The Role of Simulation in Sonographer Education:

A Constructivist Grounded Theory Study

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Abstract

Background

Growing demand for ultrasound services and workforce shortages adversely affect sonographer training in the workplace. This study aimed to investigate the role and scope of simulation in sonographer education, and to develop recommendations to ensure the effective use of simulation to facilitate optimal learning.

Methods

Following ethical approval, qualitative online interviews explored the views and experiences of 21 participants involved in UK sonographer education. Participant groups included national stakeholders, academic staff, and sonography students. Interviews were recorded, transcribed, and analysed using a constructivist grounded theory approach.

Findings

The study confirmed that simulation is regularly used in UK sonographer education, mainly for technical skill development. Most participants showed enthusiasm for simulation learning, but simulation was not consistently embedded in curricula. There is potential to use a greater variety of simulated learning to develop a broader range of skills, and to improve learning experiences.

The effective use of simulation is currently limited by availability of space and equipment, costs, time, and limited educator training in the use of simulation as a pedagogical tool. Educators need to be well informed and engaged to ensure learners benefit from simulation learning, yet there is a lack of specific guidance for effective implementation of simulation in sonographer education.

Conclusion

Simulation for ultrasound education is in its infancy, and there is huge potential to develop a wide variety of well-designed simulations in sonographer education. This in-depth exploration of experiences of using simulation is the first step in informing the effective design and delivery of ultrasound education. This study provides recommendations for good practice in the effective use of simulation in sonographer education.

Limitations

The study was limited to UK sonographer education, although the findings may be transferable to other settings.

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Candidate Declaration

I hereby declare that:

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree.
2. None of the material contained in the thesis has been used in any other submission for an academic award.
3. I certify that this thesis is my own work. The use of all published or other sources of material consulted have been properly and fully acknowledged.
4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy, and ethics approval has been granted for all research studies in the thesis.
5. The word count of the thesis (excluding references and appendices) is 72,148.

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List of abbreviations

3D	3 dimensional
ACP	Advanced clinical practitioner
AFC	Agenda for change
AHP	Allied Health professional
AI	Artificial Intelligence
AIUM	American Institute of Ultrasound in Medicine
AR	Augmented reality
ARDMS	American Registry for Diagnostic Medical Sonography
ARS	Audience response systems
ASA	Australasian Sonographers Association
ASAR	Australian Sonographer Accreditation Registry
ASPiH	Association for Simulated Practice in Healthcare
BCU	Birmingham City University
BMUS	British Medical Ultrasound Society
BSc	Batchelor of Science
CASE	Consortium for accreditation of sonographic education
CFWI	Centre for Workforce Intelligence
CGT	Constructivist grounded theory
CoR	College of Radiographers
COVID-19	Coronavirus Disease 2019
DASH	Debriefing Assessment for Simulation in Healthcare
DoH	Department of Health
EBCOG	European Congress in Obstetrics and Gynaecology
EFSUMB	European Federation for Ultrasound in Medicine and Biology
EPA	End point assessment
FAST	Focused Assessment with Sonography for Trauma
Gen Z	Generation Z
GMC	General Medical Council
GP	General practitioner
GT	Grounded theory
HCPC	Health and Care Professions Council
HEE	Health Education England
HEI	Higher Education Institution
HPC	Health Professions Council
ICS	Integrated care system
ID	identification
INASCL	International Nursing Association for Clinical Simulation and Learning
IP	Imposter phenomenon

IPA	Interpretative phenomenological analysis
IPL	Interprofessional learning
ISUOG	International Society of Ultrasound in Obstetrics & Gynecology
IT	Information technology
MSc	Master of Science
MSK	Musculoskeletal
NHS	National Health Service
NICE	National Institute of Clinical Excellence
NIHR	National Institute of Health Research
NMC	Nursing and Midwifery Council
OSCE	Objective structured clinical examinations
PICO	Patient Intervention Comparison and Outcome
POCUS	Point of Care Ultrasound
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
PSA	Professional Services Authority
PVRS	Public Voluntary Register of Sonographers
RCEM	Royal College of Emergency Medicine
RCOG	Royal College of Obstetricians and Gynaecologists
RCR	Royal College of Radiologists
RCT	Register of Clinical Technologists
SBE	Simulation based education
SCoR	Society and College of Radiographers
SHU	Sheffield Hallam University
SHURDA	Sheffield Hallam University Research Data Archive
SIG	Special interest group
SIM	Simulation
STP	sustainability and transformation partnerships
TEL	Technology enhanced learning
TV	Transvaginal
UK	United Kingdom
UKIO	UK Imaging and Oncology
USA	United States of America
VERT	Virtual environment for radiotherapy training
VR	Virtual Reality
WHO	World Health Organisation
WMA	World Medical Association
WRMSD	Work related musculoskeletal disorder
WRMSK	Work related musculoskeletal
WTE	Working time equivalent

Foreword

This research journey was undoubtedly influenced by my own values and my professional background as an experienced diagnostic radiographer, sonographer, and lecturer. My influence on research design, data collection and analysis were important considerations, and it was important to me that my voice and experiences were included. Therefore, a constructivist grounded theory approach was selected as an ideal structured and flexible methodological approach, as this allowed me to include my own voice and use co-construction and reflexivity throughout the research journey.

This study developed from my role as an educator, where I must ensure my approach to LTA is effective. My master's dissertation focused on the role of a specific high fidelity ultrasound task trainer in a single University setting, but this work raised more questions than answers about the effective use of simulation for sonographer education, and I still felt underinformed and ill-equipped to implement simulation learning in my LTA strategy for sonographer learners. Therefore, this study aimed to investigate the role of simulation in sonographer education by exploring how facilitate optimal learning when using simulation for sonographer education.

This qualitative study provides an in-depth exploration of the role of simulation in sonographer education in the UK. The study provides a much more comprehensive and nuanced view of sonographer education than previously published work, which is largely quantitative in nature and focuses on a range of health professionals rather than the specific needs of sonographers. Exploration of sonography student engagement and experiences revealed huge potential to develop a wide variety of well-designed simulations in sonographer education, but barriers highlighted by sonography educators and stakeholders suggest that effective simulation throughout the sonography curriculum is yet to be realised.

My research provides important insights into the role of simulation in sonographer education and makes practical recommendations for all relevant groups involved in sonographer training to improve and further develop the effective use of simulation learning for sonographers.

Chapter 1: Introduction

1.1. Medical ultrasound

Diagnostic ultrasound is a medical cross sectional and three dimensional anatomic and flow imaging modality which involves dynamic interactive processes between the sonographer, patient, and ultrasound machine equipment (Kremkau, 2016). It is a primary investigative tool in diagnostic services for many pathways, including hepatobiliary, renal, gynaecology, obstetrics, breast, vascular and many other clinical areas. Ultrasound provides a safe, reliable, non-invasive, and portable means to diagnose, monitor, and treat disease (Gibbs, Cole & Sassano, 2009) accounting for over 25% of all diagnostic imaging investigations in the United Kingdom (UK) (SCoR, 2022). Ultrasound imaging is also a valuable tool in several UK national programmes, such as the aortic aneurysm, fetal anomaly, and neonatal hip dysplasia screening programmes (UK National Screening Committee, 2020). Ultrasound imaging continues to develop as a diagnostic imaging tool and will continue to be a powerful tool in medical diagnosis (Kaprogh-Joslin, Nicola & Dogra, 2015).

1.2. The origins of the sonographer

Sonography is a complex area of clinical practice which includes a variety of applications and is overseen by multiple professional bodies. Historically in the UK, diagnostic ultrasound examinations were largely performed by radiologists or other clinicians (Baker, 2005; Hart & Dixon, 2008), however rapid growth in the demand for ultrasound led to the opportunity for others (including radiographers and midwives) to extend their roles to undertake ultrasound examinations. By the early 1980s ultrasound equipment was commercially available, enabling equipment to be used widely across disciplines resulting in a trend to decentralise ultrasound services. Demand for diagnostic ultrasound increased, however varying standards, varying quality of scans and misdiagnosis became an emerging problem due to lack of user experience and the absence of standardised high quality training programmes (Woo, n.d.).

In 1974 *Sonography* was recognised as a separate profession in the United States of America (USA); technical staff performing ultrasound examinations became known as s*onographers*, with the foundation of the American Registry of Diagnostic Medical Sonographers (Baker, 2005). Since then, the term *sonographer* is widely used, but the evolution of this role in different countries has varied. In contrast to UK practice, in regions such as Australasia, Canada and the USA, interpretation of images and reporting is primarily carried out by medical professionals (Professional Standards Authority (PSA), 2019).

In UK practice, there is a distinction between a 'sonographer' and an 'ultrasound practitioner' as defined by the Royal College of Radiologists (RCR) and the Society and College of Radiographers (SCoR) (RCR & SCoR 2014). All ultrasound practitioners perform sonography, yet not all ultrasound practitioners are sonographers (Centre for Workforce Intelligence (CFWI), 2017). An ultrasound practitioner is defined as:

> *"A healthcare professional who holds recognised qualifications in medical ultrasound and is able to competently perform ultrasound examinations falling within their personal scope of practice." (RCR & SCoR, 2014).*

This definition of an ultrasound practitioner is inclusive of all who scan and who are qualified to do so, whether registered with the General Medical Council (GMC) or not (RCR & SCoR, 2014). Ultrasound practitioners would therefore include a wide range of professionals who use ultrasound as a 'tool', even if it represents a small part of their overall activity. The professional background of ultrasound practitioners can be varied and will include radiologists, radiographers, sonographers, midwives, physiotherapists, obstetricians, physicists, and clinical scientists. The definition of a sonographer (RCR & SCoR, 2014) excludes GMC registered doctors but includes non-GMC registered doctors:

> *" A healthcare professional who undertakes and reports diagnostic, screening or interventional ultrasound examinations. They will hold qualifications equivalent to a postgraduate certificate or post graduate diploma in medical ultrasound that has been accredited by the Consortium for the Accreditation of Sonographic Education (CASE). They are either not medically qualified or hold medical qualifications but are not statutorily registered as a doctor in the UK."*

The role of a UK sonographer requires a high degree of skill and knowledge across a range of clinical applications, enabling individuals to practise with significant autonomy (PSA, 2019) and have a high degree of responsibility in the diagnostic process (CFWI, 2017). Due to high demand for clinical skills, UK sonographers have been able to dictate their employment terms and created opportunities to expand their practice (Mitchell & Nightingale, 2019). Traditionally, sonographers were registered radiographers (or other health professionals) who completed postgraduate education to work as advanced practitioners, but this is changing with the introduction of a new inclusive sonographer career framework from graduate (Agenda for Change (AfC) band 5) to consultant (AfC band 8) (Health Education England (HEE, 2022). Historically, training for graduate sonographers was resisted to attempt to protect the sonographer's position of perceived power (Mitchell & Nightingale, 2019), but in 2018, new occupational standards and new standards of education for FHEQ academic level 6 were introduced, followed by the approval of a sonography Batchelor of Science (BSc) apprenticeship standard in 2019 (Institute for Apprenticeships and Technical Education, 2019). In 2022, the first CASE approval of a BSc in medical ultrasound for the sonographer degree apprenticeship in the UK provided a new entry route into the profession for sonographer practitioners. This aligns with the new sonographer career framework (HEE, 2022) and meets the needs of the National Health Service (NHS) Long Term Plan, which aims to provide more staff (with better access to training and development) who can provide effective services to meet the growing workforce challenges expected over the next decade (NHS, 2019).

1.3. The Role of the UK Sonographer

Most ultrasound practitioners in the UK are working as autonomous practitioners at AfC band 7 (or above), underpinned by postgraduate education. Internationally there is no comparative list of ultrasound qualifications and clinical practice and education in other countries are known to vary from that in the UK (NHS Employers, 2023). Sonographers in the UK generally have a higher level of responsibility than their international peers, and most complete imaging reports autonomously (Gibbs, 2013; Harrison, 2018; SCoR, 2019).

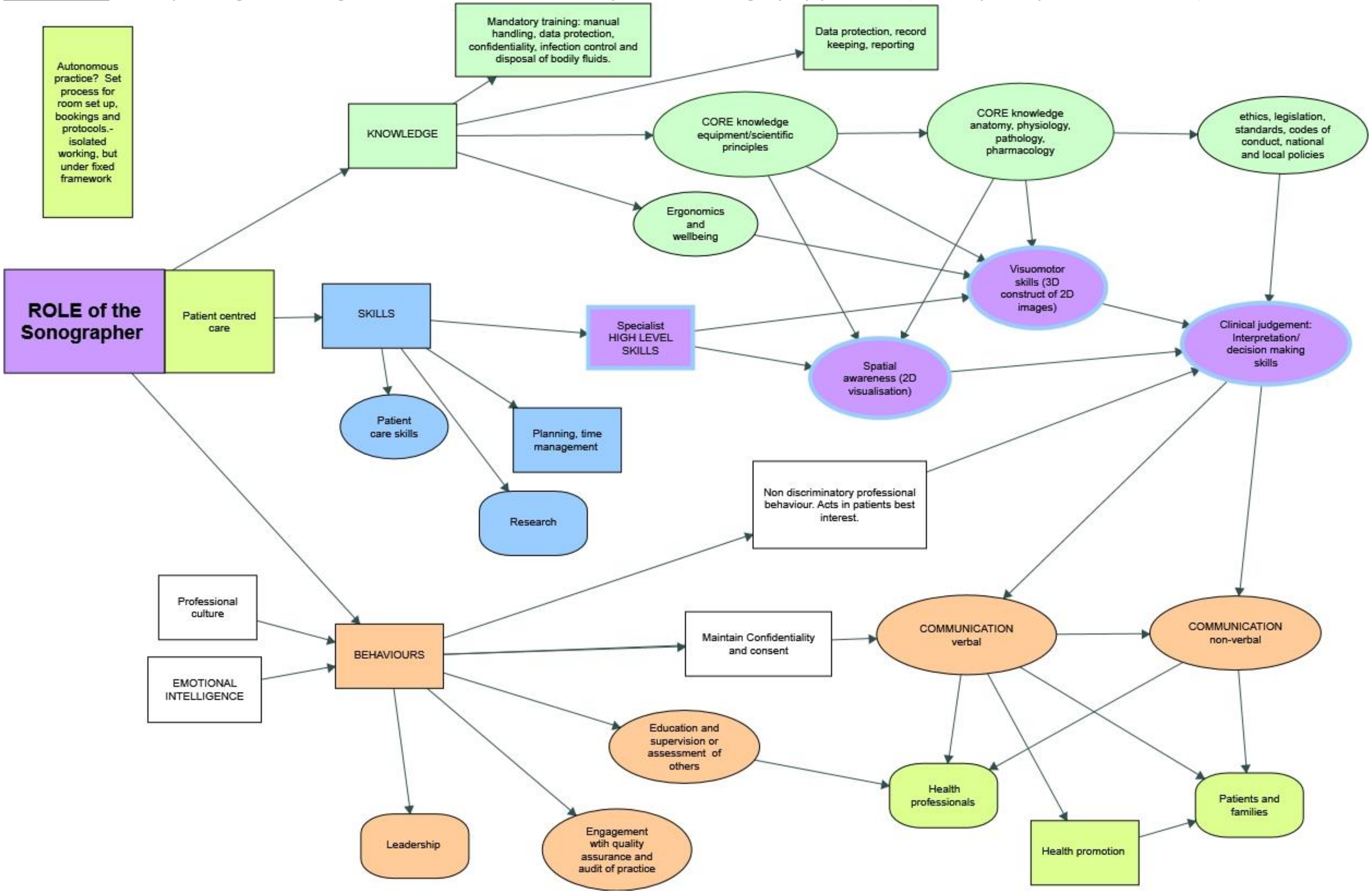
The occupational standards for sonographers defined by Skills for Health (2019) and used as part of course accreditation processes by the Consortium for Accreditation of Sonographic Education (CASE) focus largely on the clinical skills required to perform, interpret, and report on ultrasound examinations. However, the roles of sonographers vary and may extend across some or all four pillars of advanced practice as defined in the Multi-Professional Framework for Advanced Clinical Practice (Health Education England, 2017). The terms "sonographer" and "Advanced Clinical Practitioner" remain unprotected titles which are varyingly applied in both employment and educational settings. The variance in performance and skills amongst practitioners who have the same job title and different clinical roles has hindered universal acceptance and understanding of these roles in practice (Royal College of Emergency Medicine (RCEM, 2022).

Sonographers require a range of skills to provide effective diagnostic services and patient centred care. Sonographers work in a variety of areas of clinical practice, however there are key knowledge, skills and behaviours required which are summarised in Figure 1. These skills vary depending on which clinical areas sonographers practice within, and sonographers require a wide range of skills to fulfil the national occupational standard for sonographers (Skills for Health, 2019). In addition to theoretical knowledge, students in training must develop new psychomotor skills, image interpretation, decision making, clinical reasoning and communication skills.

1.4. Sonographer Registration

Sonography is not currently a regulated profession in the UK, and there are multiple workforce groups involved in ultrasound service provision (CFWI, 2017), including radiologists, sonographers, nurses, and midwives. This makes implementation of consistent professional standards, training and accreditation challenging. Many sonographers are registered with the Health and Care Professions Council (HCPC) as radiographers, or with other professional bodies such as the Nursing and Midwifery Council (NMC) for nurses and midwives (CFWI, 2017), but there is no legal requirement to hold professional registration to practice as a sonographer.

Figure 1.1 Underpinning knowledge, skills and behaviours required in sonography practice (developed by the researcher)



In the UK, the Health Professionals Council (HPC) (forerunner of current HCPC), began lobbying for regulation and registration of sonographers, and recommended regulation for sonography in 2009 (Gibbs, 2013). This was followed by a Department of Health (DoH) Command Paper (2011), which acknowledged the public protection afforded by statutory professional regulation, but identified significant costs associated with the regulatory system and the lack of workforce flexibility resulting from regulation (Gibbs, 2014). Many sonographers are regulated as professionals in their primary area of practice, but growing numbers are not, and sonography remains unregulated (Harrison, 2018; NHS Employers, 2023). Many consider that this should change, but there are still many barriers to achieving this.

The Society and College of Radiographers (SCoR) introduced a Public Voluntary Register of Sonographers (PVRS) in 2012 (Thomson & Paterson, 2014), which is now part of the voluntary Register of Clinical Technologists, but this is not a regulatory body and therefore lacks authority to investigate concern about fitness to practice of members. Some employers require sonographers to be on a statutory register such as the HCPC or NMC, but this is not universally required. The introduction of new sonography educational pathways such as full-time masters (MSc) programmes and BSc level degrees, (including an apprenticeship route) offers new routes to sonography practice, however many of these graduates are not currently eligible to join a professional register (unless they have a previous healthcare qualification which enables them to do so). There is no current statutory register for sonography graduates from these new pathways to practice.

More recently, the Professional Standards Authority (PSA) (2019) reported several inherent risks arising from sonographers' practice including misdiagnosis and misuse of ultrasound equipment and the risks associated with carrying out intimate examinations. Despite the acknowledged risks, the PSA (2019) reported that since sonographers are currently a relatively small group of practitioners (approximately 3000 in the UK), and most sonographers appear to be regulated in other professional roles, they do not support the need for a separate statutory register, as current registration in other professions already provides a level of public protection. However professional organisations such as the Society and College of Radiographers (SCoR), Royal College of Radiologists (RCR), British Medical Ultrasound Society (BMUS) and CASE, do not agree that this level of public protection is sufficient, stating that patient safety is potentially at risk from unregulated ultrasound practice. They have been campaigning for the Department for Health and Social Care to introduce sonographer statutory registration (SCoR, 2019), but despite widespread support from multiple organisations, in 2022, the then health minister said there was no immediate case to change the professional groups that are regulated. Nonetheless, this campaign continues, with lack of regulation for sonographers being raised again by the SCoR at an All-Party parliamentary group for diagnostics in Westminster in June 2023 (SoR, 2023).

1.5. Workforce Issues

Ultrasound is the second most common diagnostic imaging test performed in the UK, accounting for 10,008,955 (23%) of imaging examinations in England between March 2022 – March 2023 (NHS England, 2023). The demand for ultrasound examinations is increasing annually, however there is a longstanding workforce shortage of sonographers and radiologists, who perform most of these examinations in the NHS (CFWI, 2017; SCoR, 2021). The Society and College of Radiographers (SCoR) 2021 workforce census acknowledges the impact of the pandemic, underfunding and understaffing across all UK imaging services. The sonography workforce has experienced longstanding shortages of staff, with at least 50% of employers employing agency staff to cover sonographer vacancies since 2018 (SCoR, 2022). The existing workforce is mainly female (80%), 33% of whom are over the age of 50 years, with a large proportion working part time (CFWI, 2017). The high number of staff likely to retire in the next 10 years will further add to existing workforce pressures. The inadequate sonographer staffing levels is damaging to staff morale, planning capacity, and clinical self-efficacy (Waring, Miller, Sloane & Bolton, 2018).

The pressure on sonographers is evident when reviewing the annual number of imaging events per diagnostic radiography workforce member, with an estimated 3036 examinations per whole time equivalent (WTE), compared to only 2045 for the next most common radiological examination (x-rays, including mammography) (SCoR, 2022). Additional evidence of workforce pressures is seen in the increasing annual long term absence rates, which are recorded in 5.1% of sonographers, compared to 4.7% of diagnostic radiographers and only 1.8% in non-NHS workers during the same time (SCoR, 2022).

Sonographers are at high risk of work-related musculoskeletal injury, which in addition to the psychological stress of the role is contributing to absence rates and early retirement of experienced staff (Miller, Waring, Bolton & Sloane, 2019). A survey of 90 obstetric sonographers suggested that 88.9% of participants could be classed as having a possible psychiatric disorder such as anxiety or depression, 80% would be classed as suffering from mild (41.1%) or severe (38.9%) exhaustion (Johnson et al., 2019).

Government mandates to Health Education England have emphasised the need for a sufficient sonographer workforce to deliver healthcare (CFWI, 2017; DoH, 2012), however long-term national shortages of qualified sonographers limit available clinical placements for student training (CFWI, 2017) and negatively impact on student learning (Gibbs, 2015; Nitsche & Brost, 2013; Williams et al., 2013). The CFWI (2017) reported that for every trainee there were about seven core staff in post, and that insufficient available training staff was cited as the most likely reason that departments might not offer (or might reduce) ultrasound training posts in the future. Conversely, ultrasound departments reported that offering ultrasound training improved recruitment to qualified posts (CFWI, 2017).

Health Education England worked with partners to develop solutions aimed at addressing workforce shortages and improving education and training routes into sonography, which includes the development of a career structure, workforce reports, statutory regulation and training capacity (HEE, 2018). This led to publication of a Sonographer Career Framework in 2019, which was further updated in 2022 (HEE, 2022). However, there has been professional resistance amongst sonographers to some of these major changes to career structure and educational routes (Mitchell & Nightingale, 2018), and the complex issues of implementing the framework in practice will take time to resolve.

1.6. Sonographer professional identity and culture

Healthcare organisational professional cultures are complex and notoriously varied, varying by specialty, occupational group, professional hierarchies, and service lines (Mannion & Davies, 2018). Some staff groups may excel at articulating and enacting desirable values and practices, which may be helpful to organisational goals; others may actively undermine proposed change (Mannion & Davies, 2018). Sevens & Reeves (2018) argued that sonographers, as an occupational group, presented challenges and resistance to change as a mechanism for protecting their own roles, and that tradition and professional culture created barriers for the future development of the sonography profession.

Mitchell, Nightingale & Reeves (2019) explored the attitudes of sonographers towards clinical competences associated with a tiered career framework. Their participants expressed concerns regarding the challenges of a large-scale workforce restructure, and the existing frameworks used to define sonographer practice not being fit for purpose. Their findings were that a four-tier model of practice for sonographers was unlikely to reflect the expected level of skill across all four domains of advanced clinical practice (Mitchell, Nightingale & Reeves, 2019), however the more recently published sonographer framework produced by HEE, BMUS and the ScoR (HEE, 2022) has been influential. This framework maintains the professional identity differentiation between graduate sonographer clinical skills and advanced practice sonographer complex clinical skills and facilitates effective mapping to the Multi-Professional Framework for Advanced Clinical Practice in England (HEE, 2017).

Benefits of a new graduate entry route outlined in the HEE framework include increasing the workforce of sonographers, students training in their first-choice career, reducing the impact on other health care professions, and developing patient care and communication skills specific to the role (Parker & Harrison, 2015). Further clarification for professionals has been provided in the BMUS Preceptorship and Capability Framework (2022).

These changes have all occurred in a relatively short timescale, but they should help towards developing a more positive attitude to new educational routes and the new tiered career structure. Professional concerns are longstanding and will not change quickly, with Parker & Harrison (2015) reporting sonographer concerns that direct entry level qualifications devalued sonographers, and undermined years of hard work to improve their professional standing. Mitchell and Nightingale (2018) suggested that the longstanding workforce shortage of sonographers and increasing demand for ultrasound services, have created an imbalance which put sonographers in a perceived powerful position, and this has led to professional protectionism in this group. They noted that sonographers were reluctant to delegate to subordinates, speculating this was due to the perception that it devalued their skills and knowledge, representing a form of occupational protectionism. The higher the demand for sonographer skills, the greater the position of power to influence or resist change. To move forward, there is a need to overcome the anxiety or perceived threat to sonographer professional identity or professional status (Mitchell & Nightingale, 2019). Although considerable advances have been made in the establishment of a tiered career structure, this requires significant changes to the sonography workforce, including changes related to current professional identity, career structure and educational routes (Sevens & Reeves, 2019).

1.7. Sonographer Education

Initial sonographer education in the UK was mainly in-house training, which was superseded by the postgraduate certificate or diploma qualifications provided by multiple UK Higher Education Institutions (HEIs). Ultrasound was the commonest modality for postgraduate radiographer training for imaging staff in the NHS in 2021 (CoR, 2021), and most students were already registered health professionals, who were sponsored by their employer to study part time. Sonographer trainees require clinical training over 12-24 months, with most NHS Trusts typically training a maximum of one or two students annually.

In recent years, new educational routes have developed to address the longstanding workforce shortage. Birmingham City University (BCU) was the only UK HEI offering an undergraduate route to sonographer education until 2023, when the first BSc sonographer apprenticeship programme (Institute for Apprenticeships and Technical Education, 2019) was launched by Sheffield Hallam University (SHU). Two direct entry full time MSc programmes are offered at University of Derby and University of Cumbria, providing students with clinical placements to learn new clinical skills, but limited clinical placement availability remains a challenge (Harrison, 2018). The small numbers of graduating students from new programmes have not yet impacted significantly on workforce deficits.

Most sonographers in the UK are currently registered with the HCPC and NMC as radiographers, nurses or midwives, and the national register of sonographers is currently voluntary (Harrison & Beardmore, 2020), so it is important to note that graduates from any existing BSc route cannot apply for professional registration, as sonographer is not a recognised registered protected title. NHS Employers (2023) suggests that stipulating registration with a regulatory body, when in some cases this does not exist is not advisable, since it may reduce the number of applicants in a specialty recognised as a shortage occupation by the UK Government Migrations Advisory Committee. Many NHS Trusts already employ sonographers without HCPC registration, but BSc graduates may struggle to gain employment in some organisations. However, BSc graduates are eligible to apply for registration via the Register of Clinical Technologists (RCT), an accredited register (AR) managed by the Professional Standards Authority (PSA), which sets the same level of standards for practitioners working in unregulated health and care occupations as those on statutory regulated professions (PSA, 2022).

The COVID-19 pandemic had a huge impact on the availability and accessibility of clinical training for health care professionals, and alongside longstanding high vacancy rates across imaging services and rising demand for imaging examinations, has put extreme pressure on services (College of Radiographers, 2021). The NHS Long Term Workforce Plan (2023) identified priorities of increasing training, retaining staff, alongside ongoing work to reduce the COVID-19 backlog for elective services. Although education and training within the NHS has grown by 25% overall since 2010, the number of staff trained has not kept pace with demand for NHS services. To fill service gaps and ensure safe staffing levels, the NHS is reliant on temporary staffing and international recruitment; the shortfall in staff is predicted to increase significantly for diagnostic radiographers by 2036/37 (NHS, 2023).

Ultrasound educators can apply for accreditation for their UK courses from the Consortium for the Accreditation of Sonographic Education (CASE), which is made up of several member organisations who oversee quality of education (Harrison, 2018). However, due to the lack of professional registration, there is no statutory requirement for courses to hold accreditation, and the standards of education and training may vary considerably for non-accredited institutions. Until recently, CASE only accredited postgraduate programmes and short courses, however their guidance in 2018 acknowledged that a long-term, sustainable source of future sonographers should include direct entry to programmes including undergraduate BSc and Apprenticeship programmes (CASE, 2018), with the first CASE accreditation of a BSc medical ultrasound degree apprenticeship granted to Sheffield Hallam University in March 2023. Prior to this, there was only one HEI offering a BSc Sonography degree, but the available educational routes are growing, with more HEIs now likely to validate BSc Level programmes to meet the needs of the sonographer career framework.

Regardless of the education pathway, critical thinking, problem solving, and communication are essential skills that students should acquire during their training alongside domain-specific knowledge and skills to be able to make professional decisions and implement solutions (Chernikova et al., 2020).

1.8. External influences

Advancements in information technology, science, and diagnostics have helped improve healthcare delivery and outcomes around the world, yet human decision-making remains one of the core components of the system (Malcom, Pate & Rowe, 2020). The most complex machines require people to operate, maintain, and interpret results gained from using them, so despite increased budgets and improvements in technology, medical errors and patient safety remain critical problems (Malcom, Pate & Rowe, 2020).

Alongside the ongoing developments in sonographer career frameworks and education, there are also national changes within the structures and management of the health service more generally. In 2016 NHS organisations and local councils formed sustainability and transformation partnerships (STPs) across England (NHS, 2019), with the aim of improving health and care. These partnerships have evolved into integrated care systems (ICS), where NHS organisations, local councils and others take collective responsibility for managing services, resources and delivering high standard health care to their populations (NHS England, 2019). The ICS organisations manage their own operations and finances, and this in turn may impact on the funding and requirements for health professional education regionally. The Transforming Imaging Services Strategy for England (NHS, 2019) established imaging networks across England to meet service demands for diagnostic imaging services, and several imaging training academies have been established regionally to contribute to education for those in diagnostic imaging services (HEE, 2022), but these are not specifically for sonographer training.

Despite these developments, the increasing demand for ultrasound services and longstanding workforce shortages mean that is extremely difficult to train enough sonographers without negatively impacting on pressurised clinical staff. There is an identified need for sustained investment in infrastructure, alongside reforming education funding and strengthening social care provision to meet the workforce needs of the NHS, but training expansion and workforce growth are only possible if there is sufficient physical capacity for staff to be trained, as well as investment in technology and digital innovation and technology enhanced learning (NHS, 2023).

1.9. Sonography and simulation

The knowledge, skills and behaviours required by sonographers are extensive and complex. Longstanding workforce shortages have resulted in a lack of training capacity restricting opportunities to develop new career framework (Harrison & Beardmore, 2020). In order to address these shortages, expansion of the number of trainees is essential, but this requires alternative approaches to clinical education (HEE, 2020). Simulation is one approach which may have potential to assist in development of the full range of skills required by sonographers in practice. Simulation is a broad term and can refer to a wide range of teaching methods (Shiner, 2018) with the potential to be a powerful educational resource. Technological advances have led to the availability of several complex task trainers for ultrasound education, which alongside other methods of simulation could provide opportunities for sonographer training. However, there is currently limited evidence to ensure this is implemented effectively, which led to the following literature review research question:

"What is the role of simulation in sonographer education?"

The next chapter will explore this question and present justification and rationale for this research, including refining of research question(s), aims and objectives.

Chapter 2: Literature review

This chapter presents the findings of a systematic search and scoping review of the role of simulation in sonographer education. The chapter outlines the search strategy applied, and presents the key themes identified.

Grounded theory does not begin with a hypothesis to prove or disprove (Urquhart, 2023). The timing of the literature review in grounded theory studies is a matter of debate amongst researchers, and this controversy is a cause for some confusion for novice researchers (McGhee, Marland, & Atkinson, 2007). Initially in the development of Grounded Theory, Strauss advocated that initial reading was essential to set the context of the research, however Glaser later recommended that it should occur after data collection to avoid influencing the researcher (Glaser, 1992; Heath & Cowley, 2004; Thistoll, Hooper & Pauleen, 2016) or impose preconceived ideas during theory development (Urquhart, 2023).

