listening to someone else teach the material (e.g. on YouTube).	Retained	2	TEL resources accommodate my preferred learning method
6	TEL resources are useful for studying anatomy	Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.784 to α=.754 from factor 2 when removed.	Throughout FG discussions, all participants acknowledged that TEL resources were useful to varying degrees, depending upon topic area, source of content and educator characteristics.	Retained	3	TEL resources are useful for studying anatomy

	Original Survey Item	Quantitative Findings	Qualitative Findings	Action		New Survey Item
10	TEL resources improve my ability to visualise where anatomical structures are located within the body	Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.784 to α=.735 from factor 2 when removed.	Several references during FGs regarding the need for imagery and videos to support the development of 3D understanding of the body.	Retained	4	TEL resources improve my ability to visualise where anatomical structures are located within the body
11	Studying anatomy using TEL resources is intellectually stimulating	Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.835 to α=.817 from factor 1 when removed.	FG discussions revealed students often use anatomy as 'positive procrastination' from other subjects they are required to study. With one stating the use of TEL in anatomy is *"not a horrible way to learn"* [FG1, P1].	Retained	5	Studying anatomy using TEL resources is intellectually stimulating
13	TEL resources positively affect my experience in anatomy	Internal consistency would decrease from α=.891 to α=.885 for the overall scale, and from α=.835 to α=.811 from factor 1 when removed.	FG participants felt they could learn anatomy without TEL, however, expressed concerns around how tedious, burdensome and unsatisfactory this would be.	Retained	6	TEL resources positively affect my experience in anatomy
15	I feel more confident in anatomy when I study using TEL resources	Internal consistency would decrease from α=.891 to α=.887 for the overall scale, and from α=.835 to α=.816 from factor 1 when removed.	Majority of FG participants commented they felt they would not know as much anatomy at this point in the curriculum if they had not used TEL resources to support their learning	Retained	7	I feel more confident in anatomy when I study using TEL resources
26	I am confident I know what resources are available to me and where to find them	Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.835 to α=.811 from factor 1 when removed.	FG discussions revealed there were varying degrees of confidence in relation to knowledge of resources – e.g. "VLE is a maze" and "there might be better resources out there"	Retained	8	I am confident I know what resources are available to me and where to find them

	Original Survey Item	Quantitative Findings	Qualitative Findings	Action		New Survey Item
14	I am motivated to learn when I study using TEL resources	Internal consistency would decrease from α=.891 to α=.883 for the overall scale, and from α=.835 to α=.813 from factor 1 when removed.	FG participants revealed they were motivated to learn when the resource was provided by UoL, when it looked good and if it was clear and simple to understand.	Retained	9	I am motivated to learn when I study using TEL resources
12	I do not enjoy learning anatomy using TEL resources	Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.811 to α=.751 from factor 3 when removed.	All FG participants described enjoying using anatomy TEL resources to varying degrees and for a variety of reasons	Retained	10	I do not enjoy learning anatomy using TEL resources
7	I believe TEL resources help me to learn anatomy	Internal consistency would decrease from α=.891 to α=.883 for the overall scale, and from α=.835 to α=.808 from factor 1 when removed.	All FG participants expressed a clear perception that TEL resources were helpful. Analysis revealed this was particularly related to time efficiency, therefore, item no. 16 was added to reflect this nuance.	Retained	11	I believe TEL resources help me to learn anatomy
22	I know how to strategically use the TEL resources available to me in order to perform well in my anatomy assessments	Internal consistency would increase from α=.891 to α=.893 for the overall scale, and from α=.784 to α=.787 from factor 2 when removed.	Analysis of FG data revealed that using resources strategically (e.g. region-specific resources) and using them to perform well in assessments were two separate concepts. While the original item performed well statistically, this finding resulted in the items being split into 2 new items.	Modified (split x2)	12	I vary the TEL resources I use depending on which area of anatomy I am studying
					13	TEL resources help me perform better in my anatomy assessments
2	Using TEL resources to study anatomy is frustrating	Internal consistency would decrease from α=.891 to α=.886 for the overall scale, and from α=.811 to α=.779 from factor 3 when removed.	Frustration was evidenced in comments associated with spending time searching for new resources and not being able to find resources in a timely manner. The item was modified to reflect frustration with time.	Modified	14	It is frustrating when I have to spend time searching for resources online