As the discipline of grounded theory developed, further advocates for initial literature review emerged, including Charmaz (2014) and Strauss and Corbin (1998). A grounded theory approach is not linear, with data collection, analysis and theorizing occurring in parallel (McGhee, Marland & Atkinson, 2007). The researcher's skill and ability to be able to conceptualize concepts and develop theory from the data is dependent in part on prior knowledge gained from reading widely (Thistoll, Hooper & Pauleen, 2016), but it is impossible to know prior to a grounded theory study what concepts will emerge from the data, or what their relevance to the research might be (Corbin & Strauss, 2015).

It is widely accepted that a pre-study literature must be completed to help the researcher to identify the issue (Urquhart, 2023), which aligns with Dey (2003), who said that researchers should have an open mind, but not an empty head. Therefore, a non-committal literature review is initially useful, but the relevance of the literature is determined by the emergent theory during data analysis (Urquhart, 2023) and the literature is revisited and extended later in the research process. Therefore, a preliminary literature search was conducted to meet the initial research aims to use a grounded theory approach to investigate the role of simulation in sonographer education. A systematic search and narrative literature review was completed to evaluate existing work regarding simulation in sonography education and identify any gaps in the knowledge base. This initial search set the context for the research development and provided a source of ideas and critical reflections (Wertz et al., 2011). Alerts were set up on included databases to indicate any new relevant material during the research process.

The initial literature review (completed in 2018) enabled the researcher to develop theoretical sensitivity and identify the problem to inform the development of the research question, aims and objectives (Urquhart, 2023), and to support ethical approval applications. The initial search was repeated following data collection and, in line with a constructivist grounded theory approach, additional literature searching was completed to support emerging theory throughout the research process (Charmaz, 2014; Thistoll, Hooper & Pauleen, 2016). This is a widely accepted approach in grounded theory methodologies to ensure that the researcher was not imposing existing theories or knowledge onto the study outcomes (Birks & Mills, 2015), and the process allowed for crosschecking to ensure validity through oversight by the supervisory team.

This scoping review was underpinned by a systematic search strategy, with the findings discussed within narrative themes. Detailed findings extracted from initial search results were combined with additional policy and professional references. Researchers may conduct a scoping review over a systematic review when they seek to identify knowledge gaps, scope a body of literature, or clarify concepts (Grant & Booth, 2009; Munn et al., 2018). Scoping reviews are a useful tool for evidence synthesis to identify knowledge gaps, or where it is unclear what specific questions might be posed or addressed by a more precise systematic review. Although conducted for different purposes compared to systematic reviews, scoping reviews employ rigorous and transparent methods to ensure results are trustworthy (Munn et al., 2018).

2.1. Search Strategy

The initial research question was developed using a PICO analysis (Williams, Wilford, & Cutler, 2014), which is summarised in Table 2.1.

Table 2.1: PICO analysis

Population	Sonography educators, graduates, and trainees
Intervention	Use of simulation in sonography education
Comparison	Traditional clinical education
Outcomes	Clinical skill acquisition. Improved learning experience Student confidence and competence in clinical skills. Research informed teaching using simulation for sonography education

The initial search strategy used a range of terms and derivatives, with the main groups of search terms summarised in Table 2.2. Inclusion and exclusion criteria are outlined in Table 2.3.

Table 2.2: Search terms and derivatives

Group	**Terms/variations**
sonography	ultrasonography, sonographer, ultrasound technician, ultrasound technologist
Education	learning, pedagogy, education, training, teaching, simulation
ultrasound	ultrasound, sonography, sonography, ultrasonography
Simulation	simulation, simulator, simulated learning, training

Table 2.3: Inclusion and exclusion criteria

Inclusion criteria	Justification	Exclusion criteria
Published in the last 10 years	Modern ultrasound simulators only introduced in recent decades.	Published more than 10 years ago
Peer reviewed articles	To ensure high standards of research maintained	Non-peer reviewed sources
Studies on sonographers, allied health professionals, nurses, midwives, doctors.	Search included only those groups who can perform similar roles in performing and interpreting examinations in ultrasound practice.	FAST and POCUS ultrasound examinations
English language	Accessibility	Lack of interpreter services

2.2. Databases selected

A wide range of sources were used to ensure that anything relevant to the research topic was initially identified. Key databases and sources searched are summarised in Table 2.4.

2.3. Sorting of results

Search results for this narrative review were exported to Covidence software for sorting and further evaluation. Duplicates and any sources which did not conform to the required inclusion and exclusion criteria were removed. Following title and abstract screening, 207 full text articles were reviewed, with 13 selected for inclusion in the narrative analysis. A summary of the search results can be found in Table 2.5 and Figure 2.1 below.

Table 2.4: Key databases searched

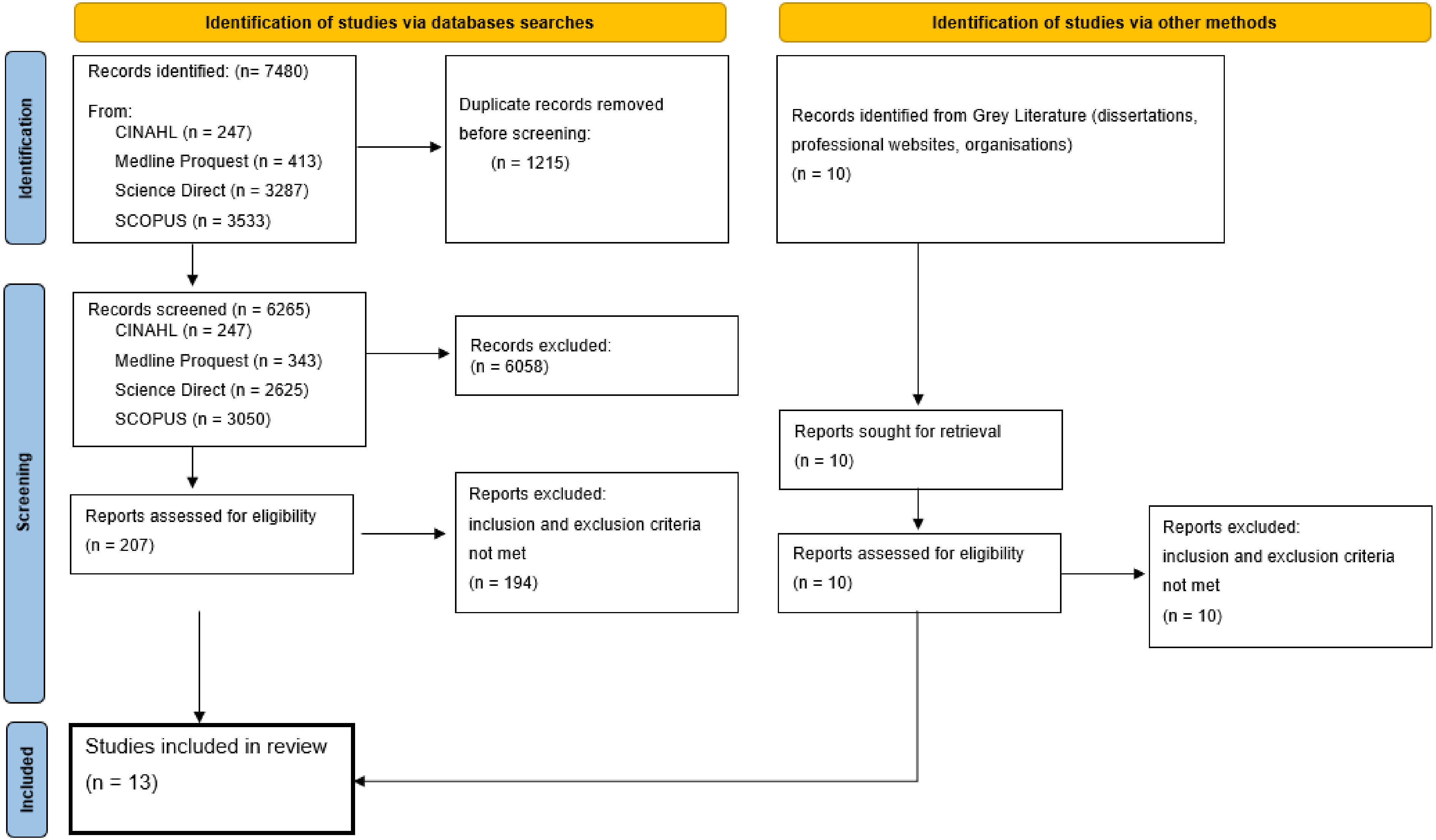
Database	Justification for selection
Science Direct	Articles from over 1000 journals
Medline (PubMed)	Database of over 18 million citations
CINAHL Plus	Articles from over 3200 journals relevant to nursing and allied health. CINAHL includes some materials that are not indexed in other databases.
SCOPUS	Elsevier's database includes a wide variety of peer reviewed journals in health sciences.
Proquest Central	Dissertations and Thesis (unpublished research)
Google Scholar	Relevant electronic book extracts or unpublished research, dissertations, or theses.
Grey literature	Hand search of ultrasound and radiography journals and professional organisation websites for professional guidelines and recommendations for education and practice.
Professional organisation websites	Relevant professional body and advisory websites included searches for appropriate professional guidelines included organisations, such as: BMUS; CASE; SCoR; RCR; Royal College of Obstetricians and Gynaecologists (RCOG); National Institute of Clinical Excellence (NICE); American Institute of Ultrasound in Medicine (AIUM); Australasian Sonographers Association (ASA); NHS; HEE.

Table 2.5: Summary of selected articles (Initial literature review completed 2018)

No.	Year	Authors	Title	Journal details
1	2013	Burden, C., Preshaw, J., White, P., Draycott, T. J., Grant, S., & Fox, R.	Usability of virtual-reality simulation training in obstetric ultrasonography: A prospective cohort study.	*Ultrasound in Obstetrics and Gynecology,* *42*(2), 213-217.
2	2020	Chernikova, O., Heitzmann, N., Stadler, M., Holzberger, D., Seidel, T., & Fischer, F.	Simulation-Based Learning in Higher Education: A Meta-Analysis.	*Review of Educational Research,* *90*(4), 499-541.
3	2016	Chalouhi, GE., Bernardi, V., Gueneuc, A., Houssin, I., Stirnemann, JJ., & Ville, Y.	Evaluation of trainees' ability to perform obstetrical ultrasound using simulation: challenges and opportunities.	*American Journal of Obstetrics and Gynecology, 214*(4), 525.e-525.e8.
4	2015	Gibbs, V.	The role of ultrasound simulators in education: an investigation into sonography student experiences and clinical mentor perceptions.	*Ultrasound,* *23*, 204-211
5	2014	Gibbs, V.	An investigation into sonography student experiences of simulation teaching and learning in the acquisition of clinical skills.	*Ultrasound,* *22*(3), 173-178.
6	2013	Gibbs, V., & Griffiths, M.	Funding and commissioning issues for undergraduate and postgraduate healthcare education.	*Imaging and Oncology,* 56-61.
7	2012	Sidhu, H. S., Olubaniyi, BO., Bhatnagar, G., Shuen, V., & Dubbins, P.	Role of Simulation-Based Education in Ultrasound Practice Training.	*Journal of Ultrasound in Medicine,* *31*(5), 785-791.
8	2008	Laschinger, S., Medves, J., Pulling, C., McGraw, D. R., Waytuck, B., Harrison, MB., & Gambeta, K.	Effectiveness of simulation on health profession students' knowledge, skills, confidence and satisfaction.	*International Journal of Evidence-Based Healthcare, 6*(3), 278-302.

9	2013	Williams, C. J., Edie, J. C., Flinton, D. M., & Harrison, G.	Transvaginal Ultrasound Simulation and its Effect on Trainee Confidence Levels: A Replacement for Initial Clinical Training?	*Ultrasound,* *21*(2), 50-56.
10	2013	Nitsche, Joshua F., MD, PhD, & Brost, B. C., MD.	Obstetric ultrasound simulation.	*Seminars in Perinatology, 37*(3), 199-204.
11	2014	Tolsgaard, M. G., Rasmussen, B., Tappert, C., Sundler, M., Sorensen, J. L., Ottensen, B., Ringsted, C., & Tabor, A.	Which factors are associated with trainees' confidence in performing obstetric and gynaecological ultrasound examinations?	*Ultrasound in Obstetrics & Gynecology,* *43*(4), 444–451.
12	2015	Tolsgaard, M. G., Ringsted, C., Driesler, E., Norgaard, L. N., Petersen, J. H., Madsen, M. E., Freiesleben, N. L. C., Sorenson, J. L., & Tabor, A.	Sustained Effect of Simulation-Based Ultrasound Training on Clinical Performance: A Randomized Trial.	*Ultrasound in Obstetrics and Gynaecology, 46*(3), 312-318.
13	2015	Ahmad, R., Alhashmi, G., Ajlan, A., & Eldeek, B. (2015).	Impact of High-Fidelity Transvaginal Ultrasound Simulation for Radiology on Residents' Performance and Satisfaction	*Academic Radiology, 22*(2), 234-239.

Figure 2.1 : PRISMA 2020 (Page et al., 2020)



The categories and subcategories identified from the literature search are summarised in table 2.6 below. The findings of the literature review will be discussed in the next section using these subcategories, with additional consideration of professional and policy literature where appropriate.

Table 2.6: Categories emerging from the literature review

Categories	**Subcategories**
Education	Origins of simulation in healthcare education
	Simulation in modern healthcare education
	Simulation realism and meaningfulness
	Ultrasound education
	Training sonographers
Simulation in ultrasound education	Simulation in ultrasound education
	Ethical considerations
	Self-led versus tutor led learning
	Simulation and assessment
	Cost effectiveness of simulation training
	Benefits of simulation in ultrasound education
	Limitations of simulation
	Student perceptions and confidence
Clinical skills	Educational theories
	Clinical skill acquisition and Competence
	Psychomotor skill development

2.4. Education

2.4.1. Educational theories

Simulation is recognised as an innovative pedagogic approach and is increasingly used in healthcare education due to a number of factors (HEE, 2020; NHS England, 2024). Shiner (2018) reported that simulation is widely accepted as a valued pedagogical approach in radiography education, with a variety of modalities and interventions used for different purposes. This fits with the concept of relevance in education, which can be traced to the work by John Dewey (1859 - 1952), who believed that it was essential for education to be embedded in ordinary life experiences (Mellanby & Theobald, 2014). Historically, different aspects of learning have been investigated by different groups of psychologists, with many theories emerging from their work (Mellanby & Theobald, 2014). Educational practices in modern universities vary considerably and are based on diverse and sometimes conflicting educational theories (Mellanby & Theobald, 2014).

The seminal work of Patricia Benner "From Novice to Expert" in 1984 proposed a model of skill acquisition in nursing which has been widely used in healthcare education. Benner (1984) identified five levels of experience, from novice to expert, which relate to skill acquisition and development of intuition as practitioners gain more experience in practice. Benner argued that intuitive decision making is a hallmark of expert practitioners and is linked to analytical reasoning – both of which are essential skills for reporting sonographers. Benner adapted the Dreyfus model of skill acquisition developed with pilots to consider career development and progression in nursing (Altmann, 2007). The concept of differentiation between theoretical and practical knowledge is important (Altmann, 2007); what can be taught by precept, and what must be learned through experience is key to the theory. Intuition cannot simply be taught, but results from a variety of learning, experiences, individual contexts, and previously experienced patterns (Benner, 1984). Clinical experiences impact on individuals' development and change perceptions, but these interactions are often too complex to be exemplified through simulations. Consideration of prior knowledge, preconceptions and levels of understanding are important, but experience is essential in the development of expertise (Altmann, 2007). In sonographer education, scanning skills must be learned through repeated, deliberate practice, which aligns with theories from Benner (1984), that intuition can be developed subconsciously and/or purposively through education and extensive, deliberate practice.

Educational theories informing simulation-based healthcare education align with different ways of understanding learning (Bearman, Nestel & McNaughton, 2018), and due to the variety within simulation-based education, a selection of learning theories must be considered (Nestel & Bearman, 2015). Adult learners are expected to be self-directed, intrinsically motivated and to have prior experience to draw upon (Knowles, 1984; Kolb, 2015), but educators in sonography should help individuals meet objectives that are relevant to practice, usable, and motivating (Zigmont et al., 2011). Kolb and Kolb's (2006) theories of experiential learning theory in higher education includes concepts that learning is a holistic process which requires opportunities for reflection and action, and involves feelings, thoughts, perceptions, and behaviours. Simulation learning can provide ideal opportunities for learning to support the development of safe and effective practice through both reflective observation and active experimentation (Becker & Hermosura, 2019).

Other key theories relevant to healthcare education include behaviourism, constructivism, and critical theory. Behaviourism was initially understood as a reaction to a stimulus; current understanding is explained as achieving a standard through demonstrated behaviours, where learning occurs through repetitive practice (Montero, 2022). Bearman, Nestel & McNaughton (2018) proposed that this would be useful for practices which learners needed to perform automatically (without complex thought processes). Potential applications in ultrasound education where repetitive behaviours are required would include:

- Learning of psychomotor skills required for scanning
- Pattern recognition of normal ultrasound appearances
- Communication skills (such as always introducing themselves)

Constructivism refers to a variety of theories relating to individual and social constructions of knowledge, which argue that individuals construct their learning based on experience and ideas (Bachtold, 2013). Cognitive constructivism acknowledges individual characteristics of learners, including stage of development, engagement, motivation and learning preferences. Constructivist teaching requires much conversation and dialogue between educators and learners, and the educators' role is to guide learning activities to support learners to build on their existing knowledge and experience (Bearman, Nestel & McNaughton, 2018). Within this theoretical framework, educators may be seen to facilitate learning for participants, rather than simply teaching their own views. These theories might be applied to ultrasound education when teaching communication skills.

Social constructivism focuses more on how understanding emerges from social encounters (Bachtold, 2013). Educators with a constructivist approach may use various educational techniques, which might include finding out about existing experiences and knowledge of students and encouraging students to set performance goals (Bearman, Nestel & McNaughton, 2018). This approach has many possible applications in ultrasound application, through demonstrating, talking through tasks, or providing opportunities for students to perform tasks on a simulator.

Kneebone & Nestel (2015) highlighted the need for repetition to improve performance, so a scaffolded approach helps students in learning individual components of the skill, then building on this to develop expertise. Schon (1991) wrote widely in health educational literature on the concepts of "reflection-in-action" and "reflection-on-action”, which differentiates between immediate response and later analysis of actions taken by professionals. Techniques in simulation education such as "pause and discuss" cannot be performed in a real clinical environment, however simulation allows a scenario to be stopped at certain points to allow learners to evaluate their thoughts and feelings, and to assess their existing knowledge. The benefit of this simulation method is that there is no risk to patients. Opportunities for students to observe each other and encouraging open discussion, peer feedback in addition to simulator and tutor feedback can help students to reflect on their strengths and weaknesses.

Critical theory in education is concerned with an outward focus on society (Thompson, 2017) which explores learning processes and how we produce knowledge (Bearman, Nestel & McNaughton, 2018). This approach tasks educators to challenge assumptions and has not been as prominent as others in simulation-based education. An example of this method would be the use of a simulated patient (actor), who then acts in a created scenario for education based on real stories to help trainees to develop their professional values, clinical knowledge, and skills (Bearman, Nestel & McNaughton, 2018). If the patient scenario is co-designed by consumers (patients), then this can provide a depth of understanding of both social and clinical aspects of patient care, which may influence professional values and attitudes in clinical practice (Bearman, Nestel & McNaughton, 2018). Students all have their own learning style, and modern ultrasound simulators can provide opportunities for these to be taken into consideration (Gibbs, 2014). Experiential learning, where students actively engage in the learning process, is recognised as an effective learning environment (Parsh, 2010), and simulation learning provides this as students are required to be active in their own learning process.

2.4.2. Origins of simulation in healthcare education

The term 'simulation' is defined as *'a technique to replace or amplify real experiences with guided experiences, often immersive in nature, that evoke or replicate substantial aspects of the real world in a fully safe, instructive and interactive fashion'* (HEE, 2020). Simulation is an artificial representation of a real-world scenario that supports student development through experiential learning with the opportunity for repetition, feedback, evaluation, and reflection (NMC, 2018). As such, the term is deliberately broad and intended to include a wide spectrum of modalities, inclusive of immersive learning technologies.

Some authors report that the use of simulator learning began in aviation and military training, yet it has been used within modern healthcare education for many years (Harder, 2009; Jones, Passos-Neto & Braghiroli, 2015). Indeed, simulation in healthcare education has been in use for at least 1500 years, and from the 18th century was widely used to help medical students learn new skills before performing procedures on patients (Owen, 2017).

Simulation was often used to facilitate learning to reduce risk for patients, or sometimes to facilitate learning for rare or inaccessible conditions. Some early simulators were task trainers, and others were developed for immersive training, where learners could practice management of rare conditions and serious compilations (Owen, 2017). In some areas of healthcare, such as childbirth, interventions were rarely required, leading 18th century educators to realise that their students encountered few complications during their training so were ill-prepared for emergencies. This led to the development of simulators for teaching the use of forceps in obstetric deliveries, with the first obstetric teaching hospital in London advertising the use of simulators as part of their clinical teaching courses in 1740 (Manningham, 1740; Owen, 2017). The use of simulation in the 19th century was not always in line with modern ethical standards. Initially the use of female cadavers as obstetric simulators was commonplace in Europe and USA, but at the time infection transmission was poorly understood and the practice resulted in many avoidable deaths through transmission of puerperal fever (Owen, 2017). Further historical examples of unethical practice are documented where an obstetrician called Osiander used living patients for teaching, using forceps more often than was clinically indicated (Owen, 2017).

With new discoveries such as anaesthesia in 1846, techniques such as bronchoscopy led to the further development of simulation, with simulators, manikins or phantoms and even live animals used to develop clinical skills (Owen, 2017). By the early 20th century, obstetric simulation was included in USA medical curricula.

2.4.3. Simulation in modern healthcare education

Simulation learning attempted to reduce harm to patients 250 years ago, and this concept is still valid in modern times, with the Chief Medical Officer (UK) in 2009 recommending that simulation should be a top priority of the health service, as it offers a route to safer care for patients (Donaldson, 2009). Current guidelines from the Association for Simulated Practice in Healthcare (ASPiH) (2023) use the term *"simulated practice"* to refer to the complete array of structured activities that represent actual or potential situations in education and practice, which allow participants to develop or enhance their knowledge, skills, and attitudes, or to analyse and respond to realistic situations in a simulated environment. Simulation learning allows healthcare students to practice a procedure or skill in a safe learning environment before treating patients. These training environments use different scenarios (e.g., role play or actors), or simulators (equipment) designed to provide a realistic imitation of a complex task. Simulation learning was advocated more than a decade ago by the Department of Health (DoH) for developing the healthcare workforce (DoH, 2011; DoH, 2012).

The NHS Framework for Technology Enhanced Learning (DoH, 2011) set out general principles for using technology in healthcare education, including the principles that technology:

- should be patient centred and service driven
- is educationally coherent
- delivers value for money
- is innovative and evidence based
- delivers high-quality educational outcomes

- ensures equity of access and equity of provision

UK government initiatives linked with patient-centred care and service efficiency, highlight the need for health care professionals to be equipped with appropriate knowledge and skills to deliver an efficient, high-quality service (Gibbs, 2015). In 2009, the Chief Medical Officer emphasised the potential for simulation to reform health care education (Donaldson, 2009), and although many education programmes incorporate simulation learning in various forms, inclusion of simulation learning in a curriculum does not guarantee a quality learning experience.

As health and care services develop and demand grows, new ways of learning and supporting a culture of improvement in patient centred care are key to addressing the ongoing changes within the NHS. Digital transformation and the use of simulation and immersive technologies remains a priority in a range of areas including workforce development, patient safety, enhancing the quality and capacity of the learning environment, service used involvement, developing simulation and immersive technology community, research, innovation and learning lessons from outside of health and care (HEE, 2020). Since real-life situations do not always provide sufficient or predictable practice opportunities (for example, critical situations appear less frequently), this can make learning inaccessible or suboptimal in healthcare education (Chernikova et al., 2020).

Types of healthcare simulation vary widely and can be classified into five major groups (Jones, Passos-Neto & Braghiroli, 2015).

1. Low-technology models or mannequins (phantoms) used to teach basic knowledge or specific psychomotor skills.
2. Screen-based computer simulators: software for training and assessment of clinical knowledge and decision making.
3. Standardized patients: actors trained to behave as patients, which enables training and assessment of history taking, physical examination, communication skills, and professionalism.
4. Complex task trainers: high fidelity computer-based simulators used for skills training.
5. Patient simulators: computer-based mannequins used for high-fidelity replication of complex and high-risk clinical conditions in lifelike settings.

The capabilities of simulation and immersive learning technologies is rapidly developing to meet predicted future requirements of health and care services. Simulation could support delivery of the patient safety strategy and syllabus and optimises how the workforce can deliver high quality, safe care and promote improvement throughout the health and care system. A higher number of simulations may not necessarily result in superior learning (Brown & Chronister, 2009), and there is a recognised need for system-wide sharing and collaboration amongst different healthcare and education stakeholders (HEE, 2020). The diverse spectrum of techniques, technologies and tools included within simulation learning can be overwhelming, and there is a lack of specific guidance available on how to best to utilise simulation within training programmes (Baillie & Curzo, 2009; Gibbs, 2015).

Modern medicine expects optimal safe patient centred care, which means that learning new clinical skills on real patients may not be acceptable to patients and is subject to ethical and legal considerations (Datta, Upadhayay & Jaideep, 2012). Simulation based activities can allow learners to develop clinical skills through repetitive practice in a safe environment (Sidhu et al., 2012), and may also provide possible opportunities for assessment of learner performance (Datta, Upadhayay & Jaideep, 2012).

Simulation-based learning offers learning with approximation of practice, allowing limitations of learning in real-life situations to be overcome. This can help achieve key outcomes for patients, the workforce and the health and care system (HEE, 2020). A variety of sources agree that simulation learning can be effective for advancing specific motor and technical skills, but the support required to allow learners with different levels of prior knowledge to acquire a variety of complex skills is relatively unexplored (Chernikova et al., 2020).

Simulation is an artificial representation of some real process or task which can provide focused learning experiences which aim to improve patient safety and help trainees to achieve competence to practice (Francis, 2013; Sidhu et al., 2012), but it is important to note that high levels of realism may not result in high levels of meaningfulness for learners, and vice versa (Nestel, Krogh & Kolbe, 2018). This will be explored in the next section.

2.4.4. Simulation Realism and meaningfulness

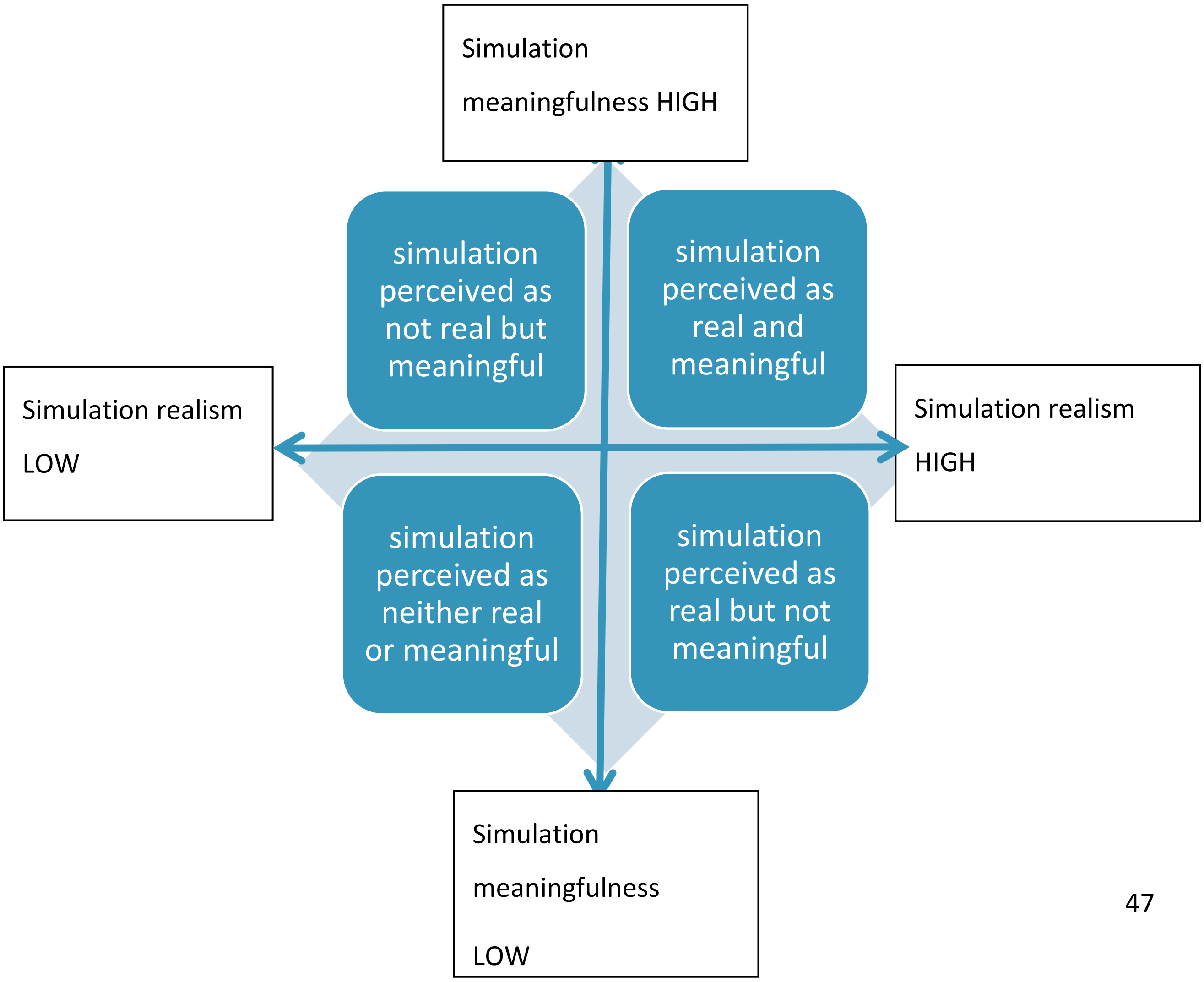
Psychologists have offered differing typologies of the fidelity (realism) of simulation learning, including equipment (changes on a monitor), environmental and psychological. Realism is a perception, and individuals have differing ideas of what is, and what is not, real (Nestel, Krogh & Kolbe, 2018). Fidelity is the degree in which the simulation method resembles a real-life experience, or accurately reflects physiological parameters (Laschinger et al., 2008), but varying terms are used to describe the realism of healthcare simulation, and there are inconsistencies in their use in different areas of research. In most cases, fidelity appears to relate to the physical resemblance of the simulator, but a simulator that is considered low fidelity in one circumstance might be considered high fidelity in another. As a result, some researchers recommended abandoning the term fidelity, as the degree of fidelity is not indicative of the educational effectiveness of the simulation (Hamstra et al., 2014; Nestel, Krogh & Kolbe, 2018). Instead, they recommend the use of the term authenticity rather than fidelity, which allows consideration of the functional alignment with the learning, instructional design, and tutor, since these factors are more likely to impact on learning, retention and transfer of skills post simulation (Chernikova et al., 2020). Authenticity is often used to describe experiences using simulated patients or team-based scenarios, which rely on interpersonal communications (Nestel, Krogh & Kolbe, 2018).

One of the challenges in healthcare education is that learners may not have any experience of the reality, and therefore have no frame of reference for the context that is being simulated (Nestel, Krogh & Kolbe, 2018). Therefore, it is suggested that educators focus instead on functional task alignment; where the physical resemblance of the simulation is less important than how the simulation corresponds with the applied context of the task being learned (Hamstra, Brydges, Hatala, Zendejas & Cook, 2014). For example, researchers in anaesthesia considered mannequins and virtual reality (VR) systems as high fidelity, but surgeons typically viewed cadavers and animal models as higher fidelity than mannequins or VR systems (Hamstra et al., 2014). Surprisingly, some research has shown that full authenticity is not always beneficial for learning, and educators should consider if there is a need to design the simulated environment to optimise learning opportunities and ensure demands on the learner are appropriate (Chernikova et al., 2020).