	Original Survey Item	Quantitative Findings	Qualitative Findings	Action		New Survey Item
4	I have the digital literacy skills to use TEL resources effectively and efficiently	Internal consistency would decrease from α=.891 to α=.884 for the overall scale, and from α=.784 to α=.729 from factor 2 when removed.	While the original item performed well quantitatively, FG participants were not immediately aware what 'digital literacy' meant. Modification to item wording required to make this concept clearer.	Modified	15	I am confident I have the digital skills to use TEL resources for learning anatomy
8	Using TEL resources to study anatomy is not an efficient use of my time	Internal consistency would decrease from α=.891 to α=.886 for the overall scale, and from α=.811 to α=.771 from factor 3 when removed.	Qual analysis revealed this to be an important concept. Participants noted the visual nature of most TEL resources allows them to understand the subject more efficiently. Re-wording of original item was undertaken to make this concept clearer.	Modified	16	I believe TEL resources help me to learn anatomy in less time than paper-based resources
9	TEL resources make my learning less efficient	Internal consistency would decrease from α=.891 to α=.889 for the overall scale, and from α=.811 to α=.748 from factor 3 when removed.	General perception that TEL is more 'efficient' than traditional resources. However, the concept 'efficiency' was mostly discussed in relation to time. The word 'effective' is distinct from time and encapsulates this item more clearly in accordance with the FG data.	Modified	17	I believe it is more effective to learn anatomy with TEL resources compared to paper-based resources
17	I use TEL resources when revising for my anatomy assessments	Internal consistency would decrease from α=.891 to α=.886 for the overall scale, and from α=.835 to α=.824 from factor 1 when removed.	It was clear in the FGs that all participants, to some degree, will use TEL for studying anatomy. The original item was therefore deemed to not be contributing anything new conceptually. However, the concept of institutional vs external resources was found to be important in relation to revision / learning. Therefore, additional survey items were required to cover this concept.	Modified (split x4)	18	I use TEL resources developed at my own university for learning anatomy
					19	I use TEL resources developed outside my own university for learning anatomy
					20	I use TEL resources developed at my own university to revise for anatomy assessments
					21	I use TEL resources developed at my own university to revise for anatomy assessments

Original Survey Item	Quantitative Findings	Qualitative Findings	Action	New Survey Item
18 I need to use TEL resources to study anatomy in order to score highly in my assessments	Internal consistency would increase from α=.891 to α=.893 for the overall scale, and from α=.835 to α=.843 from factor 1 when removed.	Analysis of FG data revealed perceived reliance on TEL was not always associated with assessment, therefore identifying this item as two concepts. With new item no.13 covering assessment, reliance on TEL was incorporated by modifying this original item.	Modified	22 I believe TEL resources are essential for learning anatomy
Not applicable	*Not applicable*	Comments from FG participants revealed that, to varying degrees, they would use their own judgement for identifying and using new resources. New item required since the pilot survey items did not cover this concept.	Added	23 When I find an anatomy TEL resource, I will definitely use it
Not applicable	*Not applicable*	Comments from FG participants revealed the educator has a significant influence on their perceptions and use of TEL resources. Original items associated with educators did not perform well quantitatively due to ambiguous wording. A new item was developed to make this concept clear.	Added	24 If my teacher recommends an anatomy TEL resource, I will definitely use it
Not applicable	*Not applicable*	Comments from FG participants revealed students rely on recommendations from their peers, sometimes more so than searching for their own resources. The original item associated with peers (no. 29) did not perform well quantitatively due to ambiguous wording. A new item was developed to make this concept clear.	Added	25 If my friends recommend an anatomy TEL resource, I will definitely use it

Original Survey Item	Quantitative Findings	Qualitative Findings	Action	New Survey Item	
Not applicable	*Not applicable*	The concept of using UoL resources to set a boundary on their learning was a commonly discussed strategy by FG participants for navigating and managing large numbers of available resources. In addition, identification of TEL resources online is, to varying degrees, guided by the resources provided by UoL. As described by participants, this is largely guided by the learning objectives set by educators.	Added	26	I will only use anatomy TEL resources that are aligned to the learning objectives
Not applicable	*Not applicable*	Resource design and aesthetics were repeatedly discussed by students as something that would influence their decision to use the resource or not. (e.g. Avoiding those with distracting colours or with lots of text).	Added	27	I prefer to use TEL resources that I find visually appealing
Not applicable	*Not applicable*	FG discussions revealed varying degrees of preference for video or animated material. Students felt this was necessary, particularly for understanding the 3-dimensional nature of structures, and suggested the dual modality made it easier to digest information.	Added	28	I prefer to use TEL resources which have audio / visual elements