In addition to authenticity, the concept of meaningfulness is also important in simulation design. This relates to how learners value the task and feel it is worthwhile for their learning or to inspire them (Iverson, Pedersen, Krogh & Jensen, 2015). In simulation design, it is possible to provide a realistic scenario with little meaning for learners. Nestel, Krogh and Kolbe (2018) propose that even a highly realistic scenario can be meaningless for learners if the debrief element of the scenario is not completed. Debriefing is a formal, collaborative process following a simulation which aims to encourage reflective thinking, provide feedback on performance (Lioce, 2020), and to foster development of clinical judgement and critical thinking skills (Johnson-Russell & Bailey, 2010).

Conversely, a scenario might be perceived as unrealistic, but might allow exploration of meaningful topics in response to the challenges raised, and this is an important consideration when planning simulation learning (Figure 2.2).

Figure 2.2: Simulation realism and meaningfulness applied to scenario-based learning (Adapted from Nestel, Krogh & Kolbe, 2018)



Suggested strategies for managing realism and meaningfulness to support optimum learning include several key steps. To ensure engagement and a realistic experience for learning, educators should consider a variety of factors before, during and after a simulation, which are summarised in Table 2.8. A wide range of factors require consideration, so educators require appropriate training in facilitation and monitoring conduct, and effective facilitation for maximum learning (Nestel, Krogh & Kolbe, 2018).

Adequate planning time for selection and development of appropriate simulations and any training of simulated patients is essential. Establishment of a "fiction contract" is required to clearly explain that learner engagement is required by both educators and learners to encourage learners to suspend any disbelief and accept the scenario as being real during their learning (Sharma, Patil & Baviskar, 2023). Learners need well timed invitations and appropriate briefing prior to simulation training. During simulations, learners require an engaging environment, with a clear indication of expectations for engagement and collaboration. An appropriate debrief and evaluation of learning is also important to both learners and educators (See Table 2.7). Prior knowledge impacts on learning success, and educators must consider the timing of simulation to avoid overwhelming learners or blocking their capacity for solving a problem during simulation learning (Nestel, Krogh & Kolbe, 2018). Early implementation of simulation can support knowledge acquisition, but appropriate tutor support is needed depending on the knowledge level of the learner (Chernikova et al., 2020).

Table 2.7: Considerations for educators planning healthcare simulation (adapted from Nestel, Krogh & Kolbe, 2018)

<table>
<tr><td rowspan="2">Before</td><td>Establish fiction contract at beginning of course</td><td>Invitation to Simulation training</td><td>Orientation and establishing task-appropriate conduct</td><td>Highlighting collaborative learning</td><td rowspan="4">Acknowledgment of learners' perceptions</td></tr>
<tr><td>Faculty and equipment requirements</td><td>Selection and development learning outcomes</td><td>Establish level of detail required (identify unnecessary elements, or things too difficult to simulate)</td><td>Training simulated patients in role portrayal</td></tr>
<tr><td>During</td><td>Creating an engaging environment</td><td>Implementing scenarios</td><td>Maintaining an engaging learning environment</td><td>Using "real" time</td></tr>
<tr><td>After</td><td>Maintaining fiction contract during debriefing</td><td>Evaluating simulations</td><td>Asking for learner feedback</td><td>Respond to feedback in future delivery</td></tr>
</table>

2.4.5. Ultrasound education

Internationally, a competency-based curriculum is widely used in healthcare education (Morcke, Dornan & Eika, 2013), but the lack of standardised training and assessment of ultrasound skills has become a matter of concern worldwide. Several international regulatory bodies have considered if ultrasound training is optimal for patient safety, and recommendations from organizations like the International Society of Ultrasound in Obstetrics and Gynaecology (ISUOG), AIUM, and the European Board and College of Obstetrics and Gynaecology (EBCOG) provide valuable guidance for ultrasound training (Leonardi, Murji & D'Souza, 2017). However, training requirements for ultrasound practitioners vary widely between countries and individual professional bodies, and wide differences in roles and practices exist globally.

In a survey of ultrasound training in Europe, half of the countries surveyed had no written ultrasound training curriculum in obstetric ultrasound (Gabor, Dimassi, Aabakke et al., 2017), and the quality of postgraduate ultrasound training was considered inadequate in many European countries. Internationally, ultrasound practice differs depending on training and tradition even within countries (Leonardi, Mufja & D'Souza, 2017). For example, D'Abate & Le Leggia (2017) reported that most sonographers employed in Mediterranean countries were mainly within the field of cardiology and vascular surgery, which is significantly different to UK practice. Similarly, the requirements for obstetric ultrasound practice vary considerably between countries (See Table 2.8), and there are considerable differences between recommendations for sonographers and physicians performing ultrasound examinations. This lack of standard practice in ultrasound internationally is problematic, with no agreed uniform standards in quality assurance and no minimum standards for the teaching syllabus (Gabor, Dimassi, Aabakke et al., 2017; D'Abate & Le Leggia, 2017; Leonardi, Mufja & D'Souza, 2017). A small-scale study by Williams et al. (2013) on a transvaginal ultrasound simulator found that self-directed learning until set goals were achieved by a student, rather than a set number of hours, was beneficial and more motivating for learners. However, a lack of empirical evidence remains on the quality of learning opportunities offered, and their effectiveness in preparing students for clinical practice (Gibbs, 2015; Brown & Chronister, 2009).

Table 2.8: International sample of training requirements in obstetric ultrasound

	Country	Course requirements for obstetric ultrasound practice	Minimum number of scans to achieve competence
Sonographers	UK (CASE, 2022)	Recommendations for both Level 6 (BSc) and Level 7 (MSc) level education. Minimum of 14 hours per week (recommend 21 hours per week) supervised clinical placement for duration of studies. Competency based curriculum in addition to logbook of 100 independently completed examinations.	None specified.
	USA (sonographers) (ARDMS, 2012)	Four-year Batchelor degree, or a 2-year allied health programme, with at least 12 months of full-time clinical ultrasound experience. (ARDMS, 2012).	No specific procedure requirements provided.
	Australian Sonographer Accreditation Registry (ASAR) (ASAR, 2023)	Competency based curriculum	None specified.
Physicians performing obstetric ultrasound	UK	In the UK, the RCOG has a competency-based curriculum, rather than focusing on a minimum number of examinations (Lees & Hinshaw, 2010).	None specified.
	Europe (obstetric ultrasound practice)	The European Board and College of Obstetrics and Gynaecology (EBCOG) require trainees to complete a logbook of at least 200 obstetric scans. (EFSUMB, 2009; Gabor, Dimassi, Aabakke, Rouveau & Ami, 2017).	EFSUMB recommend obstetric ultrasound requires 500 examinations over 3-4 months under supervision, and for advanced techniques, 800 examinations recommended.

	Denmark	Formal curriculum for training during minimum 3 weeks training (Salvesen, Lees & Tutschek, 2010).	80 scans
	Germany	Formal training and examination required.	500 scans
	France	100 h theory, 160 h practice; nationally standardized exam including practical (20-week scan)	None specified
	Italy	No required minimum course	None specified
	Sweden	No required minimum course	None specified
	USA	Minimum 3 months on accredited programme (AIUM, 2015)	Minimum 30 scans
	The International Society of Ultrasound in Obstetrics and Gynaecology (ISUOG, 2019).	ISUOG (2019) propose that doctors require a minimum of 200 scans in obstetric practice.	The International Society of Ultrasound in Obstetrics and Gynaecology (ISUOG, 2019) propose that doctors require a minimum of 200 scans in obstetric practice.

Competency based curricula focus on achieving set competencies, rather than focusing on a minimum number of examinations (Lees & Hinshaw, 2010), and this is the approach taken in the UK by the Consortium for Accreditation of Sonographic Education (CASE). This is likely to be appropriate in ultrasound education, since significant variations in skill acquisition were demonstrated amongst trainees by Balsyte, Schaffer, Burkhardt, Wesser, Zimmerman & Kurmanavicius (2010), with a difference of 70 examinations needed to obtain proficiency between the fastest and slowest trainees. Similarly, Tolsgaard et al. (2014), reported that there were large differences in learning curves for ultrasound trainees, which suggests that rather than a fixed number of practice hours, competency-based education with reliable assessment instruments is needed. Tolsgaard et al. (2014) reported that proficiency is gained at different rates for different areas of clinical practice, and although they advocated for competency-based education to ensure high standard healthcare, they concluded that further study was necessary to review factors impacting on learning in ultrasound students.

Accreditors of ultrasound programmes encourage innovation within curricula (CASE, 2022), and simulation provides a variety of opportunities for educators to achieve this. Although useful, existing guidance and general principles do not provide specific strategies to ensure that technology is effectively integrated into ultrasound training programmes (Gibbs, 2015), and existing evidence on curriculum design relates mainly to undergraduate radiographer education. St. John Matthews et al. (2020) recommended that all stakeholders (including patients) should be included in curriculum design in radiography education and identified a variety of opportunities to use simulated patients and including clinical partners in the delivery of simulated learning activities. This ambition aligns with the National Strategic Vision of Simulation in Health and Care (HEE, 2020), but careful consideration of the investment required in planning and delivery of successful simulation is important in curriculum development (Shiner, 2018). England (2018) reported that a balanced curriculum is likely to include simulation-based learning but does not define what this is for radiography education, and there are known differences between the resources available for simulation-based learning in different HEIs who provide radiography and ultrasound education nationally (Shiner & Pantic, 2019).

Some clinical specialities in ultrasound practice require more prescriptive guidance than others, for example obstetric ultrasound has more specific guidance than other clinical areas, which may reflect the high rates of litigation in obstetric practice.

The varied range of professional guidance for ultrasound training provide few recommendations regarding the use of simulation for sonographer education, and how and when simulation might be most effectively used to supplement clinical learning. This may be partly explained by the relatively recent development of modern ultrasound simulators, but this is uncertain. The variations in skill development for learners, combined with multiple national standards for different types of health professional results in difficulties in comparing and evaluating ultrasound education, and it remains uncertain how simulation might be effectively used for assessment of competence in UK sonographer training.

2.4.6. Training sonographers

Several factors can make it difficult for students to access sufficient supervised clinical practice, including current workforce shortages and time restrictions on working hours (Gibbs, 2015; Williams, Edie, Mulloy, Flinton & Harrison, 2013). If these chronic workforce shortages are to be addressed, increasing training capacity is essential, however the demand for ultrasound services is growing, which is causing growing pressures on services and staff in imaging departments (CFWI, 2017). CASE (2022) requires learners to complete a minimum of 14 hours per week supervised clinical practice in the UK, which equates to a minimum of 600 hours for completion of a postgraduate certificate qualification, and 1200 hours for completion of a postgraduate diploma. The high number of required training hours means that pressured departments can only facilitate training a small number of trainees at any one time, with the average time to successfully complete a postgraduate certificate being two years due to the complexity of the role (NHS Employers, 2023).

The CFWI (2017) reported a vacancy rate of 10% for sonographers in the UK, with 12-20% of the workforce expected to retire from practice within five years. A more recent workforce census from the Society and College of Radiographers (SCoR, 2022) showed an average of 5% of the diagnostic radiography workforce over the age of 60, and average staff turnover of 11.8% (though this is not specific to sonographers), and a steady rate of 49-51%

employment of sonographer agency staff. This long-term workforce crisis impacts on training capacity nationally, and the CFWI (2017) reported that insufficient staff was the most likely reason that departments provide limited ultrasound training posts.

If chronic workforce shortages are to be addressed, expanding the number of students will require alternative approaches to clinical education (HEE, 2020). There is growing demand for NHS imaging services, therefore education and training are increasingly important to staff retention and for securing a future workforce across clinical, practice and research roles (HEE, 2023). Delivering the future workforce is ultimately dependent on a sustainable and high-quality educator workforce to support education and training however, across the healthcare education sector and amongst service providers, there are concerns about the capacity of the educator workforce to meet current and future demands. Simulation could provide an opportunity to increase training capacity on ultrasound programmes, but there is currently limited evidence to ensure this is implemented effectively. Laschinger et al. (2008) conducted a systematic review of evidence on how simulation affected health profession students' knowledge, skills, confidence, and satisfaction, but of the 23 studies included, only one related to health sciences students, and none related to allied health professionals.

For sonography education, ongoing lack of clinical training capacity is restricting opportunities to develop newly proposed training frameworks to support the career structure (Harrison & Beardmore, 2020). Although simulators can help practitioners gain practical experience, there is a lack of standardization of the simulation equipment available for ultrasound education (Urbán et al., 2019), and variations in the implementation of simulation within curricula in UK imaging education (Partner et al., 2023; Shiner, 2018).

Simulation educational tools allow educators to alter and adjust some aspects of reality in a way that facilitates learning and practicing, and enables feedback on behaviours and skill development, as well as setting of goals for learners (Chernikova et al., 2020). Educational simulation incorporated into sonography training may be one way to reduce the training burden on clinical departments and help to address the chronic shortage of sonographers in the UK but types of simulation vary widely, depending on who or what learners interact with (real or virtual object or person), the context of the scenario, and the use of technologies in the learning environment (Chernikova et al., 2020; Heitzmann et al., 2019).

2.5. Simulation in ultrasound education

2.5.1. Simulation in ultrasound education

Traditionally, ultrasound skills training is completed in hospital clinical environments through a combination of observation and hands on training, but this can reduce the clinical throughput and is often a pressurised, time-limited environment for trainees (Burden, Preshaw, White, Draycott, Grant & Fox, 2013; Williams et al., 2013). In ultrasound education, simulation learning is acknowledged as having the potential to increase training capacity (Bains, 2017; Gibbs & Griffiths, 2013; Harrison & Beardmore, 2020), and can provide opportunities for equitable experiential learning experiences where students can learn skills in a controlled environment, with no risk to patients (Hynes, 2016; Parsh, 2010). Modern technological developments have led to several ultrasound simulators emerging onto the market for ultrasound training (Barry, 2010; Gibbs, 2015; Harder, 2009), however there is no agreement on when and how these can be effectively integrated into sonography training programmes. CASE (2022) specifies that although simulators have a valuable role in giving the trainee exposure to specific scans and pathologies in a standardised setting, the use of simulators can never replace scanning performed in a clinical setting with patients and should therefore only be incorporated as an adjunct during training.

The use of virtual-reality (VR) simulation training is an innovative training method which has been found to be effective in various medical applications (Nitsche & Brost, 2013), including the use of VERT (Virtual environment for radiotherapy training) (Appleyard & Coleman, 2010), but the research into the use of VR in ultrasound education is limited (Burden, Preshaw, White, Draycott, Grant & Fox, 2013).

CASE make recommendations regarding the number of training hours required for sonography courses, but there is no clarity regarding whether simulation learning can be included as part of these hours, and this current lack of guidance and statutory registration mean that practice is likely to vary widely in UK HEIs. More recent versions of the standards for sonographic education do not provide any detailed guidance on how and when simulation could be used to meet course learning outcomes (CASE, 2022). Other professions, such as the NMC (2018), have formally recognised simulation learning, and universities may include a maximum of 300 hours (of the total required 2300 hours) as clinical training for nurses within a simulated practice learning environment in support of providing direct care in the practice setting. The NMC notes that effective simulation facilitates the development of safe practitioners by enhancing knowledge, behaviours, and skills (Holt, 2024).

Recent initiatives by HEE (2020) encourage educators to explore and develop new and innovative approaches to healthcare education. In July 2020, universities were invited to submit bids to increase the numbers of trainees on nursing, midwifery, and allied health professional (AHP) courses in England. Since clinical placement capacity is limited, educators will need to explore all options for providing effective clinical training to satisfy the increasing demands on clinical services. To date, the role of simulation in acquisition and assessment of ultrasound skills has not been widely explored.

In response to the perceived need for standardisation of practice and guidance for simulation-based education, a National Simulation Development Project was conducted by the Association for Simulated Practice in Healthcare (ASPiH) in 2012 (Purva & Nicklin, 2017). This was supported by Health Education England and the Higher Education Academy and led to the publication of a Framework which incorporates best practice from published evidence (Purva & Nicklin, 2017). However, the standards incorporated into the Framework are not mandatory, and the level of awareness among ultrasound educators of this framework is unclear. Variations in educational practice could lead to the premature adoption of unproven training techniques which could compromise patient safety (Sidhu et al., 2012).

2.5.2. Ethical considerations

Live models provide excellent learning opportunities for ultrasound students, but this is not possible for all clinical applications due to ethical considerations, difficulties of scanning known pathology or abnormality, and the cost and limited availability of models (Chalouhi et al., 2016). Therefore, students rely on learning complex skills in pressured clinical environments, where increasing work-related pressures can compromise learning and result in inadequacies in clinical teaching (Khine, Harrison & Flinton, 2024). Proposed solutions to expand clinical ultrasound capacity include using two students to one experienced sonographer, extending the working day/week, providing dedicated training lists to speed up the skills development (Harrison & Beardmore, 2020), but all of these are likely to further increase pressures on heavily work loaded clinical staff. Providing excellent patient care through efficient and safe services, whilst ensuring positive student learning experiences is challenging (Khine, Harrison & Flinton, 2024).

Attendance for imaging investigations can lead to significant emotional distress for patients. High anxiety can be due to fear or uncertainty about the procedure, concerns about examination results, and possible consequences of health impairments (Lo Re, De Luca, Muscarneri et al., 2016). Ultrasound examinations were found to be associated with the highest levels of anxiety related any imaging examination, probably because of the likely imminent discussion of the scan results at the end of the examination (Lo Re, De Luca, Muscarneri et al., 2016). In ultrasound practice, examination of fetal abnormalities or performing invasive intimate examinations may not be appropriate for training purposes, and patients may be less willing to tolerate extended examination times due to an inexperienced operator (Williams, Edie, Mulloy, Flinton & Harrison, 2013).

Pressures on hospitals to maintain excellence and achieve quality standards can also limit the availability of training time for new staff (Burden, Preshaw, White, Draycott, Grant & Fox, 2013). Simulation could provide learning opportunities in these ethically challenging areas of practice, without any risk to patients or any impact on clinical department workloads. Previous studies have demonstrated improvements in training with simulation learning, however the constant development of new simulators and software means that more up-to-date research is required (Williams et al., 2013). It remains unclear as to the most effective way to train ultrasound practitioners (Nitsche & Brost, 2013). Little information on the most effective way to use new ultrasound simulation technologies is currently available, and there is a long-established need for further research to address this gap in knowledge to ensure that simulation training reaches its full potential in training programmes (Nitsche & Brost, 2013).

2.5.3. Self-led versus tutor-led learning

Gibbs (2014) used a qualitative approach to reveal that a small group of students demonstrated increased confidence in transvaginal ultrasound scanning technique following simulation training, however the findings were based on students' own perceptions rather than a quantitative evaluation of the impact of simulation on clinical skills. Students reported enjoying the experience of using a high-fidelity simulator for learning transvaginal ultrasound, and they valued the opportunity to practice the theories learned in lectures (Gibbs, 2014). It is important to note that the timing of simulation learning was important, with students reporting a preference for using the technology before interacting with real patients, as they felt this reduced stress during the learning process (Gibbs, 2014). In contrast to the approach used by Gibbs (2014), Burden, Preshaw, White, Draycott, Grant & Fox (2013) used a quantitative approach to evaluate measurement accuracy to demonstrate that students were able to improve the speed and accuracy of ultrasound fetal measurement using Virtual Reality (VR) simulation, and this improvement was not influenced by local trainers.

The concept of learner-led approaches assumes that individuals can successfully lead their own learning processes, based on the andrological assumption that adult learners are self-motivated and responsible for their own learning (Lewis & Bryan, 2021). However, a potential issue with self-led simulation learning of clinical skills, is that incorrect technique may not be identified until a qualified assessor observes the student (Laschinger et al., 2008). One of the threats to using simulation learning is the possibility of negative learning, where a student incorrectly learns something due to an imperfect or less than ideal situation. Given very different backgrounds and experiences, some learners will find self-led learning easy and natural, while others will find it challenging, difficult, or even impossible (Iversen, Pedersen, Krogh & Jensen, 2015). Tutor led learning and effective debrief sessions following simulations can help to avoid this problem (Gibbs, 2014; Laschinger et al., 2008). Simulation cannot remove the need for direct supervision in clinical practice on real patients (Burden, Preshaw, White, Draycott, Grant & Fox, 2013), but the role of the lecturer as a facilitator in simulation learning should be reviewed to ensure learning experiences are maximised (Gibbs, 2014).

2.5.4. Simulation and assessment

Ultrasound simulation could be a useful tool for acquiring new skills and continuous self-assessment, but further study is required to understand to what extent the learning can be transferred from the simulation to the real clinical environment (Gibbs, 2015). Chalouhi et al. (2016) reported that a group of 29 trainee midwives and physicians were effectively assessed using simulation as an alternative to live pregnant volunteers (after structured theoretical and practical training). Simulators can provide objective evidence of performance, with the potential to be used as both a formative and summative assessment tool (Gibbs, 2015; Sidhu et al., 2012). However, CASE (2018) stated that although simulators were useful for formative training, they were not suitable for summative assessment due to the lack of similarity to a real clinical environment and the lack of patient interaction.

The psychomotor skills used in medical ultrasound imaging are high-level, complex, and varied, which creates many challenges for those who teach and learn these skills (Nicholls, Sweet & Hyatt, 2014). Although various simulation methods are available for ultrasound training, there is limited knowledge and understanding of how psychomotor movements are best learned to execute complex and multidimensional transducer movements for performing ultrasound scans (Nicholls, Sweet & Hyatt, 2014). Procedure numbers and time spent training are not effective markers of technical competence (Sidhu et al., 2012); healthcare education should include objective evidence of performance.

Gibbs (2015) assessed sonography students' experiences of a Medaphor *ScanTrainer* simulator, and found that, although students did report improvements in their hand-eye coordination and understanding of image orientation, they negatively perceived the need to complete at least 75% of the simulator formative assessments on their programme because they found these onerous and time consuming. Chalouhi et al. (2016) reported that an obstetric simulator (*Vimedex*, CAE healthcare) was useful to assess students' ability to produce standardised ultrasound planes in obstetric ultrasound. Their study included midwives, specialist residents and physicians (but no sonographers), and found that the simulator task was easier for candidates to complete than scanning a live model. A standard examination provided a good early learning opportunity for students, but this raises concerns regarding the possibility of using simulation as an assessment tool, a student may not be competent for "real world" clinical practice but still able to pass an assessment. The better performance of students using simulation may be because they were less anxious than when they were scanning a real patient, and human factors such as discomfort or pain experienced during the examination were not a factor in the simulation exercise. Additionally, the simulation did not provide a realistic representation of the limitations experienced in clinical practice (such as difficult fetal position), and the fetal structures are always visible on the simulator. More complex examinations on live models may be more appropriate in later stages of training, or for use in summative assessments to ensure competence has been reached before qualification.

2.5.5. Cost effectiveness of simulation training

Global austerity has challenged HEIs to identify more efficient and cost-effective methods of delivering education (Gibbs & Griffiths, 2013). Integration of technology, such as simulators, has the potential to provide more cost-effective methods of delivering healthcare education, however complete replication of the clinical scenario is difficult to achieve (Gibbs, 2015). Many resources are allocated to simulation based medical education in multiple disciplines, but it is important to ensure that the effectiveness is not overestimated, and sustained improvements in performance should be evaluated (Tolsgaard et al., 2015), as it is unclear if the effects of simulation learning are sustained in the long term (Laschinger et al., 2008).

The costs of phantoms (mannequins), ultrasound machines and ultrasound simulators are high, and while many HEIs have made significant investments in equipment, few studies have been published on the cost effectiveness of ultrasound simulation as a teaching strategy. Carolan-Rees & Ray (2015) attempted to calculate the cost effectiveness of the Medaphor *ScanTrainer* simulator and predicted that there were potential training cost savings, however the research was based on physicians learning only obstetric and gynaecological ultrasound skills, and the results are unlikely to be transferrable to other professional groups who have different access to clinical placements, and different learning needs. Additionally, the research was sponsored by the manufacturer of the simulator being tested, which could have introduced bias and raises questions over the reliability of the research.

Several studies make claims about cost-effectiveness without evidence, all highlighting the need for further evaluation. For example, Burden, Preshaw, White, Draycott, Grant & Fox (2013) suggested that using self-led learning with a VR simulator might be a cost-effective training option, and Chalouhi et al. (2016) predicted that the use of simulation for certification of obstetric ultrasound trainees would reduce costs, as this might eliminate the need for using live models. In the trial conducted by Tolsgaard et al. (2015) residents showed initial and short term sustained improvements in their abilities, however further evaluation of the long-term effects of simulation learning was recommended alongside, again, analysis of the cost implications of this practice compared with other training strategies. Ahmad, Alhashmi, Ajlan & Eldeek (2015) recommended that ultrasound simulation should become an integral part of radiologist training as it improved both the competence and confidence of trainees; however, they acknowledged that this was difficult to calculate. Gibbs (2015) reported that tutor-led simulation learning was beneficial to guide student learning, was the only study that suggested that this would increase the cost of this learning strategy. The future development of simulation learning for ultrasound should be driven by the needs of students (Gibbs, 2015), but much of the existing evidence base does not relate specifically to sonographer trainees.

2.5.6. Benefits of simulation in ultrasound education

According to the World Health Organization (WHO), as many as 10% of patients worldwide experience harm while receiving healthcare, so although proficiency in technical skills is important to error management in specific clinical settings, non-technical skills (i.e., "soft skills") like decision-making, leadership, and communication are equally critical to effective patient care in complex interprofessional environments (Bergs et al., 2018; Farmer, 2015).

The benefits of simulation are well documented. Increasing service demands, workforce deficits, concerns for patient safety and advances in learning theory are forcing healthcare educators to seek alternatives to traditional clinical education (CFWI, 2017; Gibbs, 2014; Laschinger et al., 2008). High-fidelity simulation allows trainees to receive feedback, repeat practices, and learn in a controlled, unpressured environment with no risk to patients (Gibbs, 2014; Laschinger et al., 2008). Most students reported increased confidence in their skills after simulation learning and they felt that simulation learning made their learning experience easier (Laschinger et al., 2008).

The lack of standardised guidelines for ultrasound training is concerning, as students might only gain exposure to a small range of abnormal findings in clinical practice. Simulation learning can ensure that clinical education consistently includes abnormal findings and rare cases for all students, which can be difficult in the real clinical environment (Gibbs, 2014; Nitsche & Brost, 2013). This is of benefit to ensure that students can recognise and reach appropriate conclusions in a safe learning environment (Gibbs, 2014; Nitsche & Brost, 2013).

A meta-analysis by Chernikova et al. (2020) explored the use of simulation in higher education (medicine, education, and engineering fields) to assess if simulation could impact on the development of complex skills sets in learners with different levels of prior knowledge including physical, cognitive, and social skill development. Chernikova et al. (2020) proposed a framework that of scaffolded learner support during tasks, involving a temporary transfer of control from learner to teacher in a learning environment. According to this framework, learners with varying levels of prior knowledge would benefit from diverse types of scaffolding and varying levels of support.

2.5.7. Limitations of simulation

Some students reported that ultrasound simulators were unrealistic (Burden, Preshaw, White, Draycott, Grant & Fox, 2013; Gibbs, 2015), and the experience was not like scanning a real patient (Gibbs, 2015). As technology and the skills of educators improve, there is potential for more complex and realistic simulation education (Gibbs, 2015). Others perceived the ultrasound simulator as another technological hurdle to master, rather than a facility to enhance their clinical learning (Gibbs, 2015), and there is a lack of standard practice in how simulation is used in ultrasound education.

Although some studies have attempted to evaluate the impact of simulation on learning, these studies typically evaluate technical aspects of performance, image acquisition and interpretation (Tolsgaard et al., 2015; Gibbs, 2014). Alongside the required high-level psychomotor skills, a key part of a sonographer's role is communication, and personal interaction between the ultrasound operator and patient cannot be effectively assessed using current ultrasound simulators (Chalouhi et al., 2016), which means that simulation cannot completely replace learning in the real clinical environment. Bloom's taxonomy of learning objectives applies well to healthcare education, and includes three categories of knowledge, skills, and attitudes (Bloom et al., 1956). Ultrasound simulators may provide opportunities for students to improve their knowledge and skills but formulating attitudes to the care of patients and clinical decision making remain within clinical departments (Gibbs, 2015).

When using volunteer patients for assessment of obstetric skills, (Chalouhi et al. (2016) reported that since students were aware that patients were likely to have already undergone a normal detailed examination, this could bias their interpretation of the examination and affect the results. This can be overcome by purposefully including volunteer patients with known pathology in student assessments. Ultrasound simulators often focus on procedural training, and further development of additional skills such as report-writing skills and patient communication skills would be beneficial to trainees (Gibbs, 2015). Several studies reported that a wider range of pathological findings for simulation learning would benefit learners (Gibbs, 2015; Williams et al., 2013), and manufacturers have since been developing increasing numbers of pathological cases on high fidelity simulators (Intelligent Ultrasound, 2024; Schallware, 2024).

2.5.8. Student perceptions and confidence

Studies on small groups of sonographer learners (Gibbs, 2015; Gibbs 2014), have shown that simulation increased student confidence, however confidence does not guarantee competence, and a more objective measure of performance is required. In one study nine doctors, who used a transvaginal ultrasound simulator for ten hours training, were found to have increased confidence to attempt a transvaginal ultrasound scan on a real patient for the first time (Williams et al., 2013). Nonetheless, participants explained that they were still not confident with all aspects of the examination, and some participants were concerned that the simulator lacked realism (because it was too easy), and this could potentially give students a false degree of confidence in their clinical abilities (Williams et al., 2013).

A second study of training for transvaginal ultrasound scans for doctors found that simulation learning improved the perceived performance and confidence levels of residents, and they concluded that this improved patient safety as there was a reduction in the rate of repeated examinations in clinical practice (Ahmad, Alhashmi, Ajlan & Eldeek, 2015), however improved confidence does not prove increased competence.

A randomised trial by Tolsgaard et al. (2015) found a substantial improvement in performance in a small group of 12 residents, which was sustained 2 months after training. Students who used simulation learning initially showed significantly higher pass rates on assessment compared to the control group (no simulation used), but this did not correlate well with their subsequent clinical performance (Tolsgaard et al., 2015). Residents were required to call for assistance if needed following initial training, however this was the responsibility of the learner, and, as previously argued, their confidence level may not directly correspond to their actual clinical competence.

Learner satisfaction with simulation learning is generally high, and although a study of medical trainees by Morgan, Cleave-Hogg, McIlroy & Devitt (2002) found that there was no difference in the skills obtained between two student groups learning a task by video or learning by simulation, students learning through simulation practice reported much higher satisfaction with their learning experiences. Educators should be open to having their views on teaching challenged, and listening carefully to learners and involving them in simulation planning and design is important. If simulation learning is to be effective, educators must be very open toward students' proposals and prepared to adapt their approach (Iversen, Pedersen, Krogh & Jensen, 2015).

2.6. Clinical Skills in ultrasound

2.6.1. Clinical skill acquisition and competence

Simulation learning takes many forms, and can include a wide range of equipment, from simple reproduction body parts to complex human interactions portrayed by sophisticated simulators (Bradley, 2006). Phantoms for ultrasound simulation typically have a limited number of configurations, which limits their learning value (Nitsche & Brost, 2013).

Simulator learning allows tutors to combine theory with practical contextualised application, which increases the impact of the learning for trainees (Gibbs, 2015).

Learning ultrasound skills is a complex process, requiring simultaneous development of hand-eye coordination, spatial awareness, image interpretation skills, decision making skills, diagnostic skills, timing, and accuracy of measurement. Although ultrasound is a commonly used diagnostic tool, few health professionals are educated and trained well enough in its use (Hani, Chalouhi, Lakissian & Sharara-Chami, 2019). As previously discussed, these skills take a considerable time for each trainee to acquire in busy clinical environments. Simulation can allow learners to acquire ultrasound skills in a safe unpressured environment, with no risk to patients and might reduce the time needed to acquire skills in the clinical environment.

Burden, Preshaw, White, Draycott, Grant & Fox (2013) assessed the accuracy of ultrasound biometry measurements in participants with different expertise and found that trainees significantly improved the speed and accuracy of fetal measurements using simulation learning (VR), but they acknowledged that further research was required to assess if the improvement in skills transferred to scanning real patients in the clinical department. Gibbs (2014) recommended further evaluation of simulated learning experiences across healthcare education to explore the quality of learning opportunities offered, and their effectiveness in preparing students for clinical practice.

It is necessary to establish that elements of simulation used are effective for transfer of skills into clinical practice (Laschinger et al., 2008). A systematic review and meta-analysis of the use of high-fidelity ultrasound simulators in obstetric ultrasound concluded that simulation was best used for acquisition of technical skills and image optimisation, but the eight qualitative studies included only recruited doctors, with none including sonographers (Dromey et al., 2021; Bradley et al., 2019).

Transferability of skills learned during simulation-based learning to the real clinical environment is not well understood in sonography education. The development of high-fidelity computer simulators has provided additional opportunities for teaching and learning psychomotor and clinical skills, but the quality of this learning is not well evaluated, and a systematic review by Sidhu et al. (2012) failed to find a compelling body of evidence that ultrasound simulation-based education should be widely adopted to improve ultrasound practice skills. This may be because recommended best practices for simulation based medical education (McGathie et al., 2010) were not consistently demonstrated in the systematic review conducted by Sidhu et al. (2012). Additionally, Sidhu et al. (2012) reported that there were methodological limitations to previously published studies (including small numbers of trainees), which many have confounded the results obtained, and argued that simulation-based ultrasound education may benefit from implementation of defined standards of practice.

An experimental study by Ahmad, Alhashmi, Ajlan and Eldeek (2015) found that simulation-based learning facilitated significant improvements in performance and confidence of radiology doctors in performing transvaginal ultrasound examinations, thus improving patient safety. They recommended integrating ultrasound simulation for different ultrasound examinations, but that further study was required. Sidhu et al. (2012) reported that there was little evidence to support the adoption of simulation-based education to improve competence (Sidhu et al., 2012), however, Nitshe et al. (2013) argued that simulation must become an essential part of ultrasound training programmes. It has been widely acknowledged that simulation cannot completely replace clinical learning (Burden et al., 2013; CASE, 2018; Gibbs, 2015; Williams et al., 2013), and there is a lack of empirical evidence regarding the optimum use of simulation for sonographer learning and assessment (Ennin & Satin, 2010; Lasinger et al., 2008; Tolsgaard et al., 2015).

Approximations of practice where complexity and pressures can be reduced can help engage learners in specific aspects of professional practice and are promising to avoid confusion and efficiently use resources for learning (Chernikova et al., 2020). Simulations can allow students to use authentic problems and to create a learning environment to practice and facilitate the acquisition of target complex skills. Several ultrasound phantoms and simulators are commercially available, which are designed for the acquisition of different clinical skills (Nitsche & Brost, 2013). High-fidelity human patient simulators include software within the mannequin that can be accessed and manipulated using a computer device. Modern computer-based systems provide a potentially infinite number of configurations and incorporate a wide variety of abnormal findings into the simulation, however these systems are expensive, which has led to some researchers developing their own training systems, such as a foetal-pig training system developed by Nitche & Brost (2013).

Initial use of these systems can allow students to become familiar with the manipulation of the ultrasound equipment, normal ultrasound appearances and image orientation. Students can obtain hand-eye coordination skills in an unpressured environment, without appearing clumsy in front of a patient (Gibbs, 2015; Nitsche & Brost, 2013). Clinical practice for students can provide risk and ethical issues, and if they are not well prepared, this can prove overtaxing for learners. Simulation allows for application of knowledge, which is important for the development of complex skills (Chernikova et al., 2020). Expertise development theories suggest that learners acquire high levels of expertise in complex problem-solving tasks if they have sufficient prior knowledge and engage in large amounts of practice, but real-life practice does not always provide enough practice opportunities, with lack of predictable events, suboptimal learning spaces and limited time common in clinical departments (Chernikova et al., 2020). Practice opportunities ideally include authentic problems related to a professional field but opportunities to engage in real-life problem solving at universities are limited (Chernikova et al., 2020).

Simulators have allowed some standardisation of training, and students found it useful to have a structured, standardised learning package (Gibbs, 2015). Simulated learning allows time and repeated practice for sonography students to acquire the high-level psychomotor skills, spatial awareness and knowledge required in ultrasound practice, and the simulated environment has the advantage of providing opportunities to reflect on their learning (de-brief). Feedback can be provided by the advanced simulation system; however, students preferred a tutor to be available to provide guidance and feedback during their learning sessions (Gibbs, 2014). Ultrasound trainees appreciated the opportunity to scan a variety of different pathologies, which might not have been encountered during their clinical placement training (Gibbs, 2015), and this helps to prepare for challenges in clinical practice. Little is known about for whom simulations are particularly helpful, what scenarios are effective, and what additional instructional support makes them effective for learners with different learning prerequisites (Chernikova et al., 2020).

2.6.2. Psychomotor skill development

Psychomotor skills are movement orientated activities which require neuromotor coordination and integration of cognitive, affective, and motor skills (Oermann, 1990). Teaching relating to knowledge base is important, but it has different teaching methods to those needed for promoting psychomotor skills development. Visuospatial skills describe a sonographer's ability to create a 3-dimensional mental image of a structure, and these are central to a sonographer being aware of the axis, deviation, rotation, and anatomic variation of structures (Nichols, Sweet & Hyatt, 2014). Beginners in ultrasound imaging need to master probe handling, optimizing images, and constructing a mental 3D model of the specific organ (alongside development of many other skills, knowledge, and professional behaviours). Development of psychomotor and visuospatial skills requires repeated practice, but the amount required varies between individual learners (Oermann, 2013). Mastering these psychomotor skills takes time and it may not be cost-effective to learn this in practice (Olgers, van Os, Bouma & ter Maaten, 2022).

Oermann (1990) suggested that psychomotor learning is an egocentric process, where the learner focuses on the skills themselves, and time is needed to allow learners to focus on the movements (rather than any background knowledge or other non-motor components). For sonography learners, developing fine motor skills in clinical practice with real patients, busy workloads, time constraints and ethical considerations can be very difficult to achieve, yet they are expected to attain most of their learning in clinical practice environments which can take significant periods of time to achieve.

The psychomotor scanning skills used in medical ultrasound imaging include visuomotor and visuospatial skills (Nicholls, Sweet & Hyett, 2014). Visuomotor skills, (hand-eye coordination skills), evolve from the sonographer having a mental image of what structures should look like for a given clinical scenario (Wise & Willingham, 2009). The mental image provides a visual standard of performance and is used as a reference by sonographers when scanning. The positions of the upper limb and joints are changed through muscle activation, which modifies the transducer position, angle, or pressure until a visual standard can be achieved (Cornford, 1999; Grantcharov & Reznick, 2008).

The acquisition of psychomotor skills in sonographers has not been widely explored, but there are some studies in other professional groups. Ziada, Ditmyer & Aduvakr (2020) considered student experiences of psychomotor skill development and concluded that the inclusion of reflective practice improved efficacy of psychomotor development in preclinical learning for dental students. Similar to procedural work in dentistry, sonography is reliant on tactile sensation, which requires an element of force alongside fine movements. Nicholls, Sweet, Muller & Hyett (2018) explored a model to teach patient communication and psychomotor skill development in nursing students and concluded that communication and clinical skills are both complex and difficult to learn, and therefore they should not be taught concurrently. Yet, sonography students are commonly expected to develop both psychomotor and communication skills simultaneously when learning in clinical practice.

A few studies have explored the development of basic ultrasound skills for clinicians (Mulder et al., 2023; Schott, Kode & Mader, 2020; Skinner, Freeman & Sheehan, 2016) but little is known about this for sonographers, particularly when considering the use of simulation within the curriculum. Olgers et al. (2022) developed a computer-based game for development of technical skills, which showed some potential for allowing participants to develop psychomotor skills, but the system was not high fidelity enough, and this was tested by medical staff rather than sonographers in practice. With practice, the motor movements required to move a transducer for a given clinical scenario are learned and recalled (Nicholls, Sweet & Hyett, 2014), but in ultrasound practice, variations in anatomy, position, patient body type, pathology (and other factors) can make it difficult to learn psychomotor skills (Raman & Donnon, 2008).

2.7. Conclusions

Addressing longstanding workforce deficiencies in ultrasound practice is a complex process. There are ongoing developments in the educational model, career model and sonographer regulation, although no real solutions have yet been reached (Sevens, 2017), and the COVID-19 pandemic impacted negatively on the implementation of all these developments. The number of clinical placements available to train sonographers is adversely affected by high workloads in ultrasound departments, increasing demand for ultrasound services, and chronic staffing shortages. When combined with the extensive clinical practice hours required to train one sonographer, the capacity to educate more sonographers at any educational level remains limited.

Psychomotor skills must be developed alongside knowledge and behaviours to enable sonographers to meet the requirements and challenges of autonomous practice. Psychomotor skills allow sonographers to complete each scan effectively, but the psychomotor skills used in medical ultrasound imaging are complex and varied and take time and repeated practice to develop. This creates challenges for those who teach and learn ultrasound skills as there is limited understanding of how psychomotor movements are best learned to execute complex and multidimensional transducer movements for performing ultrasound scans (Nicholls, Sweet & Hyatt, 2014). Although simulation can help students to develop these skills (Tolsgaard et al., 2015; Gibbs, 2014), some studies found that trainee skills were found to deteriorate after the initial simulation training, and assessment of knowledge retention, and the transference of skills into clinical practice may not occur (Laschinger et al., 2008).

In order for simulation training to be successful, some authors suggest that simulation should be integrated into the curriculum, and that this should be mandatory (Shanks, Wong, Rogers, Nair & Ma, 2010; Van Dongen, Van Der Wal, Borel Rinkes, Schijven & Broeders, 2008). A scoping exercise into Ultrasound clinical teaching capacity in England reported that some respondents discussed simulation to assist with ultrasound education, and that this was likely to continue to develop (Harrison & Beardmore, 2020), but how to do this effectively remains unclear. Simulation learning may provide part of the solution to increasing training capacity for sonographers, but there is limited evidence to inform educators as to the most appropriate simulation type, timing, teaching and assessment strategies and short, medium, and long-term effectiveness of simulation in sonographer education.

2.8. Research Question

To support educators to maximise opportunities for student learning there is a need for further investigation into the effective use of simulation for optimal learning and to maximise capacity on sonography training programmes. This led to the research question:

What is the role of simulation in UK sonographer education?

2.9. Aims

This research aims to:

- investigate the role of simulation in sonographer education from the perspectives of national, academic and student stakeholders
- develop recommendations to facilitate optimal learning when using simulation for sonographer education

2.10. Objectives

To investigate:

- how simulation is being used in the delivery and assessment of current sonographer education programmes
- the experiences of educators, students and stakeholders using simulation in sonographer education, including barriers, limitations, opportunities, and challenges of this pedagogical approach.
- how the skills gained using simulation impact on students' performance in the clinical environment
- how simulation can be used optimally for sonographer education
- the potential role of simulation in the delivery of new educational routes in sonography education

Chapter 3: Methodology

This chapter initially explores the ontological, epistemological, and methodological features that influenced the design of this study. Next, the methodology and methods used in this constructivist grounded theory study are detailed, alongside ethical considerations and analytical processes.

A research paradigm is a set of common beliefs or approaches to research, each with their own expectations and rules (Thomas, 2014). All qualitative research requires an underpinning paradigm that fits the research, where different elements inform each other, therefore it is important to consider ontology, epistemology and methodology related to the research process (McIntosh-Scott et al., 2014). Researchers must be aware of their own position and how this differs from other approaches, since their world view may influence the outcomes of the research (Denscombe, 2010). Crotty (1998) proposed that all qualitative research requires careful consideration of methodology, theoretical perspective, and epistemology to ensure effective analysis and understanding the processes. Different philosophical positions are seen as competing or incompatible, with advocates of different approaches criticising other approaches (Thomas, 2014). Researchers must select an approach based on their assumptions, beliefs, and knowledge about the area to be studied.

Qualitative research is a systematic and subjective approach arising from humanistic disciplines of social anthropology and sociology which aim to understand or interpret behaviour and explain the dynamics of society (McIntosh-Scott et al., 2014). Qualitative research methods share broad philosophies (Crotty, 2018), yet there are a wide range of methodologies available (Silverman, 2006) with each approach offering individual processes and benefits for researchers. Unlike quantitative approaches, qualitative researchers must accept the subjectivity of their research (Charmaz, 2014; Finlay & Ballinger, 2006), and avoidance of preconceptions about research outcomes is important. Qualitative research methods are typically used to explore people's subjective understanding of their everyday lives (Pope & Mays, 2020) and seek to connect with their participants to see the world from their viewpoint (Corbin & Strauss, 2013). They allow the researcher to take a flexible and dynamic approach to the exploration of human experiences and responses, and to see the world from a variety of perspectives. This enables researchers to gain a deep understanding of participant perspectives, behaviours, and their understanding of their world (Braun & Clark, 2022) by allowing exploration of participants experiences in a holistic and comprehensive way (McIntosh-Scott et al., 2014). This cannot be easily achieved with structured quantitative research designs (Corbin & Strauss, 2013).

Qualitative research is well established in healthcare education to explore participant behaviours, experiences, actions, or perceptions (Holloway & Todres, 2003; Cresswell & Cresswell, 2023). There are many different types of qualitative research, with varying purposes and structure including ethnography, narrative research, phenomenology, and grounded theory (Creswell & Cresswell, 2023). Some qualitative researchers advise that researchers should avoid imposing their own structures and assumptions on the data collection and should avoid making assumptions or allowing their own views to affect data interpretation (Corbin & Strauss, 2013). A phenomenological approach was initially considered for this research, since it seeks to investigate experiences from individual perspectives (lived experience), focusing on explanation of participant perspectives (Smith, Flowers & Larkin, 2022). However, this was discounted in the early stages of research planning as requirements for bracketing and for the researcher to remain an objective observer seemed unachievable due to the inherent commonalities between the researcher and the participants in this research. For this study, the researchers' knowledge and experience was an important consideration, therefore a constructivist grounded theory methodology (where co-construction was an inherent element of the study) was selected to investigate the role of simulation in sonographer education using an inductive approach to theory development.

3.1. Philosophical perspectives

Philosophical assumptions underpin the perspective adopted by the researcher, shape the nature of the research, specify what qualifies as worthwhile evidence, and influence the conclusions reached during the investigation (Denscombe, 2010), so researchers must acknowledge assumptions underlying the design and implementation of their research. Social research will always be influenced by the expectations and values of the researcher; therefore, it is impossible for a researcher to take a completely objective viewpoint since they are part of the world they are investigating (Charmaz, 2014). In this study, the researcher views themselves as a pragmatist, focused on the practical usefulness of the research outcome, rather than adopting a single specific philosophical position (Denscombe, 2010). Qualitative research can be carried out within interpretive, positivist or critical philosophies (Urquhart, 2023), and Charmaz (2014) argued that grounded theory can be carried out in any paradigm. Interpretivism (alternatively named constructivism by some authors) includes a range of approaches which reject the basic assumptions of positivists (Denscombe, 2010), giving abstract understanding greater priority than explanation (Charmaz, 2014). This lack of complete objectivity is accepted by interpretivists, who advocate embracing the lack of objectivity and appreciating that there are multiple versions of reality and truth, and there is no reason to view one version of reality as superior to another (Charmaz, 2014; Denscombe, 2010). In the researcher's view, objective knowledge is not possible since social reality is constructed and interpreted by people (Denscombe, 2010), therefore this research applied a constructivist paradigm, which accepted that knowledge is a product of cognitive processing, and meaning is unique to individuals (Charmaz, 2014).

3.1.1. Ontology

Ontology explains beliefs about the nature of reality, what exists and what is real (Crotty, 1998; Urquhart, 2023). Positivists have a realist ontology, which assumes there is one reality which can be measured objectively (Guba & Lincoln, 2006). Positivism initially dominated social sciences, based on the assumptions that scientific research methods are the gold standard for studying social reality, and that empirical observation is essential to corroborate explanations of social reality consisting of stable relationships (Denscombe, 2010). Positivist approaches emphasise that researchers must not influence the data collection or social reality during the research (Denscombe, 2010), which fits with realist ideas that there is a single social reality (Denscombe, 2010).

In contrast to this, and aligning with the researcher's own view, interpretivism acknowledges that each individual's reality depends on their experiences (Charmaz, 2014). Research underpinned by interpretivist ontology is usually concerned with participants' experiences and their subjective interpretations of their world. This research was conducted within an interpretivist ontology which aimed to discover each participant's own reality and rejected positivist assumptions that there is only one objective reality (Thomas, 2014). Reality was viewed as socially constructed, and this approach emphasised the importance of understanding how people made sense of their world through interactions and shared meaning (Urquhart, 2023). Constructivism provided a foundation for describing multiple realities through a reflexive process (Plano Clark & Ivankova, 2016).

In line with interpretivism, this research also assumed that the researcher brought their own experiences and views to the research process (Denscombe, 2010). Critics of interpretivism dislike the degree of uncertainty and open-endedness contained within explanations of the social world, as this does not fit with traditional scientific approaches to research (Denscombe, 2010). In the view of critics, interpretivist research lacks rigour due to the lack of statistical analysis and the possibility of emergent research design, however good interpretivist research is systematic and rigorous in its approach and aware of the need for reflexivity in exploring the social world (Denscombe, 2010; Charmaz, 2014).

The researcher ensured that concepts were explored in as much detail as possible and was aware that the emerging concepts may have been very different from those predicted at the outset of the research. Interpretivism assumes that humans will react to the knowledge that they are being studied, and this awareness may result in a change in behaviour. The research process can distort or alter the thing being studied (Denscombe, 2010). Therefore, the researcher ensured that during interviews, they checked their understanding of participants' meaning and avoided making assumptions or allowing their own views to affect data interpretation (Corbin & Strauss, 2013). Nonetheless, the researcher view inevitably influences the research outcome, therefore a constructivist approach which acknowledged that the resulting theory cannot stand outside of the researcher interpretation was adopted (Charmaz, 2014).

3.1.2. Epistemology

Epistemology is the study of the nature, origin, and limits of knowledge, and how beliefs and cognitive processes work to support trust in knowledge (Thomas, 2014). It refers to how humans create their knowledge about the social world and how we know about reality (Crotty, 1998; Denscombe, 2010). Philosophers have differing views on knowledge and truth, which include positivist, naturalistic and constructivist paradigms, each with their own rules and expectations of research activity (McIntosh-Scott et al., 2014). Epistemology includes the analysis of methods, validity and scope, and cognitive processes used to make sense of knowledge, such as perception, beliefs, memory, and cultural context (McIntosh-Scott et al., 2014). It therefore informs the subjectivity or objectivity of the research approach and the researcher themselves (Crotty, 1998).

Initial positivist approaches to research advocated that scientific knowledge is the only form of factual knowledge, and only statements verifiable through direct observation or logical proof convey meaningful truth value or factual content (Gibson & Hartman, 2014). This approach lacked appropriate consideration for human sciences (Gibson & Hartman, 2014), so modern researchers accept the possibility of pursuing science in many ways in different disciplines (Gibson & Hartman, 2014). Grounded theory methodologies can be influenced by many different underlying epistemologies, and the flexibility and variety of these methods allow it to be used by researchers with different underlying assumptions (Urquhart, 2023). Charmaz (2014) argued that positivism was not the only way of accomplishing scientific work, and critics of positivist approaches have expressed concerns that the approach is too limiting and that attempts to make concepts universal make it impossible to acknowledge the importance of context in data interpretation (Bryant & Charmaz 2019; Charmaz, 2014; Clarke, 2005; Urquhart, 2023).

In contrast to positivism, pragmatism is all about the notion of "*what works*" (Maaroof, 2019) and is simply oriented toward solving practical problems in the real world rather than being built on assumptions about the nature of knowledge (Creswell, 2023; Shannon-Baker, 2016). Pragmatism emerged in the late nineteenth century and evolved to provide a set of assumptions about knowledge and enquiry that suit the use of different methods and different research strategies within individual investigations. It is evident in the work of symbolic interactionists such as Dewey, Glaser, and Strauss (Denscombe, 2010). Pragmatists choose an approach to suit the specific question and the required outcomes of the research. Therefore, knowledge is based on practical outcomes and is not absolute, and is provisional and may change (Denscombe, 2010). Rather than advocating a single approach, pragmatists instead take the research problem as a starting point to judge the value of a research method in producing a useful outcome (Denscombe, 2010). Pragmatists consider that addressing the research question with an appropriate mixture of methodological tools to best address practical problems is more important than a single method or worldview (Denscombe, 2010). This flexible approach allows researchers to mix methods and strategies, but the avoidance of assumptions and the use of reflexivity is important in producing knowledge (Denscombe, 2010). Pragmatism aligns with the researchers' approach; rather than assuming that one single approach is superior to another, several methodologies were initially considered, and one selected which best suited their needs (Denscombe, 2010).

Constructivist grounded theory (CGT) was selected as it aligns with interpretivist epistemology and emphasizes the role of individual researchers in constructing meaning and reality (Charmaz, 2014). Researchers engage with participants to uncover their individual perspectives, to enable a deep understanding of human experiences, which was a key consideration in selecting a suitable methodology for this research. Given the commonalities between the researcher and participants in this study, an interpretivist approach was selected, using reflexivity to ensure greater objectivity in the analysis. This constructivist approach aligns with the researcher's own view, which regards the social world as a creation of the human mind, where reality is constructed by individuals' perceptions and reinforced by interactions with others (Denscombe, 2010). Interpretivist researchers position themselves within their research and acknowledge that their interpretations are influenced by their experiences and background (Cresswell, 2007). It was essential that the researcher's involvement in, and commonality with, the participants was declared and transparent (Braun & Clarke, 2013). Therefore, the researcher employed an interpretivist paradigm, where the influence of the researcher was acknowledged and embraced via a process of reflexivity (Charmaz, 2014; Urquhart, 2023). The use of reflexivity in this research is fully explored in Chapter 6.

3.1.3. Axiology

Axiology explains the values and ethics in a research process, including the role of the researchers' own values in the research process (Urquhart, 2023). Constructivist grounded theory embraces the individuality and subjectivity of the researcher, as well as the importance of co-construction between the researcher and participants (Charmaz, 2014).

Some approaches including positivism and phenomenology emphasise the importance of an objective approach, where researchers must put their values aside (Urquhart, 2023), but it is likely that the researchers' values will have some influence, despite their best efforts. The researcher's values play a crucial role in shaping the questions asked, the data collected, and the interpretations made, therefore this research used a reflexive approach, where the researcher identified their influences on the data produced and analysed (Charmaz, 2014).

This research involved a strong emphasis on ethical practice, using reflexivity throughout to ensure the research was conducted ethically and respectfully. The researcher has been transparent about their positionality, and how it influenced their interactions with participants and data interpretation (See Chapter 6: Reflexivity). The researcher influence on the choice of methods and analysis of data has been acknowledged. Robust processes ensured that informed consent was obtained, and confidentiality ensured. A flexible semi-structured interview schedule allowed the researcher to be responsive to participants when exploring their experiences of the use of simulation in sonographer education. The potential influence of power dynamics was also explored, ensuring that the researcher did not interview any students who they were teaching or assessing at the time of the data collection. Care was taken during analysis and write up to ensure that the voices of participants were valued and included throughout the Discussion (see Chapter 4).

3.2. Theoretical perspective

Researchers must understand the philosophical ideas on which their choice of methodology is based (McIntosh-Scott et al., 2014), as these influence the theoretical perspectives related to particular frameworks or models which are used to explain and interpret research data. There are a variety of approaches, which provide a lens through which data can be analysed and understood. Three commonly used theoretical perspectives in healthcare research are: interpretative research which aims to make sense and find meaning in human experience (e.g., phenomenology or symbolic interactionism); feminism and critical theory, which argue that certain groups suffer due to power structures in society; and pragmatism, which is concerned with determining the value of ideas by their outcomes in practice (McIntosh-Scott et al., 2014).

Early forms of grounded theory described discovering theory as emerging from the data separate from the researcher (Glazer & Strauss, 1967), whereas Charmaz assumed that the researcher is part of the world they study, the data collected and the resultant analysis (Charmaz, 2014; Urquhart, 2023). Charmaz (2014) built her early discussions of grounded theory on symbolic interactionist theoretical perspectives, which allows researchers to learn about the worlds they study and enables development of theories to understand these worlds (Charmaz, 2014).

3.2.1. Symbolic interactionism

Charmaz (2014) advocated the use of symbolic interactionism, a sociological perspective which provides a theoretical framework for viewing social realities. Symbolic interactionism assumes that people think about their lives and actions actively, therefore constructivist grounded theorists advocate gathering rich, full data, and placing them in relevant situational and social contexts (Charmaz, 2014). This perspective views people as actively engaged in their worlds and therefore allows researchers to produce a dynamic understanding of actions and events (Charmaz, 2014). The interactions between researcher and participants during in-depth interviews co-construct meaning in the data, and researchers must ensure they understand participant perspectives. This approach acknowledges that participants may respond differently depending on their interpretation of the person they are interacting with, therefore they may give a different response based on their own interpretation of the interaction (Charmaz, 2014).

Symbolic interactionism provided a theoretical lens to allow the researcher to be more aware of social interactions and meanings, and how individuals construct their own perspectives based on their own experiences (Charmaz, 2014). Constructivist grounded theory uses constant comparison to identify categories and patterns during the analysis alongside symbolic interactionism to develop ideas inductively and develop theory which is truly grounded in the data (Charmaz, 2014) and reflects the experiences of the participants. Researchers construct theory through their interactions with people, perspectives, and research practices, which results in an interpretive analysis of the studied world (rather than an exact picture of it): the researcher generates their construction of reality based on their participants' implicit meanings and views (Charmaz, 2014). Given the similarities between the researcher and participants in this study, reflexivity was crucial for the researcher to maintain self-awareness and understand how they influenced the research process (See Chapter 6).

3.3. Methodological perspective

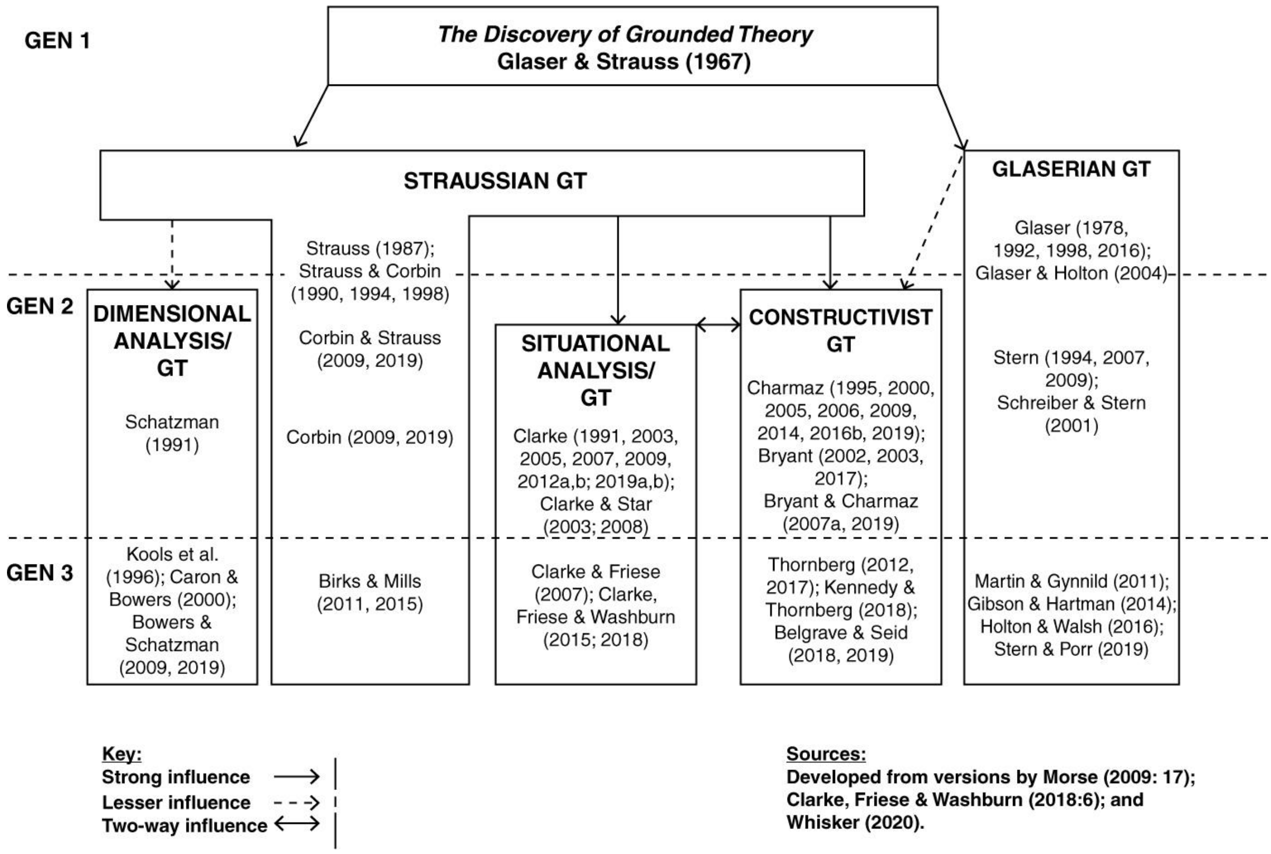
Qualitative approaches to collection and interpretation of data make the researcher as much a part of the process as the participants and data provided (Corbin & Strauss, 2013). Grounded theory is unique, in that the concepts which are used to develop theory are derived from the collected data during the research process and not chosen prior to the research (Charmaz, 2014; Corbin & Strauss, 2013; Urquhart, 2023). Instead, comparisons from different and diverse examples are exploratory and creative to lead the researcher to new ideas, not only to test an existing hypothesis (Gibson & Hartman, 2014).

3.3.1. The origin of grounded theory

Grounded theory was initially developed by sociologists Glaser and Strauss (1967) as a systematic strategy to approach qualitative research (Gibson & Hartman, 2014). They moved beyond earlier positivist approaches to qualitative research, and attempted to develop theories grounded in data, rather than deducing hypotheses chosen prior to starting the research (Corbin & Strauss, 2015; Urquhart, 2023). Traditional grounded theory methodology aimed to develop a theory from collected data which explained a subject in new theoretical terms and demonstrated the causes and conditions which influenced the topic, and explained the consequences (Glaser & Strauss, 1967). Glaser had a background in qualitative analysis which brought a rigorous approach to coding qualitative data, whereas Strauss embraced pragmatist traditions and the perspective that assumes reality is constructed through dynamic interactions and interpretative to address how people create meaning and actions (Charmaz, 2014).

Glaser and Strauss fought the dominance of positivistic quantitative research in the 1960's, but classical grounded theory later became known for its rigour and positivistic assumptions Initially, grounded theory was positivist in approach, aiming to minimise subjectivity, and emphasising generalisation, explanation and prediction based on observed facts (Charmaz, 2014). Although the approach was widely used in qualitative and mixed methods research, several researchers moved away from the earlier positivism seen in original grounded theory and adapted and evolved the method into many newer approaches (Charmaz, 2014; Urquhart, 2023). Since positivism represented only one way of accomplishing scientific work, second generation grounded theorists were concerned about limitations and decontextualization of early grounded theory methods (Bryant & Charmaz, 2007; Clarke, 2005, Charmaz, 2014). These second and third generation approaches developed from the original methodology (Charmaz, 2014; Corbin & Strauss, 2015; Urquhart, 2023), each with a variety of procedures and rules, and some approaches were constructed in opposition to each other (See Figure 3.1) (Clarke, 2019).

Figure 3.1: Genealogy of grounded theory (Clarke, 2019) (Reproduced with publisher permission).



Most grounded theory (GT) methods use an inductive process, with overlapping data collection and analysis (Urquhart, 2023), and although there are a variety of approaches, most use similar language regarding analysis (Gibson & Hartman, 2014; Urquhart, 2023). Most GT approaches focus on a constant comparative approach to data, and the approach taken will be influenced by differences in epistemological and ontological perspectives of the researcher (Urquhart, 2023). Classic grounded theory emphasised openness and flexibility, and focused on broad comparisons (Glaser and Strauss, 1967). This constant comparative method looked for similarities in data, and identified patterns which are most important to participants, rather than a context selected by the researcher (Urquhart, 2023).