FG = Focus Groups; TEL = Technology Enhanced Learning; UoL = University of Leeds

Appendix 10: Final Anatomy TEL Utility Survey

School of Medicine, Faculty of Medicine and Health

UNIVERSITY OF LEEDS

Technology Enhanced Learning (TEL) in Anatomy

Please check the boxes below if you agree with the following statements:

☐ **I agree to my data being used for research purposes**

☐ **I am happy to be contacted regarding my survey responses** (You may be selected to take part in a focus group to help us improve the resources that currently supplement your anatomy curriculum)

Student ID Number: ____________________________

Gender: Male ☐ Female ☐ Prefer not to say ☐ **Age:** ☐

The following questions are related to the technology which is available to you to supplement your anatomy learning. For the purposes of this questionnaire, these resources are described collectively as TEL Resources (Technology Enhanced Learning Resources). These resources are listed below:

- Lecture Recordings
- Lecture Slides on the VLE
- MCQs on VLE
- Dissection Videos
- Anatomy eBooks
- Anatomy MOOCs
- YouTube Videos
- Online Websites
- 3D Virtual Models (*e.g. in mobile apps or online*)

When studying anatomy, which of the following statements is true? (Please select one answer)

I only use paper-based resources (*e.g. work/text books*)	I use paper-based resources MORE than TEL resources	I use TEL resources MORE than paper-based resources	I only use TEL resources (*i.e. those listed above*)
☐	☐	☐	☐

Please think how you use TEL resources to support your anatomy learning specifically.

Below are a number of statements related to the resources listed above.
Please circle whether you agree or disagree with each statement.

Statement	Strongly Disagree		Neutral		Strongly Agree
I find TEL resources easy to use	1	2	3	4	5
TEL resources are useful for studying anatomy	1	2	3	4	5
I am confident I know what resources are available to me and where to find them	1	2	3	4	5
I am motivated to learn when I study using TEL resources	1	2	3	4	5
I do not enjoy learning anatomy using TEL resources	1	2	3	4	5
TEL resources help me perform better in my anatomy assessments	1	2	3	4	5

School of Medicine, Faculty of Medicine and Health

	Strongly Disagree		Neutral		Strongly Agree
I believe it is more effective to learn anatomy with TEL resources compared to paper-based resources	1	2	3	4	5
TEL resources improve my ability to visualise where anatomical structures are located within the body	1	2	3	4	5
TEL resources negatively affect my experience in anatomy	1	2	3	4	5
If my friends recommend an anatomy TEL resource, I will definitely use it	1	2	3	4	5
I vary the TEL resources I use depending on which area of anatomy I am studying	1	2	3	4	5
It is frustrating when I have to spend time searching for resources online	1	2	3	4	5
I use TEL resources developed at my own university to revise for anatomy assessments	1	2	3	4	5
I use TEL resources developed outside my own university to revise for anatomy assessments	1	2	3	4	5
I will only use anatomy TEL resources that are aligned to the learning objectives	1	2	3	4	5
When I find a new anatomy TEL resource, I will definitely use it	1	2	3	4	5
I am confident I have the digital skills to use TEL resources for learning anatomy	1	2	3	4	5
I prefer to use anatomy TEL resources that I find visually appealing	1	2	3	4	5
If my teacher recommends an anatomy TEL resource, I will definitely use it	1	2	3	4	5
I use TEL resources developed at my own university for learning anatomy	1	2	3	4	5
I use TEL resources developed outside my own university for learning anatomy	1	2	3	4	5
I prefer to use anatomy TEL resources which have audio / visual elements	1	2	3	4	5
TEL resources do not accommodate my preferred learning method	1	2	3	4	5
I believe TEL resources help me to learn anatomy	1	2	3	4	5
I believe TEL resources help me to learn anatomy in less time than paper-based resources	1	2	3	4	5
I believe TEL resources are essential for learning anatomy	1	2	3	4	5
Studying anatomy using TEL resources is intellectually stimulating	1	2	3	4	5
I feel more confident in anatomy when I study using TEL resources	1	2	3	4	5

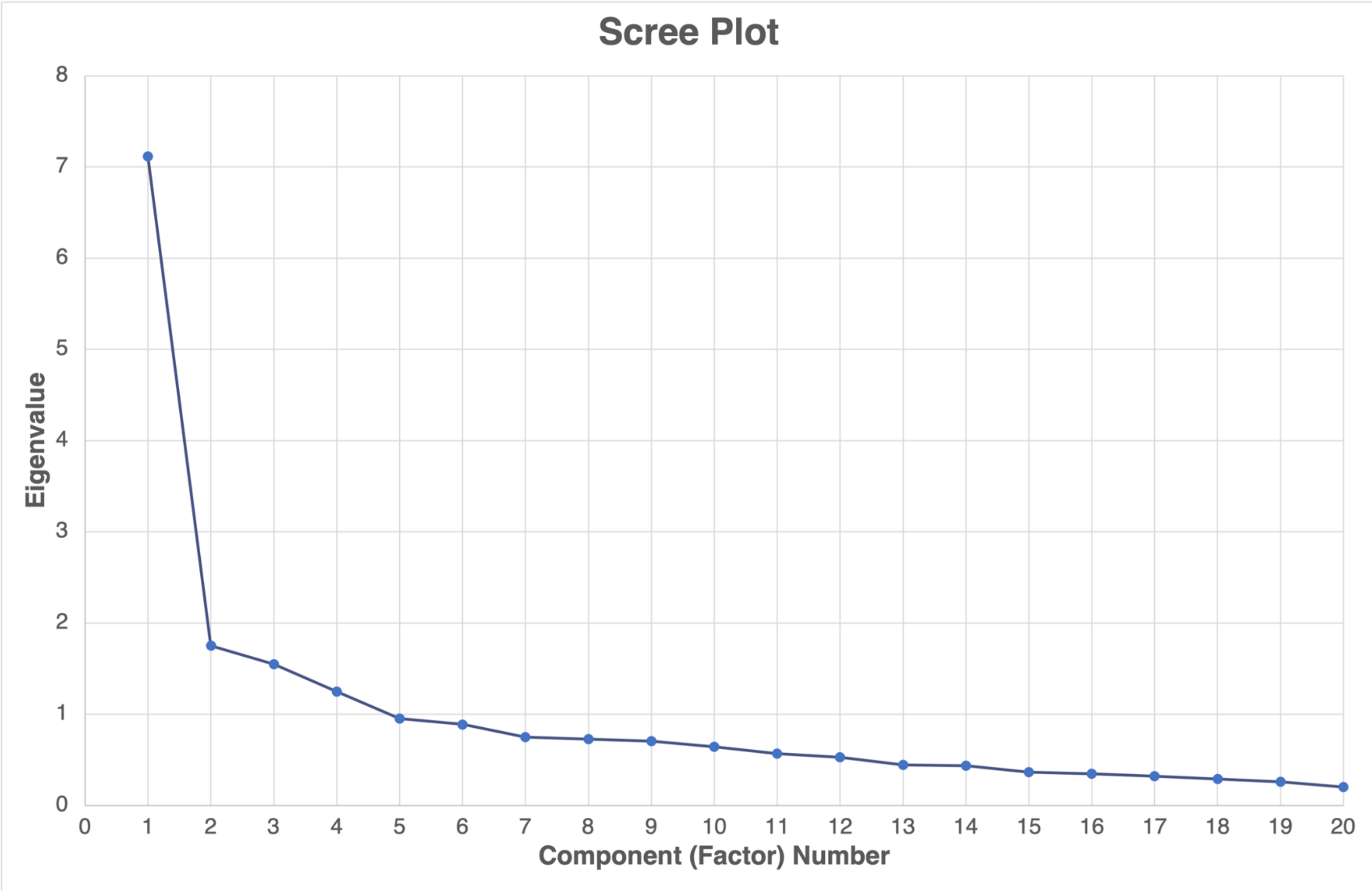
Appendix 11: Exploratory Factor Analysis (EFA) Solutions

Details of the solutions produces via EFA for the final Anatomy TEL Utility scale. The highlighted row demonstrates the most parsimonious solution, with high variance explained and conceptually sound emergent factors. In addition, the relationship between the final 23 items is demonstrated in the correlation matrix.