Grounded theorists can have different standpoints and conceptual agendas, but all begin with inductive logic, apply rigorous comparative analysis, and value grounded studies to inform policy and practice (Charmaz, 2014). Researchers are required to recognise multiple perspectives and must listen to their participants objectively. The main distinction between grounded theory and other qualitative research methodologies is the use of simultaneous data collection and analysis, and emphasis on the continual comparison between the data collection and data analysis throughout the research process (Corbin & Strauss, 2013; Urquhart, 2023). Consideration of personal contexts and philosophical assumptions were essential as there were close professional similarities between the researcher and participants, (DePoy & Gitlin, 2005; Plano Clark & Ivankova, 2016).

3.3.2. Constructivist grounded theory

Kathy Charmaz (2000, 2006, 2008, 2014) become dissatisfied with methodologies which ignored researcher subjectivity and portrayed analysis as accurate renderings of the world rather than constructions of them. She argued that objectivity is not possible and instead emphasised the co-creation of theory between researcher and participants. Charmaz (2014) further developed original grounded theory to consider relativity, the importance of acknowledging researcher subjectivity, and engagement with reflexivity. Constructivist grounded theory embraces subjectivity and aligns with social constructivism (the idea that knowing and learning are imbedded in social life), and the ideas of Lev Vygotsky (1962) and Yvonna Lincoln (2013), who stressed social context, sharing viewpoints, interaction, and interpretative understandings (Charmaz, 2014; Urquhart, 2023). Her use of the term "constructivist" relates to the involvement of the researcher in the construction and interpretation of data, and the subjectivity of this process.

Charmaz (2014) argued that although some grounded theory strategies are like other inductive qualitive research methods, using inductive data to construct abstract analytic categories through iterative processes differs from the usual practice of sorting topics in general approaches to qualitative research. Constructivist grounded theory adopts the inductive, comparative, emergent and open-ended approach of the original method, but highlights the flexibility of the method, and assumes that social reality is multiple and constructed – therefore the researcher's perspective and interactions are considered as an inherent part of the research reality (Charmaz, 2014). Viewing research from this perspective fosters researcher reflexivity about actions and decisions (Charmaz, 2014), and this formed an important element of this whole research process, which is further explored in Chapter 6 (Reflexivity).

This approach allows examination of topics and ideas from different perspectives, which enables the researcher to gain a comprehensive understanding of their research, which can change and be updated as new knowledge is acquired (Corbin & Strauss, 2015). In contrast to earlier approaches to grounded theory, Charmaz (2006; 2014) applied constructivist paradigms to grounded theory methods, which assumed that neither data nor theory were discovered but were instead constructed by the researcher based on their interactions with people, perspectives, and research practice.

A key benefit of constructivist grounded theory method is the idea of emergence, where the researcher builds theory from the data rather than relying on imposing existing frameworks (Urquhart, 2023). Researchers must consider all the variations in the data and conditions associated with these variations; meaning is unique to individuals, and the report is an analytical product rather than a descriptive account (Hood, 2007). The researcher constructs analytic codes and categories from data (rather than from preconceived hypotheses), and constant comparison during each stage of analysis allows theory development during each stage of data collection and analysis (Charmaz, 2014). To achieve this, the researcher must be sensitive to the underlying meaning of the data (Thistoll, Hooper & Pauleen, 2016), which allows concepts to be fully understanding of emerging categories (Urquhart, 2023).

Grounded theory uses structured data gathering and analytical processes, but it is still flexible enough to allow exploration of the diversity of experiences within categories, and identification of links among data categories (DePoy & Gitlin, 2005). Gibson & Hartman

(2014) argued that methodology used by Charmaz was weaker than the original approaches by Glazer and Strauss, worrying that constructivism would compromise the openness, ideas, and direction of research. The research topic is important when choosing one GT approach over another: if there is a set topic from the outset of the research, and the design includes semi-structured interviews to guide conversation, then co-construction using constructivist GT is ideal (Charmaz, 2014; Gibson & Hartman, 2014).

The research reality arises within individual situations, and includes what participants and researchers bring to it (Clark, 2007). Acknowledging that research is constructed rather than discovered allows reflexivity about actions and decisions during the research process (Charmaz, 2014). This constant comparative approach was not linear, and allowed collected data to be reviewed, compared, and contrasted with other information, and from this process, commonalities and dissimilarities among categories emerged, which then allowed the development of theories that explain the findings (Charmaz, 2014; DePoy & Gitlin, 2005). One criticism of grounded theory methodologies is that they take longer than other qualitative approaches, but Urquhart (2023) argued that this provides a depth of analysis and completed memos that allows for an easier write up process.

Constructivist GT is an iterative, interactive, and comparative approach to theory generation, which provides insight into new areas of enquiry and complex topics (Urquhart, 2023. It provides a framework that analyses data logically to identify patterns and builds with these to identify a core category (Charmaz, 2014). This allows the researcher to select the most important aspects within their data and to examine how aspects of the collected data relate to each other. Development of a theory helps the researcher to understand how things in the world are related, and can enable “predictions” about the world, however the process of achieving this can be highly variable depending on the research topic (Urquhart, 2023).

Theory can enable predictions about how things are related and provide potential to change the world in some way, but grounded theory is developed mostly to explain ‘what is going on’ in a particular field or area of human endeavour (Gibson & Hartman, 2014). Grounded theory is a perspective on how to build theory that is constructed from the perspective of the participants by studying how people experience and resolve their everyday problems (Gibson & Hartman, 2014). This should allow the researcher to explore how simulation is used in sonographer education, what people experience, and the benefits and challenges associated with it.

3.4. Study design

A constructivist grounded theory approach, which acknowledges that the research is inevitably influenced by the researcher's experiences and background was used (Charmaz, 2016; Charmaz, 2008; Urquhart, 2023). This structured approach allowed the researcher to respond to findings throughout the research process (DePoy & Gitlin, 2005), rather than the researcher imposing predetermined meanings to the data collected (Charmaz, 2006; Crotty, 1998). Assumptions are basic principles which are accepted as true based on logic without verification, and researchers must consider and explain their own assumptions in research (McIntosh-Scott et al., 2014). By applying grounded theory methods to the early stages of a research study, the researcher can acquire and develop theoretical sensitivity within a chosen field of research in advance of undertaking primary data collection (Thistoll et al., 2016). This approach is well supported as grounded theory has developed and evolved (Strauss, 1987; McGhee; Marland & Atkinson, 2007; Charmaz, 2014).

This research used a phased sequential design (Table 3.1), with each phase informing the development of the next (O'Cathain et al., 2007) to allow the concepts to develop as the research progressed. As discussed in Chapter 2, the timing of the literature review in grounded theory studies is a matter of debate amongst researchers. Completion of an initial systematic search and review enabled the researcher to develop theoretical sensitivity and identify the problem to inform the development of the research question, aims and objectives (Urquhart, 2023). Since a grounded theory approach is not linear, with data collection, analysis and theorizing occurring in parallel (McGhee, Marland & Atkinson, 2007), the initial literature was repeated and expanded following data collection to include more recent literature and to investigate relevant topics emerging from data analysis. Additional literature emerging from these searches was incorporated into the discussion (Chapter 4).

A phased study design using semi-structured interviews and theoretical sampling enabled the development of a thorough understanding of the complexities inherent in this research topic (Charmaz, 2014; Creswell & Clark, 2011; Plano Clark & Ivankova, 2016). Interviews were selected over focus groups to enable easier theoretical sampling, and to minimise any peer influence which could have biased the findings. Interviews also allowed the researcher to elicit detailed responses and explore topics based on participant individual responses.

Table 3.1: Summary of research design

<table>
<tr><td colspan="2">Initial search and review of literature</td><td>Involved a comprehensive literature search and allowed synthesis of best evidence (Grant & Booth, 2009) to investigate the role of simulation in sonographer education and inform the ethical approval application and development of the interview schedules.</td></tr>
<tr><td>Phase 1</td><td>Qualitative semi-structured interviews:
Educators (n=7)</td><td rowspan="2">Explored concepts emerging from earlier phases of the research to seek in-depth perspectives from a variety or perspectives on the role of simulation in sonography education.
A theoretical sample of a wide variety of participants ensured that a variety of views were obtained (Hennick et al., 2017).</td></tr>
<tr><td>Phase 2</td><td>Qualitative semi-structured interviews:
students (n=7) and stakeholders (n= 7)</td></tr>
<tr><td>Phase 3</td><td colspan="2">Data analysis and theory development to inform curriculum design, and development of effective teaching and learning strategies for the use of simulation for sonographer education.</td></tr>
</table>

3.4.1. Theoretical sampling

Constructivist grounded theory uses theoretical sampling, which unlike conventional sampling methods, is concept driven, rather than aiming to achieve population representativeness (Charmaz, 2014; Urquhart, 2023). It is open and flexible to enable the researcher to follow the lead of the research and direct sample selection and collection of rich data to best inform the developing theory (Charmaz, 2014; Corbin & Strauss, 2015; Urquhart, 2023).

The iterative process of grounded theory allowed the researcher to gain ideas and define patterns during the research process. As analytic categories emerged, theoretical sampling allowed the researcher to narrow focus and refine ideas. In this research, initial plans were to interview educators and students, however during the research this changed to deliberately include a range of stakeholders. This allowed the researcher to check ideas and to further explore initial categories and to develop links between categories (Charmaz, 2014). A potential limitation of theoretical sampling is the potential restrictions of ethical approval, since researchers cannot anticipate what their core categories are beforehand (Charmaz, 2014), but this was easily overcome by seeking amendments to the initial ethical approval twice during the research process (See Appendix 1).

Theoretical sampling is emergent and allows researchers to improve their data through increasing the precision of categories, providing the substance to move from description to analysis, and to develop theory which is more formal and at an abstract level across different areas (Charmaz, 2014). Exploration of participants' views and experiences allowed the researcher to develop a better understanding of how people interpreted and experienced simulation learning. Theoretical sampling was used to focus and inform the constant comparative data analysis (Birks & Mills, 2015) and allowed the researcher to iteratively explore and evaluate the role of simulation in sonographer education.

3.4.2. Sample size

There is no consensus on how many interviews should be conducted in a grounded theory study (Charmaz, 2014; Urquhart, 2023). Sampling to saturation is often required in qualitative research (Green & Thorogood, 2014), but a small number of participants is potentially adequate (Guest et al., 2006), and sampling strategy should be determined by the purpose of the research (Britten, 2006; Urquhart, 2023). The number of interviews depends on the analytic level to which the researcher aspires, as well as the need to following emergent ideas during the research process (Charmaz, 2014).

Guest et al. (2005) proposed that 12 interviews are sufficient for most researchers if they are examining a relatively homogeneous group. However, for a more heterogenous sample where interviews are the only source of data, and the researcher is seeking professional credibility, this number is unlikely to be sufficient (Guest, Bunce & Johnson, 2005). Charmaz (2014) suggested that for greater professional credibility, a larger number of interviews are required to construct complex conceptual analyses or use interviewing as your only source of data. For this research, 21 individual interviews were conducted across three participant groups (educators, students, and stakeholders).

3.4.3. Recruitment

Invitations to educator and stakeholder participants in the research were sent by publicly available professional email addresses. Invitations for student participants were circulated on social media and through invitations from course leaders which were shared with their student groups. A summary of participant characteristics is included in Table 3.2.

At the outset of this project seventeen institutions offered accredited programmes for sonographer education in the UK (CASE, 2017), which limited the number of potential participants for this research. Theoretical sampling enabled the researcher to make strategic decisions about what or who would provide the most useful data to meet the analysis needs (Birks & Mills, 2015; Charmaz, 2014; Urquhart, 2023). Inclusion of key professional organisations and leaders within NHS trusts who train sonographers provided valuable insight and a variety of perspectives on this topic. Although efforts were made to include additional perspectives from the CASE committee, no additional participants responded to invitations to participate. Several of the stakeholder and educator participants held roles as CASE committee members or accreditors, therefore this was the only available route to include this organisation in the data collection.

Table 3.2 Summary of participants (Total: 21 interviews)

Phase 1: Educators *= identified as E1- E7*		
1	Educator HEI 1: Part time MSc and BSc students	August 2020
2	Educator HEI 2: Part time and full time MSc students	March 2021
3	Educator HEI 3: Part time MSc students	July 2021
4	Educator Academy 1: Part time MSc students	October 2021
5	Educator Academy 2: Part time MSc students	November 2021
6	Educator HEI 4: Full time and part time MSc students	January 2202
7	Educator HEI 5: Part time MSc students	January 2022
Phase2: Students = identified as St1 - St7		
1	Part time MSc student	September 2022
2	Full time MSc student	September 2022
3	BSc student	September 2023
4	BSc student	September 2023
5	BSc student	September 2023
6	BSc student	September 2023
7	Part time MSc student	September 2023
Phase2: Stakeholder group = identified as Sr1 – Sr7		
1	Researcher, sonographer, educator	February 2022
2	BMUS officer/Consultant Sonographer/Clinical supervisor	March 2023
3	Clinical training lead sonographer (NHS trust, England)	March 2023
4	ICB Regional Lead/Academy lead	May 2023
5	SCoR representative	May 2023
6	Consultant sonographer/Training lead (NHS Trust, England)	June 2023
7	Simulation manufacturer: Design team lead (sonographer)	October 2023

3.5. Ethical Considerations

The Declaration of Helsinki is a cornerstone document and was the first internationally accepted code of ethics in medical research (WMA, 2024). The guidance sets out ethical principles for research involving human participants, emphasizing respect for individuals, their rights, and their welfare. University policies (SHU, 2023) require researchers to ensure the highest standards of rigour and integrity, and that all aspects of research are conducted according to appropriate ethical, legal and professional frameworks, obligations and standards.

Ethical considerations were key to all stages of this research, and consideration was given to professional codes of conduct and ethics, institutional ethical requirements, and internationally accepted practice (Cresswell, 2007; Urquhart, 2024; WMA, 2024). Ethical approval was gained from Sheffield Hallam University Ethics Committee (Application ID: ER21930888) to ensure that research was conducted to the highest standards. This ethical approval process is a standard expectation for all research conducted by university students and staff, and this process was useful to allow the researcher to gain an early understanding of the selected methodology, as well as providing an opportunity to benefit from objective peer review of research design early in the research process (Urquhart, 2023).

Key ethical issues included the need for voluntary participation and informed consent; both required consideration of respect for individuals, beneficence, and justice (King et al., 2019). Ethical approval was initially sought to interview educators, followed by two separate amendments for student and stakeholder interviews. Detailed documentation relating to ethical approval processes, consent and participant information sheets are provided in Appendix 1.

3.5.1. Informed consent

In line with the expectations of ethical research processes, informed consent was sought (Urquhart, 2023), and participants were aware of their right to decline to answer any question, and their right to withdraw. It must be acknowledged that participants are volunteers, and their belief systems or values may differ from those of the researcher, therefore every effort was made to obtain consent, maintain confidentiality, and ensure that participants were treated respectfully (Corbin & Strauss, 2015; Urquhart, 2023). Beneficence refers to the responsibility of the researcher to ensure the wellbeing of participants (King et al., 2019).

To ensure participants did not feel compelled to participate, invitations were sent to institutional email addresses only, and care was taken to recruit student participants who were not being taught or assessed by the researcher at the time of data collection.

The research was not investigating a sensitive or controversial topic, and it was unlikely that there could be any emotional harm to participants. Written consent was obtained prior to interviews using approved institutional templates. Ensuring participants give consent prior to interviews is a key step in ethical research to ensure respect for participants is maintained.

Stark & Hedgecoe (2010) raised concerns that prior knowledge of the study aims might influence participant responses, but informed consent cannot be obtained unless participants are clearly informed on the purpose of the research. However, to minimise potential bias, and to encourage honest responses, interview questions were not provided in advance. Participant information sheets clearly explained how data would be used, and participants kept these as a record of their participation (Green and Thorogood, 2014; Urquhart, 2023), however the research is low risk to both the researcher and participants and did not investigate distressing issues (Booth & Brown, 2010). Participants had opportunities to ask questions in advance and following each interview. Contact details of the researcher, project supervisor and ethics committee were provided on all participant information sheets (Stark & Hedgecoe, 2010).

3.5.2. Confidentiality and anonymity

Researchers must ensure that the information participants provide in the study remains confidential and will not be revealed as belonging to them personally (Stark & Hedgecoe, 2010). Participant identities and any identifiable information was anonymised as early as possible in the processing of data to safeguard against accidental disclosure (Corti et al., 2014). Confidentiality of data was maintained, and participants were assigned participant numbers to ensure anonymity (Corti et al., 2014).

A range of high-profile stakeholders were invited to participate, so it was possible that they might be identifiable, therefore great care was taken to ensure that participant quotes could not be attributed to specific individuals. The research topic was not of a sensitive nature, but participants were reminded that anonymised data might be used in subsequent publications (Corbin & Strauss, 2015), including selected quotes to illustrate points in the thesis.

3.6. Data collection

A grounded theory approach allows simultaneous collection, transcription, and analysis of data (Urquhart, 2023). Grounded theory can be applied to interviews, observations, or documents (Charmaz, 2014; Urquhart, 2023), but this research exclusively used individual interviews for data collection.

3.6.1. Interviews

Qualitative research interviews are flexible and open-ended and tend to focus on participant experiences and opinions (King et al., 2019). Advances in technology have provided opportunities for online research in social sciences for many years (James & Busher, 2009) with online videoconferencing platforms now widely used, particularly since the social distancing measures imposed during the pandemic (Foley, 2021). For modern researchers and participants, video-based online interviews are arguably more convenient, more easily accessible and have lower financial costs than the requirement to be physically present in an in-person interview (Foley, 2021, Weller, 2017). A potential limitation of online interviewing in qualitative research is lack of access to necessary equipment or internet (Foley, 2021), but this was not an issue in this research, as the participants were familiar with, and had reliable access to software and internet through their work or University IT accounts. Further benefits of this approach were that there was less impact on data collection during COVID-19 restrictions, and it allowed easy access to participants over a wide geographical area.

Establishing a good rapport with participants was essential to ensure that they felt comfortable and willing to disclose honest opinions (Braun & Clarke, 2013), essential to assure the trustworthiness and credibility of the research (Urquhart, 2023). Qualitative interviewing seeks to be fluid and flexible, thus having to accurately predict consequences is not always possible (King et al., 2019). The relationship between researcher and participant is crucial, enabling exploration of what is said in as much detail as possible to uncover new ideas. This requires researcher skill in ensuring that they control the interview, but do not dominate it. Rapport and observation between interviewer and participant in video-based online interviews may be more challenging, in comparison to traditional in-person interviews (Weller, 2017). However, others argue that there is little evidence to support that online rapport building is more difficult than traditional in person interviews (Foley, 2021).

Individual interviews were conducted online using the Zoom platform. A semi-structured approach using an interview guide provided control but also flexibility to immediately follow up on ideas or issues arising during interviews (Charmaz, 2014). Interview guides were tailored to suit each participant group, for example questions for student participants differed to those asked of stakeholders or educators (See ethical approval documentation in Appendix 1). These interview guides were based on a loose structure consisting of topic areas or open-ended questions that defined the areas to be explored initially, and from which the interviewer or interviewee could diverge to pursue ideas or responses in more detail (Britten, 2006; Corbin & Strauss, 2015). A semi-structured approach allowed the interviewer to introduce further topics as they became familiar with the topics being discussed (Britten, 2006). Planned questions allowed smoother, less confrontational questioning, and ensured the researcher was aware of their own interests, assumptions, and use of language (Charmaz, 2014).

The use of an interview guide and ensuring reflexivity was essential throughout the research, since emphasis, pace and tone of questioning can influence responses, or asking the wrong questions can fail to identify key issues in participant experiences (Charmaz, 2014). Questions were carefully written and asked slowly and clearly to allow participants time to reflect and respond (Charmaz, 2014), and opportunities were provided for participants to add or explore topics further to ensure that the researcher was not imposing pre-conceived interests on the interview. Interview questions were designed to be open-ended, neutral, sensitive, and clear to the interviewee, and each interview began with questions that the interviewee could answer easily, and later proceeded to potentially more difficult questions (Britten, 2006). Use of an interview guide which included introductions, prompts and well-planned, open-ended questions provided a sense of structure and control. This increased confidence and allowed the researcher to focus on what the participant was saying (Charmaz, 2014). Field notes and memos were also recorded as soon as possible following each interview.

In constructivist grounded theory, intensive interviewing is typically employed to study specific topics in which participants have extensive experience (Charmaz, 2014). Interviews are complex situations, and the interviewing approach may need to change as studies develop, so this flexible approach provided results from interviewers and interview participants co-construction of the interview conversation (Charmaz, 2014). Intensive interviewing is a gently guided conversation that explores participant experiences and perspectives in depth (Charmaz, 2014), allowing the interviewer to ask for in-depth descriptions of experiences, thoughts, feelings, and actions. This approach also allowed the researcher to stop and explore a topic further, or to request more detail in a respectful way (Charmaz, 2014). Since interviewers and interview participants have their own priorities, knowledge, and concerns (which may not always be compatible), Charmaz (2014) encouraged the flexible application of intensive interviews to allow exploration of ideas, guidelines and concerns in a way that would suit participants. During the interviews participants talked, and the interviewer listened, encouraged, and learned.

Intensive interviews allowed information gathering, which aimed for accurate detail alongside uncovering participant actions, intentions and practices and their implications (Charmaz, 2014). As this grounded theory study progressed, interview approaches changed to accommodate the situations and needs of the participants (Charmaz, 2014). This approach focused on participant statements about their own experiences and what this meant to them, therefore the researcher had to be self-aware about why and how data is collected to effectively understand language, meanings, actions, emotions, and body language of participants during each interview (Charmaz, 2014). This approach combined flexibility and control, and allowed for exploration of ideas and issues, which resulted in the conversation being a co-construction between the interviewer and participant (Charmaz, 2014).

3.6.2. Recording and transcription

With participant consent, interviews were video and audio recorded using the online meeting tools, alongside a backup audio recording using a digital recorder. Participants were reassured that anything they said was confidential, any identifying information was removed from transcriptions and notes, and once the transcription was completed and checked, anonymised recordings were archived securely. Although topics discussed were not sensitive, to ensure participants felt comfortable and able to be open, an opportunity was offered to speak freely without being recorded. This is good practice in qualitative interviews and can help build trust between the researcher and participants, leading to more honest and detailed responses (Rutakumwa et al., 2020). Several stakeholder and educator participants choose to add further details which they felt might be controversial when they were not being recorded.

Interviews were transcribed verbatim, but names of people, places, or any other potentially identifiable data were excluded to ensure confidentiality was maintained. Transcription is always a time-consuming and demanding task (King et al., 2019). Initial interviews were transcribed by the researcher, but due to time constraints and to reduce demands on the researcher, all subsequent interviews in the project were transcribed by a university approved confidential transcription service using anonymised audio files. King et al. (2019) noted that the consequence of transcription services is that the researcher may not develop the same familiarity with the data, however the line-by-line initial coding process, and concurrent data collection and analysis ensured that the researcher quickly gained familiarity with the data. All transcripts were anonymised prior to sharing with the transcription company in Microsoft Word format, in password protected files. Accuracy checking of transcripts was completed by the researcher, and member checking was offered to participants as a credibility check.

3.6.3. Data Management

University policies and procedures promote ethical standards for good research practice and ensure the highest standards of integrity, impartiality, and respect for data. Effective research data management through the research life cycle is a key component of good research conduct and contributes to a culture of research excellence (SHU, 2019). A data management plan was submitted alongside ethical approval applications (Appendix 1).

Online interviewing requires consideration of privacy, confidentiality, and security of information; however, professional video-conferencing platforms operate securely (Foley, 2021). Zoom (2021) provided a secure, reliable cloud platform for videoconferencing, which allowed easy access through mobile devices, computer, or telephone. The platform provided robust security features to ensure safe and secure communication, including secure and encrypted meeting information, advanced encryption for secure communication and meeting access and recording (Zoom, 2021). Interviews were audio recorded (with consent) using secure recording functions in Zoom, as well as on a separate a digital recorder as a backup. This enabled the researcher to focus on the participant and their responses (rather than having to take detailed notes during each interview). Upon completion of each interview, recordings were downloaded and stored using files labelled by participant ID number and interview date. These were stored on an encrypted research site file on the university server. The digital recorder was kept in a secure home office, to which only the researcher had access. Backup audio recordings were deleted from the digital recorder once the digital audio file was checked and functioning correctly.

Although participants were offered an opportunity to withdraw prior to analysis, none requested to do so. Consent forms and ethical approval documentation are not typically stored on the University Research Data Archive, and these were archived in the researcher's confidential research drive where they will be stored for three years after completion of the research.

Anonymised transcripts were stored on a secure university encrypted, cloud-based server, in line with the UK Data Service (2025) recommendations. Research data is a valuable asset, and the University advocates that research data should wherever possible be made openly available for use by others in a manner consistent with relevant legal, ethical, disciplinary and regulatory frameworks and norms (SHU, 2019). Good research data sharing and management means that research is more transparent and easily scrutinised, easy to re-use or build upon, and fosters a collaborative and efficient approach to research (UKRI, 2024). Therefore, as part of the consent process, participants were asked for permission for anonymised interview transcripts to be stored securely for re-analysis in any relevant future research projects at Sheffield Hallam University. Research data archiving policies were considered to ensure safe keeping and confidentiality, and Sheffield Hallam University Research Data Archive (SHURDA) research data preservation policy (SHU, 2024) requires transcripts to be retained for at least 10 years from the date of deposition, after which they will be permanently deleted. This will ensure the integrity of the research by allowing only approved parties to access the data to verify the research output. This is not accessible externally to ensure the anonymity and confidentiality of participants.

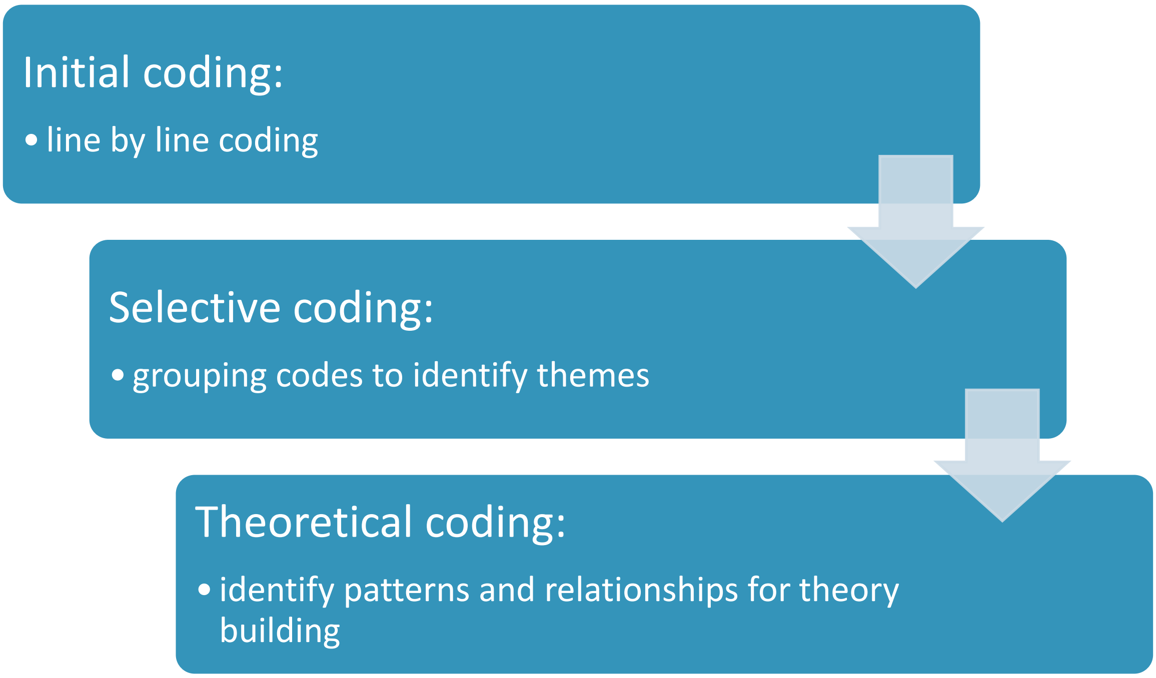
NVIVO-12 (Lumivero, n.d.) software supports management and analysis of qualitative data, and provides tools that allow researchers to efficiently manage, organise and analyse qualitative data. As well as interview transcripts, the software facilitated recording of memos and diagrams so they could be easily integrated into the analysis and theory generation. Memos were created and managed within the NVIVO 12 software in a password protected encrypted project file.

Information regarding potential publication was provided on the participants' information sheet and consent forms. All data used within the PhD thesis, conference presentations or subsequent publications is fully anonymised.

3.7. Data Analysis

Analysis in grounded theory methods is not a linear process, but instead uses a constant comparative approach, with some variation in the terminology and number of stages in coding procedures (Urquhart, 2023). NVivo12 software was used to support review, coding and analysis of the qualitative data obtained (NatCen, 2016). Charmaz (2014) suggests initial open coding, focused coding, optional axial coding, and theoretical coding. Axial coding was not included as part of the process of this research, as it imposed a fixed framework and procedure during analysis, which was complex and lacked the flexibility required to allow the researcher to understand the data in a more emergent way (Charmaz, 2014; Urquhart, 2023). A summary of the coding process used in this research is presented in Figure 3.2. Theoretical frameworks (used in many types of qualitative research) are not encouraged during the analysis phase of a grounded theory study, but comparisons between emerging and existing theories may be appropriate to explore similarities and differences between theories in later stages of the research process (Corbin & Strauss, 2015; Charmaz, 2014; Urquhart, 2023).

Figure 3.2 Coding process (Adapted from: Charmaz, 2014)



Data were analysed using constant comparative analysis, with continued collection and analysis of data based on concepts derived during the research. This is a typical approach in grounded theory, where each data collection session is followed by some analysis. Integration of analysis and collection provides direction for the researcher and allows the researcher to avoid becoming overwhelmed by huge volumes of data (Corbin & Strauss, 2015; Urquhart, 2023). This concurrent collection and analysis of data was used throughout the research process until the grounded theory was fully integrated (Birks & Mills, 2015).

Grounded theory methods enable the researcher to reach down to fundamentals during initial coding, explore experiences during focused coding, and reach up to abstraction during theoretical coding processes (Charmaz, 2014). The continuous comparative process enables the researcher to ask questions, see possibilities and establish connections in their data. This inductive approach of building theory from the data itself has been a core principle from the beginning of grounded theory methods (Glaser & Strauss, 1967), however more recent evolutions of grounded theory make more use of abduction during the analytic process (Birks & Mills, 2015). Abduction leads researchers to go beyond induction and requires consideration of all plausible explanations for the data with a critical stance toward the emerging theory (Charmaz, 2014). Abduction builds on the pragmatist tradition of problem-solving, where reasoning and making inferences about the data is used to allow the researcher to raise questions, push ideas and inform theoretical sampling during the research process (Charmaz, 2014).

3.7.1. Initial coding

Open coding was first introduced by Glaser (1978), and this remains a key step in constructivist GT methodology, where initial 'line by line' coding allows detailed consideration of the data without imposing any preconceptions (Charmaz, 2014; Urquhart, 2023). This stage is deliberately "open" and allowed the researcher to attach initial labels and develop in-depth knowledge of the data. Open coding initially allowed data to be broken down into manageable pieces, which were then regrouped into categories (higher level coding) used to build a theory (Corbin & Strauss, 2015; Charmaz, 2014).

Initial codes are provisional, comparative and grounded in the data (Charmaz, 2014). It should be acknowledged that the interpretation of data is a complex process, and the researcher used reflexivity throughout this research to ensure they remained conscious of how they developed their own interpretations and how their past experiences might have influenced their analysis (Corbin & Strauss, 2015; Charmaz, 2014). (See Chapter 6: Reflexivity).

The process of careful line-by-line coding prevented the researcher from becoming too immersed in individual participant views and helped to separate the data into initial categories which were not influenced by the researchers' own views or experiences (Charmaz, 2014). Coding entire transcripts provides ideas and understandings that researchers may otherwise miss (Charmaz, 2014). Constant comparison is used at all stages of the analysis, initially to find similarities and differences, and later to test ideas emerging during analysis (Charmaz, 2014).