Total no. of items	Questions Removed	Internal Consistency (α)	KMO	No. with Eigenvalue >1	Factors Forced	Parallel Analysis	Scree plot inflection	Total Variance Explained	Internal Consistency (α) of Emerging Factors			
									1	2	3	4
28	0	0.871	0.804	8	0	4	4	66.46%	-	-	-	-
28	0	0.871	0.804	8	3	4	4	42.17%	-	-	-	-
27	19	0.878	0.817	7	3	4	4	43.59%	-	-	-	-
26	15,19	0.877	0.840	7	4	4	5	50.20%	-	-	-	-
26	19,23	0.879	0.822	6	4	5	5	51.23%	0.889	0.832	0.075	0.864
25	19,23,24	0.885	0.826	6	4	4	5	51.77%	0.889	0.743	0.196	0.656
24	15,19,23,24	0.885	0.850	6	4	4	4	52.48%	0.816	0.769	0.748	0.656
24	15,19,23,24	0.885	0.850	6	3	4	4	46.31%	0.843	0.759	0.622	-
23	15,16,19,23,24	0.886	0.860	5	4	3	4	54.31%	0.862	0.748	0.626	0.656
23	15,16,19,23,24	0.886	0.860	5	3	3	4	47.89%	0.881	0.742	0.574	-
22	3,15,16,19,23,24	0.890	0.865	5	3	2	3	49.40%	0.877	0.767	0.687	-
22	15,16,19,20,23,24	0.888	0.869	3	3	2	5	49.08%	0.860	0.785	0.660	-
21	3,15,16,19,20,23,24	0.892	0.874	3	3	2	2	50.41%	0.866	0.785	0.660	-
20	3,15,16,19,20,22,23,24	0.895	0.882	3	3	1	2	51.58%	0.866	0.785	0.606	-
20	3,15,16,19,20,22,23,24	0.895	0.882	2	2	1	2	44.08%	0.866	0.792	-	-

Highlighted iteration = most parsimonious output; KMO = Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy; Internal consistency measured using Cronbach's alpha (α); Note: measures of internal consistency were only gathered when all emerging factors had >3 items loading.

Appendix 12: Scree plot and components matrix for final survey



Scree plot for final Anatomy TEL Utility survey. Four emergent themes were identified to have an eigenvalue greater than 1 and were therefore retained.

Correlation Matrix	AA1 Easy to use	PE2 Useful	AA9 Knowledge of resources	AA12 Digital Skills	RD1 Visual Appeal	RD2 AV Elements	AA5 Preferred Method	AA10 Help Learning	AA3 Intellectually Stimulating	AA7 Negative Experience	AA2 Confidence	AA8 Motivation	AA4 Enjoy	AA11 Perform Better	PE2 External // Learning	PE1 External // Revision	PS1 Personal Influence	PS3 Teacher Influence	PS2 Peer Influence	PE4 Time Efficiency	PE5 Learning Effectiveness	RD3 Ability to visualise	AA6 TEL Essential
AA1 Easy to use	1.00	.559	.310	.437	.139	.171	.515	.476	.472	.444	.501	.436	.374	.448	.444	.350	-.061	.115	.022	.483	.366	.435	.411
PE2 Useful	.559	1.00	.140	.364	.351	.305	.395	.408	.454	.481	.419	.446	.246	.371	.496	.405	.006	.266	.037	.344	.339	.621	.267
AA9 Knowledge of resources	.310	.140	1.00	.332	-.155	-.004	.216	.095	.184	.123	.144	.163	.244	.179	.073	.080	.052	.026	-.049	.253	.050	.102	.223
AA12 Digital Skills	.437	.364	.332	1.00	.188	.119	.284	.350	.244	.279	.240	.157	.148	.365	.334	.162	-.065	.127	.043	.218	.097	.201	.185
RD1 Visual Appeal	.139	.351	-.155	.188	1.00	.479	.012	.325	.364	.343	.254	.233	.122	.240	.273	.138	.081	.225	.166	.123	.328	.338	.153
RD2 AV Elements	.171	.305	-.004	.119	.479	1.00	.051	.333	.398	.199	.300	.300	.098	.236	.203	.128	.209	.327	.388	.153	.243	.261	.204
AA5 Preferred Method	.515	.395	.216	.284	.012	.051	1.00	.352	.339	.438	.319	.417	.349	.373	.287	.192	.045	.183	.066	.391	.309	.291	.217
AA10 Help Learning	.476	.408	.095	.350	.325	.333	.352	1.00	.507	.554	.431	.375	.241	.474	.301	.268	.128	.215	.172	.301	.278	.349	.385
AA3 Intellectually Stimulating	.472	.454	.184	.244	.364	.398	.339	.507	1.00	.531	.599	.518	.311	.430	.337	.187	.208	.299	.139	.444	.410	.465	.457
AA7 Negative Experience	.444	.481	.123	.279	.343	.199	.438	.554	.531	1.00	.491	.385	.384	.394	.308	.202	-.039	.119	.021	.247	.311	.426	.312
AA2 Confidence	.501	.419	.144	.240	.254	.300	.319	.431	.599	.491	1.00	.475	.377	.426	.341	.186	.111	.093	.115	.462	.407	.449	.356