3.7.2. Focused coding

The second stage of analysis uses focused coding, to identify most significant or frequent codes, and to begin to make analytic sense of the categories emerging in the data (Charmaz, 2014). At this stage, definite themes began to emerge in the data (Urquhart, 2023), and this grouping of initial codes into larger codes contributed to theory building (Urquhart, 2023).

As the project progressed, continuous comparison became more complex, and the researcher used a variety of data visualisation tools available in NVIVO to identify common terms and coding density across transcripts (See Appendix 2). Word frequency and coding frequency tools were useful to review data for each participant, as well as the whole data set. Alongside reflexivity and oversight by the supervisory team, this provided assurance that the researcher remained unbiased in their approach to interviewing and analysis, since different participants had different areas of focus in their interviews. Hierarchy charts were also useful to provide an overall view of the data set and coding patterns, and this proved useful for data sorting and identifying key themes during analysis.

3.7.3. Memo writing

A key element of grounded theory generation is the use of memos throughout the research process to document thought processes and facilitate growth of ideas to move the analysis forward (Corbin & Strauss, 2015; Charmaz, 2014; Urquhart, 2023). Memo writing was a key step between data collection and write up of research findings and was crucial in grounded theory to prompt early analysis of data. This process allowed the researcher to make comparisons, and to document cumulative and complex ideas that evolved throughout the research process (Corbin & Strauss, 2015; Charmaz, 2014).

Memo writing was extensively used during the write up stages to force questioning and identify gaps. Creating memos throughout the research process ensures the researcher develops their ideas during analysis, increases the level of abstraction and idea generation throughout the research process, and provides a record of theory construction (Charmaz, 2014). Grounded theorists have different approaches to memo writing but Charmaz (2014) advocates writing memos in informal language for personal use which should initially be free and flowing, with increasing analytic content as the research progresses towards theory generation (Charmaz, 2014). Memo writing allowed comparisons and helped to identify patterns in the data. They can be written informally and remain private, preserving the researchers natural voice (Charmaz, 2014). Memo writing allowed exploration and discovery of ideas and helped clarify and direct analysis and organisation of codes and categories throughout the research process. Alongside memo writing, a research journal was used to record dilemmas, directions and decisions and was useful to avoid preconceptions during analysis and raise questions relating to the data (Charmaz, 2014).

3.7.4. Theoretical sensitivity

Theoretical coding is a sophisticated level of coding, where the researcher began to relate codes to each other, and patterns and relationships between codes facilitated theory building (Urquhart, 2023). Charmaz (2014) cautions against imposing existing frameworks on the data to maintain objectivity, and aligned with her approach, the researcher was careful to use reflectivity throughout the analysis (See Chapter 6), and the analysis emerged from participant data (Charmaz, 2014). According to Glaser and Strauss (1967), theoretical sensitivity is deeply personal to the researcher, reflecting their intellectual history as well as their own level of insight into themselves and their area of research. Researchers are a sum of their personal experiences, and the concept of theoretical sensitivity accounts for this in the research process (Birks & Mills, 2015). Theoretical sensitivity is the ability to understand phenomena and the relationships between concepts (Charmaz, 2014). As the researcher collects and becomes immersed in more data, their theoretical sensitivity increases (Birks & Mills, 2015; Charmaz, 2014). Early applications of grounded theory advocated the use of coding families, but Charmaz (2014) advises avoiding existing frameworks, and instead avoiding preconceptions and allowing themes to emerge from the data in a more open way.

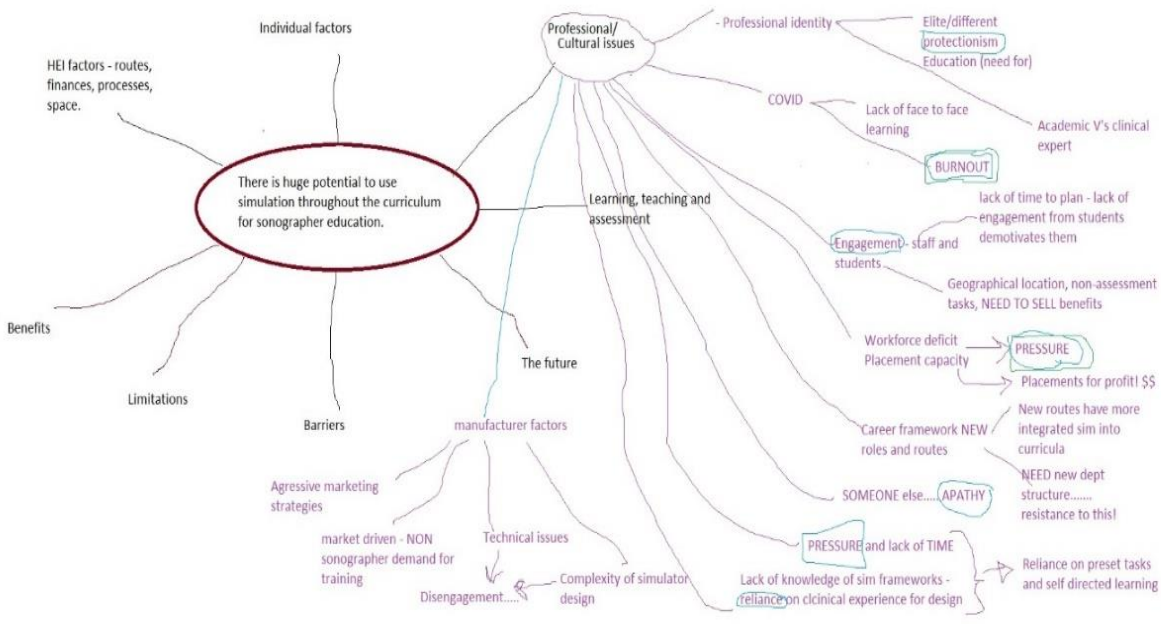
One of the key benefits of grounded theory is that the data was not shoehorned into any preconceived analytical frameworks (Urquhart, 2023), but for a novice researcher, the volume of data can become overwhelming. It is important to ensure that the categories emerge from the data, not from the researcher’s pre-conceived ideas, therefore the developing categories were reviewed with the project supervision team as categories emerged and theory was developed. All qualitative researchers use methodological strategies such as sorting, diagramming, and integrating materials, however grounded theorists use these strategies to facilitate theoretical development of analysis (Charmaz, 2014).

3.7.5. Theoretical integration

Theoretical integration allowed the researcher to relate their theory to other theories in the literature (Urquhart, 2013), which is as an essential component of good scholarship. This allows assessment of the contribution of a theory, by reviewing how it might extend or challenge other literature. This approach is a long-standing element of grounded theory methodology, where Glaser stressed theoretical sensitivity was attained by reading widely (Urquhart, 2023), and this was achieved through the repeated and extended literature review completed after data collection was completed. This approach allowed researchers to review how their work related to existing literature, and how their work extended or contradicted the evidence base (Urquhart, 2023).

As part of the theoretical phase of analysis, theoretical sorting, diagramming and integration of memos were conducted simultaneously. Sorting through the data allowed the researcher to organise the analysis and make comparisons (Charmaz, 2014). As ideas emerged, diagramming provided a visual representation of the data which helped to define categories in the data prior to theory development (See example in Figure 3.3).

Figure 3.3 : Example of diagramming during early analysis



3.7.6. Saturation

Hood (2007) viewed theoretical sampling as a crucial criterion for grounded theory studies. It is a circular process, which continues until saturation, when no new concepts are emerging and all major categories in the research are fully developed (Corbin & Strauss, 2015; Urquhart, 2023). In simple terms, saturation is reached when there are no new theoretical insights related to the core categories (Charmaz, 2014), but sample size is an important consideration in research design, and there is a lack of consensus on how saturation is achieved. Glaser (1992) argued that sampling continues until categories are saturated, even if the sample size is small. However, Mason (2010) argued that sample size and saturation must consider the skill of the researcher and quality of data obtained during the research process.

Theoretical saturation is what grounded theorists aim for, and this is an individual researcher judgement (Charmaz, 2014). Researchers must also consider practical matters such as time and funding, and more than one phase of data collection can be beneficial to achieve saturation (Charmaz, 2014). In this study there were two phases of data collection. No new codes emerged following completion of the 19th interview, but two further interviews were completed to ensure that saturation had been achieved.

3.8. Trustworthiness

Early approaches to qualitative research emphasized the need for researchers to be neutral observers and to minimise subjectivity to protect their work from charges of bias or failing to meet traditional quantitative standards of reliability and validity. Critics of qualitative research doubt the reliability of qualitative data based on an individual (possibly biased) researchers' recordings of interactions and impressions. Merriam (1995) proposed that rigour in qualitative research can either accept traditional views of validity and reliability, or more commonly take a post-positivist approach, and acknowledge that qualitative research is based on different assumptions regarding reality. Charmaz (2014) embraced the interpretive process and promoted the benefits of a reflexive researcher constantly interacting with their data to develop their ideas; therefore, constructivist grounded theorists stand *within* their research process, rather than outside it.

Trustworthiness results from rigorous scholarship to ensure that research findings reflect the meaning of the participants as closely as possible (Lincoln & Guba, 1985). Murphy and Yielder (2009) instead suggested that the term 'rigour' should be replaced by the term "trustworthiness" in qualitative research, which requires consideration of credibility, dependability, transferability, and confirmability.

The credibility and dependability of any research starts with the depth and scope of the data (Charmaz, 2014), and the methods of data collection shapes the content. Interpretive researchers must make concerted efforts to understand the perspectives of their participants, and careful interpretive understanding requires researchers to test their assumptions, and not unwittingly reproduce these assumptions (Charmaz, 2014). As recommended by Charmaz (2014), reflexivity (See Chapter 6) was used throughout the research process to ensure transparency and improve trustworthiness.

Credibility was demonstrated through several strategies including member checking to assess accuracy of data, and supervisor oversight of the research process to provide objectivity. Credibility was ensured through informal critical discussions with experienced sonographers and researchers, and formal peer review through presentation of research findings at national and international conferences (Appendix 3). Cross-checking of documentary evidence against published literature enabled a form of triangulation to increase the credibility of the research (Murphy & Yielder, 2009). Constant comparison, and the long timescale of this research, increased the likelihood of emerging concepts and potential implications being accepted (Charmaz, 2014; Murphy & Yielder, 2009). Qualitative research requires researchers to construct interpretations of their data, and although coding may be subjective, there are things that can be done to ensure that findings are valid and reliable (Murphy & Yielder, 2009).

The dependability of this research was ensured through careful consideration of each step of the process. Clear documentation of decisions and processes during the research journey ensured transparency, including memo writing, field notes and a reflective journal (Charmaz, 2014). The use of theoretical sampling and a semi-structured approach to interviews ensured the participants guided the direction of the research, ensuring credibility (Charmaz, 2014). Interview schedules were independently reviewed during ethics review processes and by project supervisors. Member checking of transcripts was offered to check theory construction. Constant comparison and the diverse group of participants achieved using theoretical sampling, provided multiple viewpoints during the research process (Urquhart, 2023).

Transferability of the study needs to be considered, but generalisation is not a goal in qualitative research that considers the unique experiences (Murphy & Yielder, 2009). Qualitative analysis builds on natural ways of thinking through interpretation, but grounded theory uses procedures more consciously and aims for accurate interpretations of the data (Corbin & Strauss, 2015), but these represent the researchers' impressions of the data and it not an exact science (Urquhart, 2023). Analysis is never completely finished, as researchers can extend, amend, and reinterpret data as new insights arise with continued immersion in the data (Corbin & Strauss, 2015).

The final part of trustworthiness is confirmability, which refers to the degree to which the results can be collaborated by others (Murphy & Yielder, 2009). Interpretive qualitative research requires the researcher to enter participants' worlds, to which the researcher perspectives may not always align. A grounded theory approach ensured that data and interpretations were clearly derived from the data. Constructivist grounded theory follows a chain of evidence that is irrefutable, since the researcher will be able to provide many examples of each code from their data (Urquhart, 2023). Supervisor review of emerging categories during analysis provided oversight and some objectivity to check the relevance and validity of the emerging theory.

Respect of participants' perspectives is paramount, since how data is collected can shape content and context (Charmaz, 2014). The researcher made concerted efforts to learn about participants' views, and to try to interpret their perspective; this requires the researcher to be aware and test their own assumptions (Charmaz, 2014), which was achieved through reflexivity and memoing throughout the research process. The researcher argues that it is impossible to eliminate all bias in subjectivist approach, and co-construction ensures that the researcher experience and voice contribute to the analysis. Consistent use of reflexivity ensured the researcher remained non-judgemental and was aware of their own subjectivity through reflexivity (See Chapter 6) and careful documentation a clear audit trail of documents to support this neutrality.

3.9. Generating Theory

Charmaz (2014) acknowledged the difficulties of defining what a theory actually is, since it might not be a single fixed concept, and may be represented in different ways, such as a diagram or storyline of emerging data. Having a large volume of data is not enough, theory should also explain why patterns or relationships were seen in the data (Urquhart, 2023). The process of proving or disproving a hypothesis is not enough: grounded theories are not testing an existing theory but instead build a new theory to explain concepts and the relationships between these (Urquhart, 2023). Grounded theory aims to go beyond defining a problem, and instead explores possible solutions based on lived experiences of participants (Urquhart, 2023).

Charmaz (2014) and Urquhart (2023) emphasised the importance of a researcher building a theoretical contribution in grounded theory. Researchers must explain how concepts are related, ensure that they are grounded in the data (Urquhart, 2023), and that a simple explanation is important if a theory is to make a contribution. From the early versions of grounded theory methodology, Glaser (1978) advised the development of just one core category, and this remains important to ensure clarity, but Charmaz (2014) advised that although clarity is important, this should not limit the scope of the work.

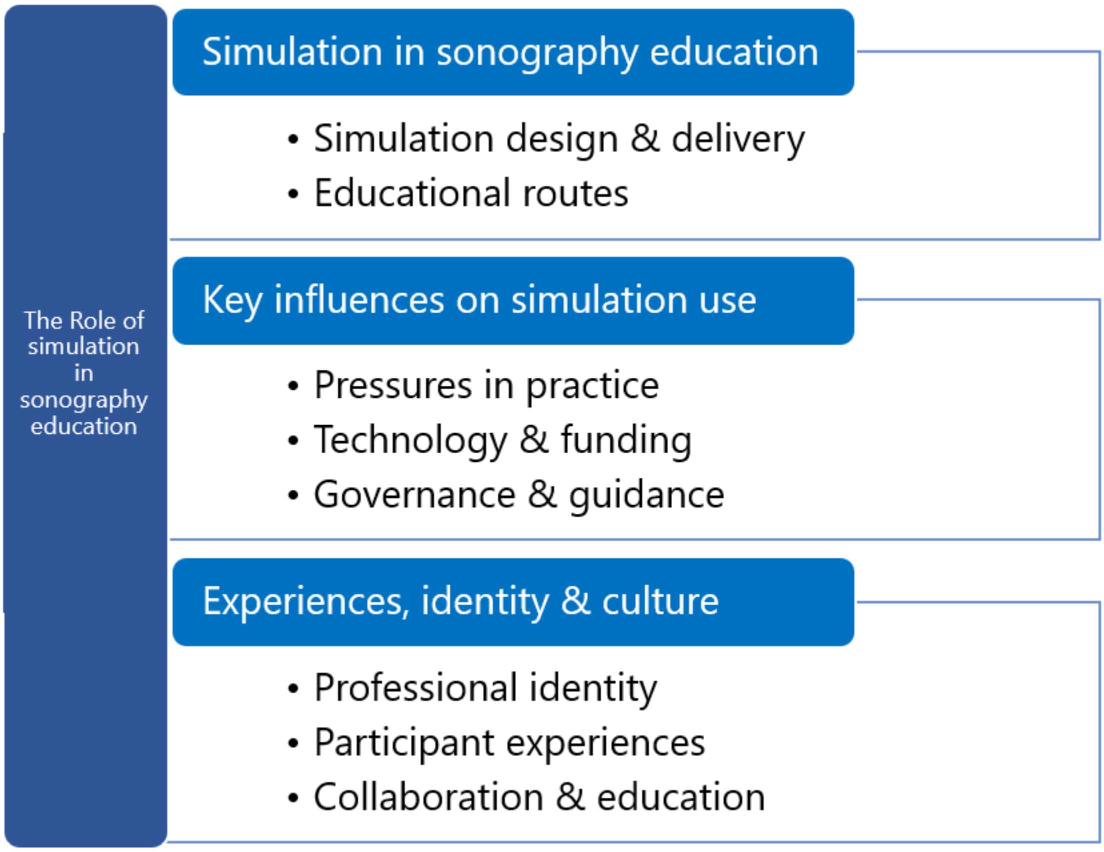
Theory is generated and tested repeatedly throughout the research process. Grounded theory methodology does not eliminate all bias or assumptions, but there are steps which can help to manage these (Corbin & Strauss, 2015). The constant comparisons made during the research process can check for consistency and check how the researcher analysed the data (Corbin & Strauss, 2015). A constructivist approach studies how and why participants construct meanings for themselves, and that the theory generated is an individual interpretation (Charmaz, 2014).

Researcher questioning of the data during open coding facilitated a more analytical approach to giving meaning to the data and helped to identify central and reoccurring categories (Charmaz, 2014; Corbin & Strauss, 2015). Exploration of the data to assign concepts that represent that data are codes, and analysis includes the thought processes that went into denoting those concepts, and the meaning behind the data set (Corbin & Strauss, 2015). In line with GT methodology, the analytical process was flexible and driven by insight gained through interaction with data (Corbin & Strauss, 2015). Analysis of data required knowing what ideas to follow and maintained balance between concept development. This was to some extent an art, but by grounding interpretations in data, using reflexivity, and checking these with participants and against data, it was possible to validate the research findings (Charmaz, 2014; Corbin & Strauss, 2015).

Grounded theory guidelines describe steps of the research process, but these can be adapted to solve problems and conduct diverse studies, whether the researcher intends to develop a theory (Charmaz, 2014). To arrive at meaning, brainstorming, comparison, idea testing and development (or elimination) of interpretations allowed the researcher to construct concepts and theory that *"feel right"* to the analyst, which required exploring different concepts during analysis phase of the research (Corbin & Strauss, 2015). Corbin & Strauss (2015) define a theory as a set of well-developed concepts that are systematically organised according to their properties and dimensions, and these are linked together to form a framework that explains something about a topic. If the theory is to be cohesive, integration of concepts around a core concept is required to elevate conceptional ordering to the level of a theory (Corbin & Strauss, 2015). Theories are individual, and can differ in their scope, level, generality, and applicability (Charmaz, 2014). Researchers should remain open to the idea that their theory may not fit with previously developed concepts, as their perspective is unique, and alternative theoretical explanations can emerge from the same data (Corbin & Strauss, 2015).

This research used a constructivist grounded theory approach and a phased sequential approach to investigate the role of simulation in sonographer education. An initial comprehensive literature search was followed by 21 qualitative semi-structured interviews of a diverse range of participants. Theoretical sampling and constant comparison were employed to identify core categories and inform theory development. The core categories (summarised in figure 3.6) will be explored in detail in in the subsequent chapter.

Figure 3.4: Core Category and subcategories



Chapter 4: Results and discussion

This chapter presents the study findings and theory developed during the research and it is structured around the three core categories and their subcategories (See Figure 3.5). There are many approaches to writing up qualitative research studies (Merriam & Tisdell, 2016). Unlike other grounded theorists, Kathy Charmaz has long preferred to present detailed interview quotes and examples in the body of her work to keep the human story in the forefront of the reader's mind, and to make the conceptual analysis more accessible to a wider audience (Charmaz, 1995). The same strategy of presenting verbatim quotes from participants has been used in this chapter to present the data in a meaningful way, with the findings and discussion presented together as one chapter. This combination of the author's own narrative interspersed with short, quoted passages produces an easy and attractive presentation style, which should allow readers to closely experience the reality of the research findings (Yin, 2016). Please note that participant quotes are indicated as follows using individual colours to clearly identify each participant group:

Educator group: identified as E1- E7

Stakeholder group: identified as Sr1 – Sr7

Student group: identified as St1 - St7

Three categories and eight related subcategories generated during data analysis are summarised in Table 4.1, which are all interlinked under the core category of the role of simulation in sonographer education. Each subcategory will be explored with consideration of relevant literature identified during theory development.

Table 4.1: Categories, subcategories and content summary

Core category	Categories		Subcategories	Content summary	
The role of simulation in sonographer education	A	Simulation and sonographer education	Simulation design and delivery	• Authenticity and meaningfulness • Psychomotor skill development • Live models, role play and communication • Pre-brief and debrief	• Preferred learning approaches • Innovative use of simulation • Simulation and assessment
			Educational routes for sonographers	• Simulation in postgraduate education • Undergraduate routes	• Training academies • Moving towards the future
	B	Key influences on simulation use	Pressures in practice	• Educator pressures • Workforce pressures	• Student pressures • Attitudes and assumptions
			Technology and Funding	• Technology enhanced learning	• Financial considerations
			Governance and guidelines	• Regulation and accreditation • Guidelines for simulation in healthcare education	• Sonography career framework
	C	Experiences, identity, and culture	Experiences of learning	• Understanding learner needs • Engagement • Wellbeing and psychological safety	• WRMSK disorders • The patient perspective
			Professional identity	• Sonographer identities	• Becoming a sonographer
			Collaboration and education	• Cooperation and consistency • Interprofessional learning	• Educator education and research • Leadership

Category A: Simulation and sonographer education

This category encapsulates two subcategories: simulation design and delivery, and educational routes in sonography education, which are summarised in Table 4.2.

Table 4.2: Summary of subcategories Category A

Core Category		Subcategory	Content summary
A	**Simulation and sonographer education**	**Simulation design and delivery**	• Authenticity and meaningfulness • Psychomotor skill development • Live models, role-play, and communication • Pre-brief and debrief • Innovative use of simulation • Preferred learning approaches • Simulation and assessment
		Educational routes for sonographers	• Simulation in postgraduate education • Undergraduate routes • Training academies • Moving towards the future

Methods of sonographer education have changed significantly over the past 20 years, moving away from traditional didactic lectures and towards greater use of simulation learning. Educational routes for UK sonographers vary, with entrants from a variety of backgrounds (Harrison & Beardmore, 2020). The development of technologies has provided new opportunities for using simulation in sonographer education, however participants reported varied availability and use of simulation nationally. Participants focused primarily on clinical skill development and image appearances, with more limited consideration of the development of technical, communication and decision-making skills.

Sr4: there's variance … some universities may only have one (simulator)… some have got a whole suite which is an excellent resource.

4.1. Subcategory A1: Simulation design and delivery

Participants showed some uncertainty regarding the scope and definition of simulation-based education, and educators lacked confidence in their knowledge of the role of simulation for ultrasound education. Chernikova et al. (2020) described limited understanding of the support required for complex skill development in learners with different levels of prior knowledge, similar to educators in this study who were in the early stages of using simulation in their programmes. Participants in this research outlined a varied trial-and-error approach to using simulation within sonography education, with educators and stakeholders reactively adapting their delivery in response to student feedback as they progressed through their programmes.

E7: we've got a full clinical skills suite ... we are just at the beginning

Sr2: Trial and error! … the simulator … we were struggling to work it out

In-situ simulation learning (within clinical departments) was less common, but this provided opportunities for learners which were perceived as more authentic and provided valued opportunities for evaluating their own practice and developing decision-making skills.

Sr2: we have two simulators, we use them for the sonographers where we can, to basically aid the fact that we may not be able to find enough lists for them to attach to and just to get those basic skills initially.

St5: we've done all sorts … which has helped me. I'm learning things in my own way … when I'm doing something myself from scratch it almost goes in a little bit better, and I take in the knowledge more.

St6: we've used models, phantoms, the simulators, the machine … getting that hand eye coordination and moving things around, and the anatomy.

All participants reported that the content and timing of planned simulation learning were important, with general agreement that simulation was most useful in the earlier stages of learning for developing basic scanning skills. However, course delivery patterns vary, so consideration is needed for how and when simulation is delivered within programmes. For full time MSc routes, some HEIs were using intensive simulation learning prior to clinical practice; they aimed to ease pressures in clinical departments by helping students develop initial basic skills using task trainers. This approach may not be suitable for all learners since students on different educational routes have had varied amounts of clinical experience prior to on-campus learning.

E7: At the beginning, because it gets them used to that hand-eye coordination.

E6: most of the students go why are we doing this now, we're already scanning in the department?

St5: I would never have been able to recognise those gaps in knowledge if I didn't have my simulations at university … it's helped us recognise where we needed to put a little bit more work in … and given us opportunities to do that

St6: I basically tried to run before I could walk. I needed to go back to the beginning: I can't just play all this music, I've got to learn the notes, before I can put everything together.

One educator felt they had developed a wider awareness of the scope of simulation through experience and engagement with specialist simulation groups within their HEI, however most participants felt simulation had not yet reached its full potential. Simulation was used on a relatively small scale, mainly for self-directed individual learning, but even with limited use, students felt this had some benefit for their learning.

E1: when I started … I just saw the simulators and thought that was simulation … going to meetings with the simulation team really broadened my horizons

St4: being able to review … without the pressure of the patient being there … helped … because I've had a moment to reflect, review something and then decide

Overall, participants acknowledged there was limited understanding of available simulation equipment and a lack of confidence in design and facilitation of simulation learning. There is limited evidence on how simulation-acquired skills correlate with clinical performance, or how the skills obtained are sustained in the long term (Dromey et al., 2021), which may partly explain why simulation was not prioritised within the curriculum, and why there was little consideration of using simulation for developing the full range of skills required in sonographer practice.

Sr3: I think it's still ad-hoc … it's still got a long way to go to be fully integrated.

E1: We base it more on clinical experience

E7: … honestly every year I go and look at the scantrainer and think right, remember what you've got to do … I think time is the biggest barrier

4.1.1. Authenticity and meaningfulness

Authenticity is important to students, so that simulation resembles their clinical practice, but although their simulation experiences were not always completely realistic, students still felt they were beneficial for their learning. Sharma et al. (2023) proposed that low fidelity builds knowledge; medium fidelity facilitates acquisition of competencies and high-fidelity aids in generating the action, all of which have potential applications within sonography education, but perhaps a better understanding of the purpose of simulation learning would result in more realistic expectations. Some areas of practice are more difficult to simulate than others, and experiences of simulation did not offer enough variety of challenging cases for students to represent the range of patients and conditions they experienced in practice. Simulations which fully replicated real life were challenging to create, particularly in obstetrics, because live models are not always appropriate, and the variations in fetal appearances and movements make clinical practice challenging.

E1: …to be effective, the more realistic (simulation) is, the better it is for their learning experience

Sr3: with a simulator is not as realistic as a real person. I think simulated patients are actually a really good compromise.

Some researchers have suggested that the physical resemblance of simulation is less important than how the simulation corresponds to the context of the task being learned (Hamstra et al., 2014), but in this study participants felt that the lack of authenticity was limiting the use of simulation for sonography education. Realism can be considered as a property of the learner's perception rather than a property of the simulation, and a clear understanding of the purpose and planned outcome of simulation learning influences learner experiences.

E1: You can't just set up a simulation and think "that's it"! You've got to have experienced staff … you could simulate lots of things, but it doesn't mean it's worthwhile!

Sr3: what steps we need to take to make it realistic … how we'd make sure that they've actually learned something useful

The ultrasound appearances and variations in practice were not sufficiently represented during simulation learning for students. Student participants felt the lack of variation, combined with lack of authenticity and lack of interactive tutor feedback limited the usefulness of simulation for their learning. The lack of fidelity and lack of variation that is seen in clinical practice, mean that simulation task trainers did not challenge students enough, and taught them a *"perfect"* image rather than a realistic expectation of what they could achieve in practice. The limited variations in available phantoms, made their application limited for student learning.

E7: the scan trainer, it being a haptic device does put some students off. They can't see it as a person. I think it needs to improve and become more realistic.

St2: It's just not the same … you get into the room, and you realise you don't know what to do what with the machine.

St2: … the patient care, the admin part of it, it's just not comparable … you're not talking, so you're not trying to listen to a patient talk to you whilst you're trying to scan, so it doesn't build up that multi-tasking

St4: The scan trainer … it's very clunky and … it's almost the wrong type of movement and the wrong type of pressure you're applying … it doesn't feel real

St2: learning how to do a TV [transvaginal] for example, I didn't find it translated across there at all … I didn't feel that that helped me prepare at all for doing a TV scan.

Usability and reliability of simulation equipment was an important factor for educators who had experienced a variety of issues with integrating task trainer systems with internal IT systems. Participants found task trainer systems complex and difficult to set up and use, and regular experiences of technical issues with task trainers negatively affected educator confidence and student experience. This perceived lack of reliability of task trainers for simulation meant that educators preferred using models and phantoms with an ultrasound machine for teaching clinical scanning skills.

E2: You pretty much know that if you turn on the ultrasound machine, then it's going to work … I've got a hell of a lot more faith in using live models for simulation sessions.

E3: Technical settings … can be an issue: because the parameters are so narrow … that can be a huge disincentive to the students and that is one of my reservations about them using it on their own, because they can end up feeling quite down.

Students reported that the ultrasound machines they were using for practice within their HEI were not comparable to those used in clinical practice, which detracted from the realism of simulations using phantoms or live models. The lack of similarity of the task trainers to a real ultrasound machine was an issue for some participants and limited the transferability of their learning into clinical practice. Educators felt more comfortable with use of "real" machines and models or phantoms because they felt this was more reliable and ensured smoother running of their teaching sessions. Student participants also preferred the set up and adaptability of these simulation experiences, which aligns to the findings of Chernikova et al. (2020), where good simulation design optimised learning opportunities and ensured learner needs were met.

St4: it doesn't feel very natural going back to a machine again.

E7: the machine settings do not mimic what you would have in real practice.

Sr2: once you've scanned a real patient, the simulation ... it just doesn't cut it.

Although students may be able to complete a task in simulation environments, this does not always transfer into the real world, especially with higher stakes or higher risk procedures. Participants felt that even high-fidelity simulation cannot fully replicate the pressures experienced in clinical practice due to the lack of authenticity of the experience and different equipment used for simulation learning. This can sometimes result in different reactions and behaviours from students, which are not comparable to clinical practice and less useful for their learning. However, when used effectively, simulation could provide predictable, repeatable teaching opportunities enabling equitable learning. Sharma et al. (2023) believed that if learners observed that their instructor was open with respect the fidelity and the realism of a simulation scenario, they were more likely to focus on their learning objectives and perform better in the simulated scenario; even if there are physical differences from real life, participants could still make conceptual sense of a simulation that was experientially and emotionally relevant to their practice.

St1: when I engage in simulation, the following day in my practice, you could see a positive change. And then learning became exciting, learning became faster, so having that simulation-built confidence.

It is important to emphasise that the "realness" should not be the primary focus in simulation design: within the same simulation similar experiences can have different meaningfulness for different learners, and high-quality learning and reinforcement of safe and competent clinical practice is the ultimate outcome (Sharma et al., 2023). There are many factors beyond the design and facilitation of simulation which affect the meaningfulness of simulation for students, including their preferred learning style, alignment with learner needs, fidelity, pre-briefing and appropriate debrief (INASCL Standards Committee et al., 2021).

St6: I'm a very practical learner, and I've got to do, so I think kind of having a go myself and thinking and seeing it, and getting to work to work out the different shapes of the structures, that's something to get into your head

4.1.2. Preferred learning approaches

Simulation should offer learning opportunities that allow students to transfer the skills they acquire back into their clinical environment. Although previous studies have been uncertain regarding the transferability of skills from simulation to clinical environments (Chernikova et al., 2020; Gibbs, 2014; Laschinger et al., 2008), some students in this study reported that skills learning during simulation learning improved their skills, informed their practice, and increased their confidence. For others, the lack of authenticity of task trainers and phantoms meant that they felt their learning did not transfer back into practice at all. The varied responses from participants may be partly due to the wide variations in educational practice, alongside the different learning styles and preferences of each student. Learning styles refer to how students attain, interpret, organize, evaluate, and retain information (Chick, 2019). Sociologists describe five generational trends, where students from each generation have unique characteristics which affect their perceptions of learning (Polakova & Klimova, 2019). Student participants had different personalities and different needs in terms of what worked best for them, but although learning styles vary considerably, Shinnick & Woo (2015) argued that simulation was effective for teaching most nursing students, irrespective of their learning style.