Note: items coded to emergent factor: AA = Affective attitude; PE = Perceived Effectiveness; RD = Resource Design; PS = Personal norms and Social influence

Correlation Matrix	AA1 Easy to use	PE2 Useful	AA9 Knowledge of resources	AA12 Digital Skills	RD1 Visual Appeal	RD2 AV Elements	AA5 Preferred Method	AA10 Help Learning	AA3 Intellectually Stimulating	AA7 Negative Experience	AA2 Confidence	AA8 Motivation	AA4 Enjoy	AA11 Perform Better	PE2 External // Learning	PE1 External // Revision	PS1 Personal Influence	PS3 Teacher Influence	PS2 Peer Influence	PE4 Time Efficiency	PE5 Learning Effectiveness	RD3 Ability to visualise	AA6 TEL Essential
AA8 Motivation	.436	.446	.163	.157	.233	.300	.417	.375	.518	.385	.475	1.00	.323	.317	.366	.182	.193	.253	.041	.447	.398	.402	.255
AA4 Enjoy	.374	.246	.244	.148	.122	.098	.349	.241	.311	.384	.377	.323	1.00	.181	.123	.071	.132	.080	.034	.258	.160	.231	.253
AA11 Perform Better	.448	.371	.179	.365	.240	.236	.373	.474	.430	.394	.426	.317	.181	1.00	.341	.288	.044	.187	.163	.300	.289	.400	.306
PE2 Learning	.444	.496	.073	.334	.273	.203	.287	.301	.337	.308	.341	.366	.123	.341	1.00	.712	.213	.238	.070	.398	.367	.346	.176
PE1 Revision	.350	.405	.080	.162	.138	.128	.192	.268	.187	.202	.186	.182	.071	.288	.712	1.00	.229	.273	.093	.363	.331	.341	.063
PS1 Personal Influence	-.061	.006	.052	-.065	.081	.209	.045	.128	.208	-.039	.111	.193	.132	.044	.213	.229	1.00	.381	.397	.243	.061	.048	.179
PS3 Teacher Influence	.115	.266	.026	.127	.225	.327	.183	.215	.299	.119	.093	.253	.080	.187	.238	.273	.381	1.00	.389	.251	.248	.256	.163
PS2 Peer Influence	.022	.037	-.049	.043	.166	.388	.066	.172	.139	.021	.115	.041	.034	.163	.070	.093	.397	.389	1.00	.123	.236	.205	.163
PE4 Time Efficiency	.483	.344	.253	.218	.123	.153	.391	.301	.444	.247	.462	.447	.258	.300	.398	.363	.243	.251	.123	1.00	.548	.372	.366
PE5 Learning Effectiveness	.366	.339	.050	.097	.328	.243	.309	.278	.410	.311	.407	.398	.160	.289	.367	.331	.061	.248	.236	.548	1.00	.471	.272
RD3 Ability to visualise	.435	.621	.102	.201	.338	.261	.291	.349	.465	.426	.449	.402	.231	.400	.346	.341	.048	.256	.205	.372	.471	1.00	.294
AA6 TEL Essential	.411	.267	.223	.185	.153	.204	.217	.385	.457	.312	.356	.255	.253	.306	.176	.063	.179	.163	.163	.366	.272	.294	1.00

Note: items coded to emergent factor: AA = Affective attitude; PE = Perceived Effectiveness; RD = Resource Design; PS = Personal norms and Social influence