E6: … some of them don't see the value of using simulation equipment.

St2: Looking at my own experience, it has played a marginal role

St6: It's been quite good for the lecturers to be watching us and critiquing us before you go into practice

Participants described varying levels of access to simulation and a variety of activities used within sonography education. Opportunities for simulation learning helped students to identify and address gaps in their knowledge. Observing others and sharing experiences helped students to accept and overcome difficulties during their learning. For maximum benefit for students, simulation should be a routine part of their learning, both at their HEI and in their clinical environments. Occasional use is unlikely to have a significant impact on learning and some students did not see any value in the few opportunities for simulation learning during their course.

*E7: G*etting students immersed in ultrasound from the beginning, allowing them to make mistakes that aren't going to impact on staff or on patients

Sr1: I think it's got to come earlier…it can be quite difficult because they have academic blocks out early on. So that takes them completely out of their practical training environment, and there appears to be little progress when they return.

E5: I think there are departments who have got a simulator, but it's just sitting there because there's no time.

Alongside developing psychomotor skills, simulation learning provided students with opportunities to apply theory to practice, and feedback from tutors developed their understanding of the scientific principles of ultrasound, image optimisation, and effective and safe operation of the ultrasound equipment to acquire optimised diagnostic images. This is something which was difficult to learn in the pressured and time sensitive clinical environment, where there was little time for experimentation or questioning.

St7: it was really useful with the physics … putting what you've learnt into practice definitely helps … being able to take your time and play around with the settings on the machine in a simulated environment is really useful.

Although they were adult learners, students required support and guidance in their learning. *S*tudents wanted clearer guidance and instruction to help them in their learning, and *s*imulation provided important opportunities to access support, guidance, and reassurance on their progress. Constructive feedback from tutors and peers was important, and the guidance and tailored live feedback helped them to apply theoretical learning and discover their limitations, which was especially important to students. This aligns with findings from a scoping review by Shorey et al. (2021) which reviewed preferences of the latest generation Z (Gen Z) learners in healthcare and reported that they need immediate and constructive feedback from educators, as well as assistance with their overall development for their future careers. Simulation learning provides opportunities to meet these needs, but careful planning is required before integrating new technologies in the curriculum (Shorey et al., 2021).

E1: … not having a patient there, not feeling the pressure, not having a queue outside is invaluable

E7: … a safe space to ask those what they think are silly questions.

Participants in this study reported a prevalence of using simulation for sonography as a self-directed activity on a task trainer. This self-directed approach was not appealing to students, perhaps because clinical problems are ill structured, therefore novices are unlikely to develop the expertise necessary for independent problem solving (Becker & Hermosura, 2019). Students expressed strong preference for completing simulation with the support of a tutor; this was due to the opportunities for questioning and discussion, and the immediate and personalised feedback they received in an unpressured space.

St1: I think my brain works in a very structured way, because I feel like I'm methodical. If I'm scattered all over the place I can't think

St3: I liked it. For me that was perfect. Just concentrate on one thing, really nice and slow.

E1: although there are set learning plans on the simulators, they like to have somebody there to guide them, to ask questions … to make it more real.

A structured learning experience was preferred by learners as it allowed them to gradually build on skills and helped them feel less overwhelmed. Becker & Hermosura (2019) argued that scaffolding is a key component of health professions simulation and education, and the scaffold may be a simulator, faculty member or co-learner, depending on the simulation type and topic. Participant responses suggest that using scaffolding (which is a well-accepted approach in education design) could improve student experience by integrating a more systematic approach to curriculum design and integration of simulation learning, which could allow optimisation of complex skill development (Sardo & Sindelar, 2019; van de Pol, Volman & Beishuizen, 2010).

St1: … if I had a choice, I would choose the group peer learning together over a simulator. Because with a computer package it's just you and the simulator, and it's almost like you can't put your human touch to it. The simulator's not really talking back to you and giving you that dynamic feedback.

St3: you need a facilitator … to say to I'm struggling with this, can you help?

This scaffolded approach using dynamic and flexible support to students allows them to accomplish tasks that would otherwise prove difficult (Sardo & Sindelar, 2019). A Delphi Consensus study to set standards for scaffolding in health science education focused on four key areas, including programme structure, sequence of educational activities, resources, and instructional strategies to support learning (Masava, Nyoni & Botma, 2023), and this approach could easily be applied in sonography education. Repeated practice using simulation helped students to learn a methodical approach to scanning and provided a "safe space" where students could build confidence, which helped them to feel prepared for clinical practice. The removal of any risk to patients allowed students time to practice, identify their learning needs, overcome fears, and seek help from tutors. All participants agreed that simulation provided a valuable opportunity for students to experiment and repeat practice at their own pace, which is not usually possible in clinical practice.

Most participants viewed the opportunity to learn in an unpressured environment as a key benefit of simulation learning, with most acknowledging the benefits of simulated learning in developing learner confidence. There is immense value of a safe unpressured learning space where students feel well supported and mistakes cannot negatively impact on patient care, but as previously acknowledged, improved confidence does not prove increased competence. Williams et al. (2013) raised concerns that an ultrasound simulator lacked realism (because it was too easy), which could give students a false degree of confidence in their clinical abilities. It should also be noted that students may not perform better during simulation than they might in a pressured clinical environment, and the higher stakes of real clinical practice will always differ from simulated environments.

E3: I think a huge benefit is confidence.

E4: They can learn it in their own time and it's not in a stressful situation. They don't have to contend with a moving target … they could concentrate on that image … they don't need to be afraid if they made a mistake

St1: simulation … is a non-threatening, non-intimidating environment where you can make your mistakes, you can make errors and not be judged, not be critiqued for it.

St3: using (simulation) … it's learning by playing; and it's fun and it makes you learn without the trauma of just being sat there with a book.

Sr2: It just helps those levels of confidence without the pressure.

Sr3: For intimate examinations … I think it builds confidence

St1: I think it was my confidence … it was like a snowball effect

Students' experiences of simulation-based learning were not always positive. One participant strongly preferred learning alone, but is should be noted that they had very limited experience of simulation learning during their studies. Although some individual learners might prefer to work alone, self-directed learning in isolation was not the most effective strategy for learning. Task trainers were designed with individual learners in mind, yet students may not realise that they are making repeated mistakes, and they miss opportunities for peer support, questioning and discussion. Some student participants described a negative atmosphere, lack of facilitator support and pressure to complete tasks quickly during busy group teaching sessions. Group work was not always a positive experience, and although peer feedback was useful, one student felt impatient that their learning was sometimes held up by others who were still working to grasp ideas. Group size is an important consideration for educators: if the group is large, there is a lot of observation time, and students prefer active participation over observation during simulation learning.

St3: … everybody was so moany

St6: you might not always get the time to scan, you know you feel like you've got to do it quickly cos the next person is waiting

St6: I was a bit like sceptical … it's hard when you get people together that have different thoughts, and different brains that process information. If you understand it, you just want to go away and do it

St3: (least favourite bit): … too much time watching other people because I'm bored; … that's the bit I think I can already do at this point.

St3: … they do split us into groups … we all get a little go. But then we're stood around … because even though there's a small group you want to be doing something

Students did not always see the relevance of simulation included later in their programmes, although some educators valued using simulation as a trouble shooting tool if students were experiencing difficulties in practice. For students who had already had several months of clinical time prior to starting their course, they felt simulation learning was less useful. The timing of when simulation learning is introduced to students is another important factor in student engagement. Most participants agreed that early introduction of simulation for skill development was useful, and students wanted structured learning which provided challenging learning opportunities.

Facilitated group learning sessions were preferred by students, both in their HEI and particularly if these were provided within their own clinical environments. Students valued the opportunity to learn using practical activities and simulations, where they could experiment, learn, share experiences, and get tutor feedback. Most students enjoyed and valued the use of simulation for small groups of learning because these opportunities benefited student confidence when they worked together as a group developing knowledge and skills. Group learning provided student opportunities to share experiences, observe and learn from others, which was usually not feasible in routine clinical practice. Peer supported learning was valued by student participants, and they felt it helped them to have realistic expectations of their abilities, develop clinically and academically, and to foster positive relationships with peers and tutors.

St1: … the more robust learning came from talking to each other … some of these things you can't find in a textbook. It comes from that experience … that's what made my practice improve

E7: learning in isolation is always difficult … the best way really would be to have groups of students working with each other, so they get a bit of peer learning with a tutor overseeing and there for difficult situations

Peer supported and group learning also had benefits for staff as it could be more time effective for busy clinical educators (rather than the traditional one-to-one approach to clinical training). Nonetheless, a group approach may not suit all learners, and a supportive and inclusive environment is highly valued by students. Trust between group members is important to minimise self-consciousness, fears of making mistakes or concerns about being judged on their abilities.

Appropriate facilitation and group size are key considerations for educators when planning simulation learning to ensure students get *'hands on'* scanning time and do not feel rushed. In larger groups, students spent most of their time observing, but they preferred more time to practice and test their skills. One stakeholder speculated that the supportive environment during simulation learning was most important, rather than the fidelity of the simulation itself.

Sr2: … it's got some use I think it can be limited.

Sr6: We rely on the students to volunteer, and they'll have a bit of a scan of each other.

There were wide variations between study participants in how simulation was used, the equipment available, and educator understanding of effective simulation design. Some educators appeared to value simulation learning more than others and worked to provide a supportive and equitable environment which facilitated learning and peer support. Educator promotion of the benefits of simulation learning appeared to influence student attitudes and engagement. For most stakeholders, the expectation was that learning relies largely on clinical experiences, with simulation playing a supplementary role for learners.

4.1.3. Pre-brief and debrief

Pre-brief and debrief were not routinely used during simulation-based learning by participants in this research. Educators acknowledged the importance of time for discussion and reflection on learning, but this is not always possible in the busy clinical environment. There are three recognised phases in simulation delivery for healthcare education: pre-briefing, scenario and debrief (INACSL standards Committee, 2016). ASPiH guidelines (2023) emphasise the need to effectively pre- and post-debrief in healthcare simulation, yet there has been relatively little research into pre-brief methods (Brennan, 2021). Facilitation of simulation pre-briefing should be based on learner experience and should create a safe and trusting learning environment and promote student engagement (Brennan, 2021). Setting clear expectations and "a code of practice" before engaging in simulation learning is useful to help students understand the expected behaviours, and to ensure there is balance between ensuring confidentiality and allowing students to share their learning experiences. Effective pre-briefing can influence student achievement of learning objectives and enhance simulation practices (Brennan, 2021). Development of simulation scenarios including training of simulated patients using guidelines for best practice (ASPiH, 2023), and consideration of introducing students to a fiction contract to establish realistic student expectations as part of pre-briefing activities (Nestel, Krogh & Kolbe, 2018) could significantly improve expectations and understanding of authenticity, and therefore improve simulation experiences for sonography students.

A few participants mentioned debrief and felt this needed to be flexible and responsive to student requirements, but educators appeared focused on gaining feedback from students on the usefulness of the simulation, rather than exploring student learning and reflecting on their experiences.

Sr4: It's OK just using the simulation equipment or undergoing a simulation activity but if you don't debrief after in terms of the discussion, the learning points … then some of that learning is lost

Sr5: it's good for them to challenge their thinking and approach … I don't think that's something that they get

Students feared getting things wrong, both in simulation learning and in their clinical environment, and they put a lot of pressure on themselves when learning ultrasound. It is important that students have realistic expectations of themselves and the difficulties of acquiring the skills required to be a sonographer.

St2: I think at first it felt like a really abnormal situation for some reason, sitting there and almost a spotlight being on you and there were all these people watching you.

St7: that was quite daunting for me because I felt like everyone else kind of had done that before and I felt a bit silly

Evidence suggests that debriefing is an essential element of simulation-based education, with a variety of frameworks available to provide structure (Cheng, Eppich, Sawyer & Grant, 2014) and how constructive feedback is given and received by learners is an important consideration. Participant reports of limited use of structured debrief in sonographer simulation learning is concerning, since even highly realistic simulations provide little learning if the debrief element of the scenario is not completed adequately (Nestel, Krogh & Kolbe, 2018). Effective use of pre-brief and debriefing tools would improve learner experience and ensure they have realistic expectations.

Kim & Yoo (2020) reviewed 22 studies related to debriefing in healthcare, and although there is no absolute best practice in debriefing, maximum learning was achieved through simulations when educators chose debriefing types appropriate for learner needs, and in line with recommended standards of best practice, such as those from the INACSL Standards Committee (INACSL, 2016) and ASPiH (2023).

A variety of standardised terminology (Merguerdichian et al., 2022) and multiple debriefing frameworks have been developed for simulation learning and debriefing in healthcare education. Debriefing frameworks include PEARLS (Bajaj et al., 2018; Eppich et al., 2015), INASCL Standards (INASCL, 2021), Debriefing Assessment for Simulation in Healthcare (DASH) (Tanoubi et al., 2019), and Debriefing for meaningful learning (DML) (Sawyer et al., 2016). These frameworks enable educators to design effective debriefing sessions, which can enhance student learning and ensure consistency. This may include establishing rules, ensuring psychological safety, addressing learning objectives, using open ended questions, and using silence (Sayer et al., 2016), but participants in this study did not use these frameworks as part of their simulation planning or facilitation. Participants in this study mentioned some informal discussion following simulation, but there was no mention of formal pre-brief or debrief, with little awareness and no reported use of well-established debriefing techniques or frameworks, which are key to establishing psychological safety for learners.

E2: they feel that there are just working on their own, and not being taught.

St7: just to have a go … if we've got any questions, the tutor is there.

Establishing a safe learning environment and facilitation from an experienced tutor is important to ensure that students feel safe and can speak without fear of harm or rejection (Sawyer et al., 2016) so that students do not fear negative consequences to self-image, social standing, or career development. Key considerations of a quality debrief include the need for a competent facilitator, a confidential and supported environment, use of a theoretical framework to structure debriefs in a purposeful way, and congruence with the learning outcomes of the simulation-based experience (INACSL, 2016). Optimal debriefing methods with structured feedback can improve learner performance and increase the impact of simulation learning (Cheng, Eppich, Sawyer & Grant, 2014). It is important that there is a structured approach to simulation design, which must include pre-brief and debrief, and faculty development and training in effective facilitation of simulation could increase educator confidence with simulation and maximise learning opportunities for sonography students.

4.1.4. Psychomotor skill development and task trainers

Observation alone is not enough to develop scanning skills, and students must have hands on experience to develop competence. Novice learners find it challenging to recognise sonographic anatomy and optimise ultrasonographic images (Slater et al., 2014). Such complicated tasks can become more automated with practice, which reduces sensory overload when a learner performs an examination of a patient.

Across all participant groups, simulation was seen as a useful tool for psychomotor skill development, and recognition of image appearances (anatomy and pathology). Simulation provided opportunities to develop skills and knowledge, and participants had a variety of simulation equipment and spaces available for students, including task trainers, phantoms, ultrasound equipment, and varied levels of simulation suites and facilities. These facilities were largely based at HEIs, with some clinical departments having access to task trainers and facilitated simulated learning.

St4: that hand-eye coordination and building that 3D picture in your head … it's definitely helped with that

Sr3: It builds that 3D kind of ability to look in 3D and to think in terms of planar imaging, something simple like how to hold the probe, how to hold it the right way, how to move it.

Skill development varied between learners, and similar time spent scanning (or using simulated learning tools or in clinical practice) did not correspond to equal progress. The spatial understanding required for undertaking effective ultrasound scans is challenging for learners because they must interpret various textures and shapes while conceptualising a 3D anatomical mental model from 2D ultrasound images (Jamniczky et al., 2016; Knudsen et al., 2018). Developing 3D mapping and psychomotor skills is difficult, and most participants agreed that simulation was beneficial for early sonographer skill development, which participants acknowledged was difficult in practice. Since learners progressed at different rates, this could make effective planning and delivery of simulation teaching difficult for educators.

E5: Some people have a natural hand-eye coordination, whereas some just struggle

E1: it's complex, isn't it, I mean we do it without a second thought, but when you are learning, it is very complex … developing their psychomotor skills and their cognitive skills, and their knowledge

E3: sonographers are developing multiple different competencies at the same time

Participants reported widespread use of high-fidelity task trainers for self-directed simulation learning of specific ultrasound skills, with some tutor led simulation learning using task trainers, phantoms, and volunteers. Although educators were aware of the need for planning, they largely relied on predesigned training packages provided with task-trainers, and if there was none available, then for some, simulation was not considered possible. Simulation was commonly used for some areas of clinical practice, particularly abdominal, gynaecology and obstetrics (which are the commonest areas for students to learn in practice), but there was little discussion of opportunities for simulation for other clinical areas. This may be due to lack of demand, or the lack of availability of predesigned packages on available task trainers.

E5: Because there is no "package" on the simulator, simulation for breast ultrasound is not used

High fidelity task trainers provided a range of cases and pathologies, but even these were not comparable to real clinical practice. Live models and simulated patients offered opportunities to develop this further (within the limits of ethically permissible practice discussed earlier). Practical hands-on activities helped learners to understand theory, and participants demonstrated good awareness of the complexity of the skill required to be a sonographer, and the benefits of a "safe" learning environment away from the pressures in clinical practice. Use of task trainers or other simulation learning was limited by the lack of time for educators to become familiar with the equipment, and a demanding curriculum with limited time for students on campus.

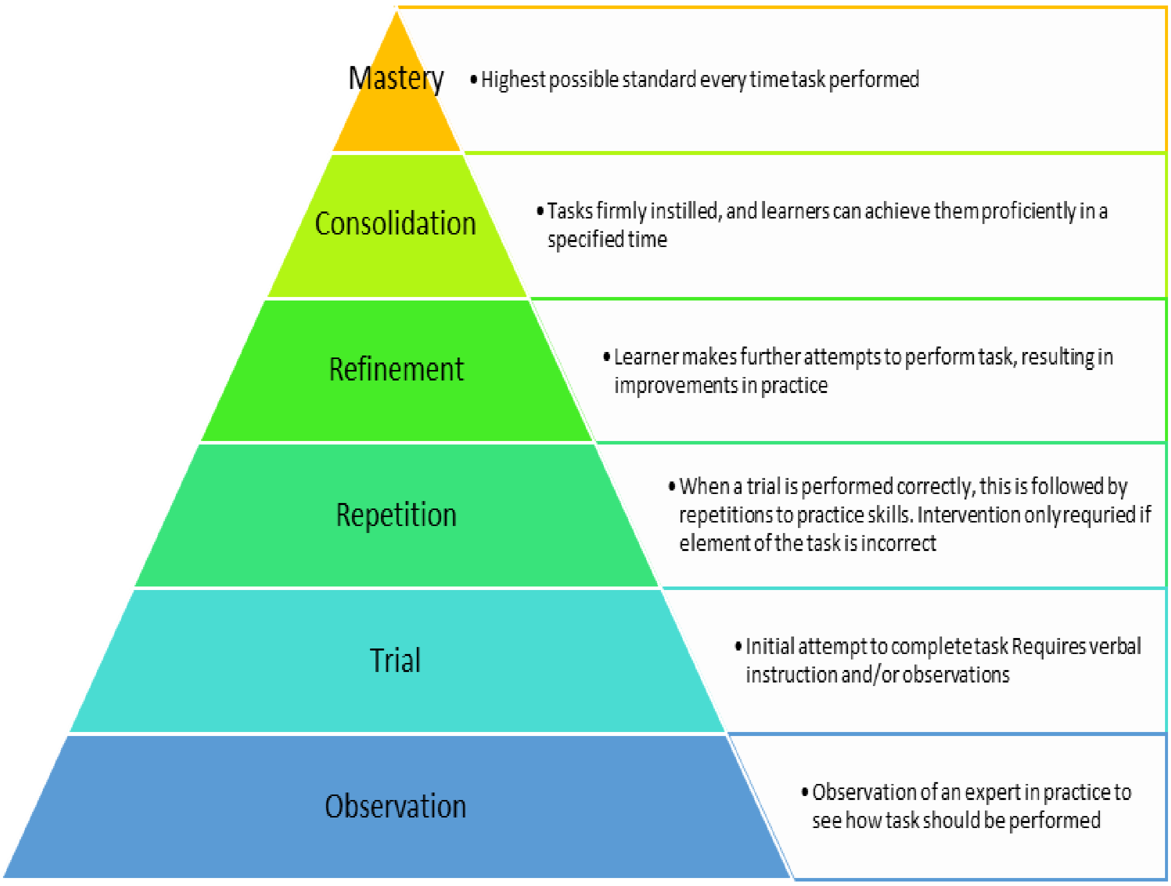
St7: right at the beginning … because I'd never actually had a go with an ultrasound machine or held a probe … So that was really useful for me to … get an idea of kind of how it all works together without being in a pressured environment, that was really good.

Sr2: when you've got a patient in the room, there's a whole host of other things that they've got to think about … it takes that pressure off learning those basic things … it becomes a natural instinct because you've done that in simulation

St6: It doesn't matter if you make a mistake … it just feels more like I can relax

Various theories have attempted to explain the stages of psychomotor skills development, including Simpson (1966), Dave (1970), Harrow (1972). A variety of pyramid-based taxonomies have previously focused on educational contexts, with little consideration of the complexities within health professional education (Perry, Bridges & Burrow, 2021). Dawson's psychomotor taxonomy (Figure 4.1), which outlines a pathway from observation to mastery, was successfully adopted for consideration of competency in sonography in a small study by Thoirs & Coffee (2012), but the model lacked any consideration of the background knowledge required to enable students to attempt skills acquisition. Most theories emphasised the need for tutor feedback to allow learners to adjust their performance, and the essential need for appropriate supervision and verbal prompts to correct errors and provide positive reinforcement. Perry, Bridges & Burrow (2021) considered various taxonomies within dentistry education and found that there were limitations to the application of pyramid models. Therefore, they proposed a new comprehensive clinical simulation psychomotor taxonomy with a cyclical format, which goes beyond the hierarchical approach of previous models. Their more complex model is more iterative, and considers pre-skill knowledge, which is important to ensure optimal conditions for learners (Figure 4.2).

Figure 4.1: Dawson's psychomotor taxonomy and level descriptors (adapted from Perry, Bridges & Burrow, 2021)



In response to the educational changes resulting from the COVID-19 pandemic, Bilyeu, McDevitt & Judd (2023) tested a framework developed by Nicholls et al. (2016) for knowledge and psychomotor skill development in physical therapy students, with a blended learning approach. They found positive learning outcomes for students provided that cognitive load is carefully managed as students develop their foundational knowledge, psychomotor skills, clinical reasoning, and reflective skills. This aligns with earlier findings from Gibbs (2014), where sonography students expressed a preference for tutor-led learning for practical skills. Their model proposed to guide incorporation of simulation into the dental curriculum (including haptic virtual reality simulation) (Perry, Bridges & Burrow, 2021) and this could easily be applied to sonography education from early learning to proficiency development (Table 4.3). Simulation could enable the development of complex skills using repetitive and refined practice, which if completed prior to clinical practice, could provide a structured approach to allow learners to focus on higher level skills in practice (Perry, Bridges & Burrows, 2021). However, the current use of self-directed simulator-based systems is insufficient to meet the needs of sonography students who need to develop a range of complex skills.

E1: it's not realistic enough, it's not holistic - it doesn't involve a patient.

Figure 4.2: Clinical simulation psychomotor taxonomy (Perry, Bridges & Burrow, 2021) (reproduced under licence from Wiley & Sons)

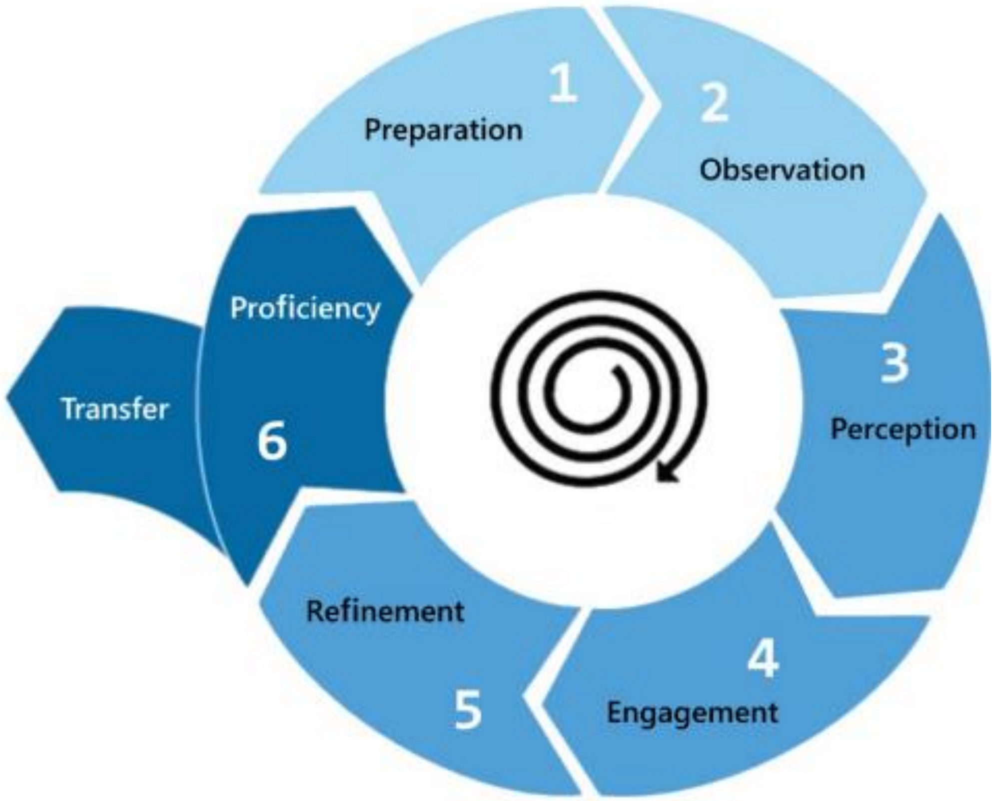


Table 4.3: Clinical simulation psychomotor taxonomy (Adapted from Perry, Bridges & Burrow, 2022)

Stage	Level	Description
Pre-skill	(1) Preparation	Readiness to perform requires appropriate knowledge, motivation, physical ability, innate ability, personality and the appropriate environment
	(2) Observation	Observation of expert completing skill to develop learner understanding of requirements
Practice	(3) Perception	Awareness of varied sensory inputs during early attempts at new skill development
	(4) Engagement	Responding to feedback and environment to improve skill performance
	(5) Refinement	Modification of technique to achieve proficiency and improve accuracy and speed
Proficiency	(6) Proficiency	Acquisition of skills to meet required competencies

4.1.5. Live Models

Participants in this research described the use of live models as common in abdominal, musculoskeletal, or vascular modules. Some educators expressed reservations about the potential issues of scanning live models, but for others being a live model was routine, and the use of ultrasound and live models for anatomy learning is well established in medical education.

Blickendorf et al. (2014) trialled a programme for using medical student volunteers as human models for teaching ultrasound of the chest, abdomen, head and neck, extremities, and transabdominal pelvis. This proved to be a feasible and sustainable method of fulfilling the need for normal anatomic models, with robust ethical procedures which excluded intimate examinations and ensured volunteers were protected from unwarranted pressure to expose sensitive areas during scanning sessions. A similar model could be applied in sonographer education to allow for valuable hands-on practical training to provide a useful learning experience for student volunteers without substantial financial investment.

Sr2: I've had many of my body parts scanned over the years, so I generally will jump on the bed if nobody else steps forward.

E3: We always have a good range of willing victims from the radiography team as well. So, if we are scanning people … we demand they have registered with the GP, and we use the BMUS consent form before we scan anyone.

St5: That's been really good, because I think because we're all, as humans, we're all different shapes and sizes, we've all got different things in different places, so you're getting that time to work on someone.

High fidelity simulation, with inclusion of live models and simulation within their own clinical environment was highly valued by students because it helped with skill development, understanding the variations they might encounter in practice, and learning to adapt technique to suit different patients. Most participants reported that live models were easy to find, and most had no issues with being a model and being scanned for abdominal, transabdominal gynaecological or musculoskeletal applications.

St3: I like being a model … so I can help other people and I don't mind what they do … you can also, see if there's anything wrong with you.

Sr2: generally, they're quite happy to be scanned and to scan each other.

Students found scanning and acting as live models useful for their learning, as they enjoyed a shared learning experience through the peer support offered during group learning. For some students, embarrassment and self-consciousness were initially a barrier to acting as live models for scanning, although most overcame this quickly. However, it is important to note that for some student participants, there were initial anxieties and concerns about the potential for identifying something abnormal or unexpected findings on their own scans when they were a live model during teaching sessions. For learners, their lack of experience and background knowledge to reassure them about the consequences of any abnormal findings or normal variants must be carefully considered. Informed consent using BMUS guidelines (SCoR & BMUS, 2023) and the presence of an experienced tutor when using live models is essential, and although it may be time consuming, consideration should be given to ensuring that any models are scanned by a qualified staff member before engaging in any teaching sessions to ensure the model is prepared for any findings, and to ensure that required referrals are already completed prior to teaching sessions.

E7: … some of it is to do with culture. I think they're just more aware of perhaps exposing themselves to comment from other people, so social media. You don't really want to put yourself out there, do you? … perhaps students therefore are more reluctant, more body conscious

St3: you know you've got to show your tummies and your, your legs and whatever … everybody's different. We're not really bothered anymore. We've tried to make them feel comfortable … that's important.

Several participants acknowledged that correct governance is important to ensure safe practice, which aligns with current policies for safe practice (BMUS, 2009; SCoR & BMUS, 2023). It is important to note that the use of live models is only possible in some areas of practice, since there are ethical considerations around using live models in obstetrics or for intimate examinations, where using live models is not ethically acceptable (SCoR & BMUS, 2023). Therefore, in some areas of practice, students were unable to access simulation opportunities, and they were limited to learning within their clinical environment, which can be difficult.

Sr2: Obviously … if we do happen to find anything that we would refer on, write an official report

Sr4: I think if you use live models ... you don't necessarily know what you'll find so we need to ensure that we've got all the governance and everything in place … we've got the ethical issues and the safety issues … particularly for obstetrics

E2: One of our students, we found a thyroid cancer it turned out to be, and they ended up having surgery and having it removed, and they're now doing really well.

Moak et al. (2014) compared training in transvaginal ultrasound for novice learners and found that simulators did not perform as well as live models for training; although their study was approved at the time, the performance of more than 70 intimate examinations on a standardised patient was ethically questionable, and this would be unacceptable in modern UK sonography training. Their trial found that phantoms used had lower overall scores for scanning technique and image acquisition compared to live models, but students from each group performed equally well in terms of professionalism, so although simulation for learning intimate examinations had limitations, it was still useful for student learning and had a positive impact on their professional practice.

Participants in this study reported some use of live models for learning of scanning technique, and there is potential to further develop this to include the use of simulated patients (SPs), who are individuals trained to portray a real patient in a clinical scenario. Using trained simulated patients could allow development (and perhaps assessment) of a wider range of skills, including communication and the professional behaviours which are key elements of sonography practice. This method of simulation-based education is often included in healthcare education to teach and assess communication skills (Lopreiato, Downing & Gammon, 2016; Nawathe & Alaina, 2024), but costs, training time and logistical complexities of using simulated patients can limit the potential of this approach (Nestel & Bearman, 2014). To minimise the challenges of using SP for training, outlining clear objectives, resource allocations, quality assurance and specialist training for staff are required. Careful planning and preparation could enhance the simulation experience for students and further investigation into this learning approach for sonographer learning is required.

4.1.6. Role play and communication

Role play is a well-established method of education in healthcare and was discussed by several participants. Students have long engaged in unstructured role play, which has proved valuable for some healthcare learners (Van Soeren et al., 2011). However, many participants in this study did not see any value in simulated learning for communication skills, and others described negative experiences of simulation role play, and felt that it had not helped their practice, so they were strongly averse to the concept as a learning tool.

Although simulation had potential to enable students to try a variety of approaches with their peer group without worrying about upsetting a patient in practice, there were concerns from many participants that role play was difficult or embarrassing for students, with poor levels of engagement, therefore this approach was not used regularly by participants.

Sr3: I'd done a lot of simulation in terms of delivering unexpected findings to parents … I'd done roleplay with that for years.

Sr6: absolutely there's a place for that. But we don't use it a lot

E7: students really struggle with roleplay … it really is excruciatingly embarrassing and painful for them, and they just don't engage with it at all. So, we don't tend to do a lot.

Sr1: I hate roleplay. It's worse than any other real-life situation; the only time that I've ever really used roleplay was when it was forced upon me as a trainee in an obstetric clinical scenario in giving bad news … I died on the inside. I just fell into this big hole.

Learning communication skills in sonography practice is challenging, and some participants felt that simulation learning experiences helped students to start to develop their communication skills. Consideration of the educational level of learners is also important here, as undergraduate learners are likely to require more development in this area than postgraduate learners (who are often registered health professionals with experience in health care communication).

E7: I think the one area possibly that we need to really expand upon is the communication and talking to patients, because I think that's, particularly radiography students find it challenging, don't they? They've not had to do it before, suddenly you throw them in the deep end, go and do this, so I think more simulation and training and yeah, it'd be good if we could … simulate what might happen in real life and in practice because I think they struggle with that.

Jasemi et al. (2022) compared standard lectures and role-playing for nursing student learning around ethics in practice and found that roleplay was more beneficial than standard lectures for student learning. Although lectures were effective in expanding knowledge in the short term (Vizeshfar et al., 2019), implementing role play as a teaching method is time-consuming when compared to lectures (Pourghaznein et al., 2015). Observation of role play proved more effective than lectures because learners established an emotional connection which improved their learning, but simulation is unlikely to fully replicate the realities of clinical practice and therefore it is unlikely to adequately represent the variety of challenges in clinical practice. Educators acknowledged that there is potential to further develop how simulation was used within curricula to develop communication skills. This may be more useful for training undergraduate students rather than postgraduate learners, who are more likely to have highly developed communication skills in healthcare settings.

Since students work in a variety of environments with unpredictable work lists, one educator felt that there was potential in using simulated patients to offer predictable, equitable challenging cases for their students.

E2: we need to have that experience with real patients. It's about the communication, it's the different variants … dealing with challenging patients

E6: I know there's definitely more that we could do around communication skills … we have access to experts by experience … there's lots of scope for how you could develop simulation in that scenario even further ... we need to be exploring every way of how we can develop those skills on campus.

From participant experiences, there is a clear need for better opportunities for sonography students to develop their communication skills. Communicating unexpected findings to patients is acknowledged to be a challenging task (Johnson et al., 2023) as sonographers must carefully manage their body language and facial expressions, in addition to simultaneously conducting and formulating the scan results (Hardicre et al., 2020). Partner, England, Young, Shiner & Bridge (2023) advocated that role play for development of inter-personal skills for radiographers could be developed if there was good construction of the scenarios, but that further research was warranted. Due to the additional roles and responsibilities of sonographers, careful design and facilitation of role play is required, and this needs further investigation.

There are alternative methods of improving communication skills in practice which students might find more acceptable than participation in role play scenarios. Dalwood et al. (2020) completed a systematic review of peer simulation in healthcare education, which is an evolved form of role-play, in which students are trained to portray patient roles for their peers. This approach was an effective and well-received method of providing training to develop communication skills for medical and nursing students. Furthermore, Dalwood et al. (2020) found that peer simulation had wider applications in physiotherapy and OT, where it has been implemented for the learning of additional skills such as physical assessment and management. Based on the review by Dalwood et al. (2020), there is potential to expand beyond the current role of live models for developing scanning skills. Further research is recommended into the potential use of peer simulation for sonography students for developing communication, confidence, self-efficacy, and patient empathy.

A potential approach by Kaur, Arezina, Bryant et al. (2023) assessed communication coaching as in intervention for qualified sonographers in obstetric practice, which showed promise. Their participants felt that their role in delivering unexpected news often led to a build-up of suppressed emotions and potential burnout in practicing sonographers, and communication coaching was viewed as a useful intervention (Kaur et al., 2023). Similar findings have been reported in other areas of health care education, with Pilnick et al. (2023) using conversation analyses-based simulation in a dementia care setting, with positive results in improving communication skills.

Debenedectis, Gauguet & Makris et al. (2017) used simulation to assess radiologist communication skills using standardized patients and trained faculty for assessment, which was found to increase confidence. However, this approach required substantial resources and planning, which potentially makes this difficult to implement routinely in sonography education. Given the limited availability of resources, alongside the importance of developing empathy in health professionals, further development of peer simulation should be considered for sonography students.

Dalwood et al. (2020) were unable to definitively determine the cost and value of peer simulation in healthcare education, but this approach may be more viable than current models of simulation-based education (SBE) using simulated patients. Interventions like conversation analysis, standardised patients and peer simulation could be explored for sonography trainees to minimise the emotional impact of the pressured role they perform in clinical practice, but further evaluation is required, and the time and costs of implementing strategies like these require careful consideration.

4.1.7. Simulation and assessment

The use of simulation-based summative assessment is well established in healthcare education, with use of OSCEs (objective structured clinical examinations) introduced in the 1970's and continuing to be implemented in medical and healthcare education today (Bouleon et al., 2022). As technology has developed, more flexible simulation systems become available, which may have potential for teaching and testing sonography student knowledge and skills.

Use of simulation for summative assessments was not used in practice by participants. Some educators had attempted using task trainers as a summative assessment tool, but found this ineffective, and most participants felt strongly that it was essential to assess student competence in the real clinical environment.

E1: We were using the Scantrainer, but we decided to take that out ... we felt it wasn't a good assessment tool. We felt that it disadvantaged students, because it was another added pressure to have to use that technology ... I don't think it was particularly a fair assessment of their ability.

E3: I'm not convinced … I prefer to see a student interact with a patient. I want to see them do the whole examination … I don't believe that clinical assessment should be boiled down to simple technical ability.

E6: we are looking at whether we have more of a summative process on site at the university so that we're providing full consistency and parity across the cohort. But there's limitations … challenges to using that strategy from a summative perspective

Some participants saw wider potential in using simulation as a formative assessment tool, and some educators reported using this approach to monitor skill development and to ensure students had reached a basic level of skills prior to clinical placements. Simulation was occasionally used as an assessment tool for formative assessment, with one full time

MSc route requiring students to pass a formative simulated assessment before being allowed to progress to placement. However, most participants felt that the lack of realism, and difficulty in replicating the wide variety of skills required in practice, meant that simulation was unable to adequately assess a full range of clinical competencies.

E6: we do expect that they have achieved a certain level before they go out onto placement to a point where, we do a formative assessment prior to them going out and actually if they haven't achieved that level, we would tell them that and stop them from going out into placement.

Sr4: I think what is lacking … is something about the assessment of communication, interpersonal skills that are so important for a sonographer … it doesn't fully provide a realistic assessment of those skills. I think it has got a use, but not fully in its current format.

Summative assessments were typically performed in clinical practice, but students often feel very pressured in practice, and being assessed in a tense environment adds to this stress. Students liked the idea of using simulation to practice and prepare for their assessments in practice, but students reported finding the simulated environment unfamiliar and "*strange*" when compared to their usual clinical practice, and they were concerned that this would affect their performance in any simulated assessment tasks.

St1: our actual practical summative assessment is a live list with patients, so there's no simulator used for any form of assessment

E6: from a clinical assessment point of view, we do that fully within the clinical department

St3: (assessment in practice is) really stressful because I don't want to fail, and I don't want to get anything wrong.

Standardising clinical assessments for sonography students in practice was difficult since variations in workloads and unpredictability of clinical practice lists makes consistency difficult to achieve in practice environments. Although this challenges students to demonstrate their adaptability and ability to perform in the real clinical environment, further development, and use of a wide range of simulation based educational methods is required to enable thorough assessment of clinical skills.

Sr3: I think some people would prefer a standardised assessment in simulation

Sr4: on a summative clinical appraisal in the department, you might have five patients that you've booked who all turn up and are perfect body habitus for scanning who are normal and have got no pathology to identify or abnormality.

A review of simulation-based assessment in healthcare found that use of simulation based summative assessment is promising, but requires careful development, delivery, and appropriate supervision (Bouleon et al., 2022). This approach is increasingly used in healthcare education, but formal guidelines for good practice are required to ensure consistency and quality. If summative assessment is to be successfully implemented, consideration should be given to how this assessment tool might impact learner behaviours, and it is essential to ensure that formative assessments are also included in the curriculum. With further development, simulation-based assessment for sonographers has potential to provide challenging, varied, and equitable assessments for learners.

Participation in simulation or high-stake simulated assessment may have psychological impacts on all participants (Gaba, 2004), so it must be rigorously conducted and supervised. While considering the term 'competence' in clinical practice, older taxonomies did not allow for the subjectivity of assessing student performance; even with defined marking criteria and rubrics, the clinical assessor's disciplinary expertise and subjectivity remain an important factor in assessor judgement (Perry, Bridges & Burrow, 2021).

A systematic review by Dromey et al. (2021) found that most simulators focus on technical skills, but do not address the need to develop communication or clinical decision-making skills, which are key elements of clinical competency for sonographers. Implementation of simulation based summative assessment is complex, requiring coordination of teams, writing of assessments, agreement of standard marking scheme, training of standardized patients, as well as considerations of the financial, logistical, and practical elements of this assessment strategy (Bouleon et al., 2022). High quality simulated assessments must have clear objectives, and carefully designed scenarios to ensure the tasks are predictable, standardized, and reproducible (Bouleon et al., 2022). Introducing this in sonography education would require development of formal guidelines for good practice and rigorous training of facilitators to ensure a good experience for learners and participants. Further exploration of the use of simulation for sonographer assessments may help to alleviate some of the pressures on clinical staff and could provide equitable and predicable assessment experiences for students.

Educators must ensure that the assessment method is aligned with learning activities and objectives (Bouleon et al., 2022) and further training of faculty and facilitators in sonography education is required if this strategy is to be successfully implemented for sonography education. These are important considerations for implementation of the end point assessment (EPA) examination for new undergraduate apprentice sonographers, where simulation is currently a key element of the assessment strategy (Institute for Apprenticeships, 2019). As technology and educator expertise in the use of simulation improve, further research into this area will be required. However, without further development and careful design, simulation is unlikely to be high fidelity enough in all areas of practice to allow students to demonstrate a full range of skills and their ability to work in pressured clinical environments.

4.2. Subcategory A2: Educational routes for sonography

Traditionally, sonographers are postgraduate part time students (registered health professionals), who focus their time at HEIs on knowledge development and academic achievement to support their clinical learning. Over the past 10 years there have been significant technological developments in healthcare and educational practice, alongside changes to educational routes and the introduction of a new sonographer career framework (HEE, 2022). Participants discussed clear differences between the educational routes with undergraduate, part time postgraduate and full-time postgraduate students all having different learning needs. Educators were more enthusiastic about embedding simulation into their programmes for new undergraduate or full time MSc routes, particularly for students who had not already scanned “real” patients.

E4: I know there is that debate on the traditional route and the new route, it would help them to appreciate that actually the sonographer’s profession is not being devalued, but we have to think innovatively on how to address the shortages, because I think the traditional way we’re doing things is very expensive, very longwinded and is not sustainable

Participants discussed the difficulty of achieving consistency between programmes as they recognised variations in delivery patterns for masters' programmes in different HEIs. Sevens (2017) recommended exploring ways to supplement clinical experience through increased use of simulation, but it was evident from participants in this study that the reliance on clinical placement for sonography training remains largely unchanged, and given the variety of learner experiences and needs, it is difficult for educators to find a way to use simulation optimally for training sonographers.

E5: We've been talking about ultrasound training for so many years ... I don't think we've quite cracked it yet.

4.2.1. Simulation in postgraduate programmes

Most postgraduate part time students spent only limited time on campus at their HEI, and this time was largely spent on knowledge development and academic achievement to support the development of clinical skills. Practical skill development relied largely on time in clinical practice. Although learning outcomes for postgraduate routes are similar (CASE, 2022), the delivery patterns of different MSc courses vary considerably.

Since educators felt simulation was most useful in early skills training, they used this more consistently for full time route students prior to any time spent scanning "real" patients. There was less use of simulation, and a lack of engagement from part time postgraduate students, who have already spent time in clinical placements.

E6: So, for the full-time students it is really engrained in what we're doing with them.

E6: We find that some of the part-time students don't take to it as well. Because they've already had that experience of scanning in the department, scanning real patients, and we do get a lot of comments about well it doesn't feel like a real patient.

E5: … they use the simulators on their own

Sr4: sonographer training is very intensive … departments haven't got the time to coordinate, to arrange training sessions … for actual simulation I think they haven't got the time, but I also think they've perhaps not got the skillset

The current reliance on use of simulation only within HEIs is not sustainable since a crowded curriculum left little time on campus for more integration of simulation into student learning. However, time and expertise to deliver simulation in clinical environments is currently limited, therefore how simulation could be used more effectively must be carefully considered.

4.2.2. Undergraduate routes

Undergraduate programmes for sonography education have recently been introduced alongside changes to the sonography career framework (HEE, 2022), and they are still in the early stages of being adopted in practice (Hynes & Hood, 2024). Mitchell (2018) explored the attitudes to graduate sonographers and reported a lack of enthusiasm and negativity towards implementing changes within sonography educational routes, using the lack of professional registration to justify why a graduate sonography would be unemployable Despite this resistance, there are at least two BSc programmes for sonography training running from 2024, and a growing number of BSc graduates will become employed within NHS Trusts. These programmes are supported by a national drive for change, including the development of the BSc apprenticeship standard, CASE accreditation of BSc graduate sonographer routes and the publication of the career framework (HEE, 2022) (which have all developed despite the ongoing lack of professional registration). Despite this, some participants reported that new apprenticeship routes were viewed with uncertainty and resistance from clinical sonographers, with a lack of understanding of the course and the requirements of learners.

St3: … the first [undergraduate course] … they couldn't get their heads around it … They couldn't work out how it was going to work, so that was a problem … People just want clarity. They want to know what they're doing.

Lingering professional opposition to undergraduate routes for sonographers is still evident from participants. Students experienced uncertainty and resistance from supervising clinical staff. The reported lack of understanding of new apprenticeship routes and the requirements of these learners is concerning, and it appears that the professional protectionism among sonographers noted by Mitchell & Nightingale (2019) remains largely unchanged. This might partly explain some of the negative feelings about clinical learning experiences expressed by participant learners within this study, and why the use of simulation was so valued for their skill development.

4.2.3. Training Academies

Radiology Academies for specialist radiologist training were initially established by the Department of Health and the Royal College of Radiologists in 2005 (HEE, 2017). Between 2005-2017, Health Education England (HEE) invested £2.42million annually in the three original academies (HEE, 2017). By 2024, seven UK imaging training Academies have been established in NHS regions of England (HEE, 2024). These academies deliver education to a variety of learners across the imaging workforce and aim to provide greater health system value than traditional education models. Training is provided to the whole imaging workforce in a multi-disciplinary environment (HEE, 2024).

HEE advocates a multi-professional approach to managing the quality of education and training for all healthcare learners, claiming that consideration was given to accessibility of Radiology Academy training infrastructure to wider multi-professional imaging and clinical teams (HEE, 2017). Whilst there is some national oversight, each of the training academies operates differently to provide training and education across their region, enabling access to dedicated learning environments and the use simulation equipment and models for training (HEE, 2024). There are wide variations in their operation, which has added to the complexity and variations in ultrasound education nationally.

Sonographers were acknowledged in the HEE (2017) report as having a valuable role in clinical radiology teaching with excellent radiology trainee feedback (HEE, 2017), yet participants in this research described some current academy models as inaccessible or unavailable for sonographer training, depending on local rules, funding stream and geographical location. Some academies support groups of Trusts regionally, but participants felt that sonographers were largely excluded from access to training at these facilities, which appeared to focus on supporting radiologist education. The lack of accessibility for sonography students to academy training, mentioned by several participants, means they remain largely reliant on one-to-one supervision and learning in busy clinical environments.

> *Sr2: from a sonographer point of view …we don't share training facilities*
>
> *E3: it would be absolutely fantastic to have a multidisciplinary model where people … actually understanding where the boundaries are, and not being territorial about ultrasound.*

Some participants discussed the success of regional academies in obtaining funding for simulation learning for ultrasound training, but this appeared to be limited to the use of self-directed learning using task trainers, which were now a few years old. Participants reported that academies often relied heavily on clinical experts delivering clinical training lists (on real patients), with simulation used only as a self-directed and limited early activity for learners. Although academy models appeared to be offering an alternative to traditional clinical placement support for ultrasound training, they still follow more traditional models of training, where development of clinical skills relies mostly on one-to-one training with real patients and training lists from a local NHS trust.

> *E3: I think that people are looking for answers in the wrong places, and the answer is imaginative use of simulation, more clinical placement.*
>
> *Sr3: simulators get bought … get stuck in a room and they don't get used as much as they should*

Regional academies were configured locally, in collaboration with local imaging networks to reduce pressures on understaffed clinical departments and provide high quality clinical learning experiences for students (NHS England, 2024). Participants in this study reported that their academies largely functioned by simply mimic clinical practice experiences scanning real patients with additional time per examination. Although this may provide some respite for busy clinical staff, this is still a pressured learning environment for students where implications of a mistake are serious.

Simulation learning provides flexible and consistent learning for clinical skills, and it remains a priority in the NHS Long-term Workforce Plan, with an estimated £15 million of funding invested through HEIs in 2021/22 to increase simulation capacity for AHPs and doctors

(NHS, 2023). Academies were designed in line with common principles, including access to dedicated learning environments and the use of simulation equipment (NHS England, 2024), and the NHS Long-term Workforce plan advocated increased simulation use to reduce the pressure on placement providers in health and care (NHS, 2023).

A national review of training academies (HEE, 2017) reported that radiology academies have used simulation-based teaching for active and experiential learning to supplement hospital-based training schemes, and radiology trainees appeared to demonstrate accelerated development and early core competencies, which appeared to help academy-based learners' transition from full supervision to working independently more quickly than their contemporaries in traditional schemes.

Increased simulated learning aims to provide learners with opportunities to enhance their critical thinking and decision-making skills and gain insights into complex areas of healthcare provision that they may not otherwise access in their training (NHS, 2023). Although many participants were aware of the academies (and several were directly involved in these initiatives), participants did not feel well informed about the purpose or function of the academies, and they reported a lack of coordination between groups in different regions, including minimal sharing of experience or expertise between different academies.

Sr1: I feel like it's a bit of a shambles at the minute, nobody's got anybody at the helm. I feel like everybody's pulling in different directions

Sr3: it's just a hotchpotch of different settings, different models, different ways of working. Some academies are fully staffed … others have got someone for maybe one or two days a week … there's a disparity with the ultrasound academies within an imaging region.

E3: Nobody can tell me what is meant to result from this (academy) … I haven't met anyone involved in it who can tell me exactly what the aim is

Sr4: central funding went out to regions and regions have all done different things and that's not helped in terms of looking at consistency of education

Currently, there is little robust evidence available to inform the effective use of simulation learning for teaching and assessing ultrasound clinical skills for sonographers, and since training academies run alongside teaching within HEIs and clinical departments, this makes any comparisons between different educational models difficult. Although NHS England maintain national oversight of the imaging training academies (NHS England, 2024), there is no obvious established baseline for evaluating these, and several stakeholders in this research commented negatively regarding the lack of transparency in how the academies were funded and running in different regions. Sharing of knowledge and resources could be beneficial, but for stakeholders, balancing the training provision for multiple professional groups and meeting the varying needs of different clinical departments was challenging, with significant differences noted in training expectations for different groups of trainees. Several participants felt that sonographers were excluded from these learning opportunities, therefore they felt that academies had little or no impact on sonographer training.

HEE (2017) reported that training in Radiology Academies was, on average, more than twice the cost of training in traditional hospital-based training schemes. Although these academies aim to be self-sustaining, they currently remain funded by NHS England (NHS, 2023), which could make this model unsustainable in its current format. It remains unclear if the investment in these academies has been good value for overall learning experience, and participants in this research reported they had seen very little impact in sonography education.

4.2.4. Innovative use of simulation

Some participants had used simulation in innovative ways, including one example of simulation designed to develop student understanding of research skills, supporting one of the four pillars of advanced practice. Several participants used simulation as a trouble shooting tool for evaluating or resolving issues for individual students. Others were aware of new developments in healthcare education such as virtual reality (VR) headsets, but these have yet to be fully explored for use in sonography education, with costs and limited software developments inhibiting their use.

E3: It's a dream at the moment, because we haven't got the right kit.

E7: I think we should use it [virtual reality] a lot more.

Simulation was sometimes used to help students to apply theory to practice and gain a better understand of the scientific principles of ultrasound, image optimisation and image interpretation skills. Simulation provided opportunities for students to review normal ultrasound appearances, as well as a chance to review complex cases or pathologies. This allowed predictable, equitable, planned teaching sessions for all students.

E6: we try to emphasise actually doing simulation for the more advanced techniques and we're looking at case studies

St6: I haven't seen much pathology yet but its' good to see what normal looks like … So, then I'm familiar when you come to using it on someone

Sr2: It's something that we don't really do … maybe because I haven't got a good library of images

Reporting and image interpretation was learned mainly in clinical practice, although there was acknowledgement that development of reporting skills can be limited by access to an appropriate range of cases and pathologies during training. Participants saw potential in using simulation for developing image interpretation skills for pathologies or advanced techniques later in the curriculum. Simulation offered some opportunities for students to develop and test their clinical reporting skills and could be used more extensively to support student learning.

Sr2: It's something that we don't really do other than when they're scanning at the moment

Sr4: I think there are other methods …that we've not fully explored … it's still relatively new technology … it's about the exposure to it and exploring the opportunities that they present. I think now is the right time to be looking at this sort of thing particularly since there's been investment from Health Education England

One participant mentioned an online simulation programme used to help develop ultrasound skills, but its use was in the early stages and little robust evidence is available on how this tool impacted on sonography student learning. A trial of the online simulator showed that students improved their scores on the simulation system, but no evaluation of real practical skills was included (Meuwly et al., 2021).

Educators who had introduced newer full time postgraduate or undergraduate educational routes have had to innovate and reported more simulation use within their curricula, possibly due to their need to maximise training capacity for their learners. However, these participants described a variety of issues which negatively affected student experiences of simulation in sonographer education, including technical issues, poor ergonomic design, and potential for negative learning or overconfidence.

Sr6: …. I think you've always got that underlying current of, "no one's going to die" if I do the wrong thing in this situation. And I guess that's where the limit comes, is it can only go to a certain point before they're out there in real world

Simulation use does not have to be limited to new learners. Developing expertise in practice may be difficult as some pathological conditions are rare, so there can be significant pressures in practice when a sonographer identifies something unknown on a patient examination where they have limited time, lack of familiarity with the appearances, and inexperience of reporting the findings. Use of simulation could help to lessen these pressures if students had already experienced similar findings during their simulated learning. Simulation also has possible applications for supporting advanced practice skill development, including the development of interventional skills, but this has not been fully realised in practice.

Sr7: *What's really useful for even a very experienced sonographer is to be able to see abnormalities*

E1: … experience of difficult or complex cases is advantageous.

St5: I learn a lot in these simulations that I maybe don't get the opportunity in other situations … there's endless amounts of simulation opportunities.

Sr1: It's about developing everybody else and transitioning rather than making people ready for their next step.

Simulation should be designed to be appropriate for educational levels and type of skills required. Careful consideration of the needs of learners is essential to ensure that simulation is used effectively within curricula for different levels and stages of learning.

4.2.5. Moving towards the future

Educational practice is constantly evolving, and although the number of sonography students on newer educational routes is growing, most graduates are still from part time postgraduate routes. Technological incorporation into learning content, as well as in enhancing clinical skills via virtual reality stimulations, could potentially enhance future curricula in healthcare education (Marshall & Wolanskyi-Spinner, 2020). Nestel & Kelly (2018) predicted the increasing use of innovative simulation within HEIs and healthcare services to support healthcare students and professionals to develop and maintain knowledge and skills, with potential for simulation to also inform patients and carers about health literacy and navigation of healthcare systems.

Simulation learning remains a developing area, and there is a lack of understanding of the full potential of this pedagogical approach for sonography education. A meta-analysis by Dromey et al. (2021) reported that of 8 qualitative studies, most focused on functionality and usability of simulators, and there was little focus on transfer of skills from simulation suites into the clinical environment, or if skills were maintained over time. An appetite for change was seen amongst participants, but the time constraints and pressures in practice (and education) are limiting the opportunities for developing simulation learning for sonographers. Educators are encouraging a change to traditional training, but clinical staff may not have sufficient time or training to facilitate simulation learning effectively.

E4: Simulation training before going out to clinical placement would be a great advantage

E3: I would love to know how other people are using it … that would be the most valuable thing.

Sr1: I do think that some hospitals now are starting to get some … I'm not sure how useful that is.

To ensure that simulation is used effectively to support sonography student learning, further work is required to develop strategies for its effective integration of more (and better quality) simulation learning throughout the curriculum. Access to simulation resources as an educational method for sonography remains variable, but there is much potential for developing healthcare simulation education which includes healthcare service user views to ensure holistic scenario development for learners (Nestel & Kelly, 2018).

The emergence of new educational routes for sonography introduced more diverse groups of learners, who are likely to benefit from different types of simulation at different stages of their learning. Participants engaged with these newer educational routes (such as full time MSc and BSc programs) appeared to have embraced the use of simulation more within their curricula, but there were a variety of factors which made the introduction of new routes challenging.

Developing expertise in simulation and adopting different approaches (such as dyad models and more group learning) could improve the cost effectiveness of these initiatives. Better access for sonography learners, and better coordination between academies and other organisations would also benefit all stakeholders. Tolsgaard et al. (2015) found that dyad practice improves the efficiency of simulation-based training and is non-inferior to individual practice in terms of skills transfer for obstetric ultrasound training, but their participants were medical students, who required a different level of competence than autonomous sonographers working in the NHS.

The importance of leadership, collaboration, support networks and funding within sonography training programmes was recognised, but the lack of coordination between HEIs, clinical departments, regional academies and the variety of stakeholders involved in sonography and ultrasound education is a barrier to change. Given the complex skills required by sonographers in practice, there is potential to explore the use of simulation for development of a much wider range of skills. The requirement for advanced practitioner sonographers to demonstrate skills in education, research and leadership could be helped by the better integration of these skills into curricula.

Sr1: There's no national approach. There's no specific funding … and there's no guidance

Barbaroux (2022) investigated the role of simulation-based training in the development of leadership skills (outside of healthcare settings) and found that there was potential for these to provide experiential learning, provided that the training was carefully designed, and aligned with the level of expertise and professional experience of the learners. There is a growing interest in exploring links between healthcare and skill development in an industry like aviation (Malcolm, Pate & Rowe, 2020; Kapur et al, 2016). Aviation training programmes include technical skill development, as well as psychology, decision marking, leadership, and teamwork (Malcom, Pate & Rowe, 2020). High-reliability industries like aviation are complex and dangerous environments, with a low incidence of error, but where the result of an error is significant. Although technical aspects of the two industries are inherently different, there are similarities, since both sonographers and aviation crew operate in highly specialized, complex environments that rely heavily on technology and human decision-making where an error can have significant implications. Further research is required to develop strategies to ensure a coordinated approach to establishing a cost effective and sustainable models of sonographer education.

4.3. Summary Category A: Simulation and sonographer education

The range of skills required for competent sonography practice is wide, and although there is potential for simulation learning in many areas of practice, there are large variations in practice nationally and the use of simulation-based education remains largely unexplored. Most participants demonstrated some awareness of the need for worthwhile and well-planned simulation learning for students, but educators were not always well prepared to implement simulation within their programmes. Educators had to adapt and change as technology improved and new equipment was procured, but this proved difficult in their pressured (time poor) roles. There was a self-acknowledged lack of awareness by educators and stakeholders regarding ultrasound simulation equipment, and limited knowledge of the variety of available simulation methods and their applications in healthcare education. Educators had limited opportunities to support their development of simulation in sonographer education, which restricted their ability to implement simulation within the sonography curriculum.

Development of basic scanning skills using simulation appears reasonably well established in sonography training, but this was variable, and a wider range of sonographer skills could be gained or enhanced through simulated learning experiences. A desire to use more simulation which is better integrated throughout the curriculum was noted. To achieve this, the use of simulation needs to be expanded beyond task trainers and self-directed learning, with widespread opportunities a possibility, including exploration of high fidelity in situ simulation, live models (where appropriate), image interpretation and reporting skill development, communication skill development, safe ergonomic practice and risk assessment, case studies and pathological findings.

Students valued opportunities to learn in a supported and safe environment, where time pressures and fear of mistakes and feelings of being an inconvenience were not a concern. Students enjoyed simulation learning opportunities when a variety of challenges were presented, particularly those using live models or complex case evaluation. Reliance on only self-directed learning using task trainers is not sufficient for effective, enjoyable learning experiences, and existing resources are not always used effectively. For simulation to reach its' full potential, it should be embedded in curricula in a structured way to support learning, allowing students to move away from current over reliance on training in pressured clinical environments.

Students particularly valued tutor support and interactive group work, with personalised verbal feedback reported as most useful. Unassisted use of a task trainer was technically complex, and often not high fidelity enough for their learning needs. The findings of this study suggest that moving away from current trends for self-directed task trainer learning, to more expertly facilitated group learning is essential. Individual or group tutor support during well facilitated simulations promoted questioning, problem solving, challenged decision making and encouraged discussion and sharing of practice between learners. This can only be achieved with well-planned simulations with effective inclusion of pre-brief and debriefing for learners.

Educator training in facilitating simulation learning may be beneficial to improve knowledge and confidence of simulation design and delivery within sonographer education. Simulation was not well integrated into some current programmes, with simulation perceived as an optional and unimportant element of the curriculum. Although it was not used consistently, simulation did have a significant positive impact on learning for some participants, providing valuable opportunities in areas of practice which they were struggling to access within their clinical departments.

Simulation increased confidence and is valued by students where it is used at the right time for their learning needs, and they have sufficient access to relevant facilities and support. Additional training time used during training lists in practice is beneficial, but this approach does not provide the same opportunities for students to learn in a safe supported space, since the presence of a patient and the pressures of clinical practice make learning through experimentation impossible (and sometimes unethical).

Simulation should be available to students for regular use, and participants noted the value of easy access to simulation learning within their own clinical environments as well as within their HEI. This had the benefit of easy regular access, and simulation using live models in their own clinical environment was a higher fidelity and more beneficial learning experience for the student participants, allowing for easier transfer of skills into their clinical practice.

Although funding was available for training academies, a reliance on clinical one-to-one training in practice remains prominent. Training for staff in design and facilitation of simulation, appropriate funding availability, as well as time to implement this in practice are necessary to support the ongoing development of simulation learning in sonographer education.

Category B: Key influences on simulation use

This category will explore the key influences on simulation use in UK sonographer education, with three subcategories: pressures in practice, technology and funding, and governance and guidelines (See Table 4.4).

Table 4.4: Summary of subcategories Category B

Core Category		Subcategory	Content summary
B	Key influences on simulation use	**Pressures in practice**	• Educator pressures • Workforce pressures • Student pressures • Attitudes and assumptions
		Technology and Funding	• Technology enhanced learning • Financial considerations
		Governance and guidelines	• Regulation and accreditation • Guidelines for simulation in healthcare education • Sonography career framework

4.4. Subcategory B1: Pressures in practice

All participants described a variety of pressures within HEIs and clinical ultrasound departments which impacted significantly on student learning and the use of simulation for sonographer education.

4.4.1. Workforce pressures

As identified within the literature review, workforce shortages are longstanding in sonography (SCoR, 2022) and most participants reported that staff shortages in clinical departments negatively impact opportunities for teaching and training. Sonographers have multiple areas of responsibility for clinical work, leadership and the supervision, training, and assessment of students. Clinical staff and educators are working in pressured, understaffed environments, and they have insufficient time to offer robust student support, or for effectively planning teaching.

Sr2: with the pressures of the NHS and I know we're still under massive amounts of pressure

Sr3: in clinical practice … you're pressured, you don't have the time … sonographers are overwhelmed

Sr5: we need more sonographers … some years we have six trainees now rather than two, and it's really hard to try and give the same training opportunity to six people compared to what used to be for two people.

This aligns with findings by Khine, Harrison & Flinton (2024), who described deficiencies around supervisor training and lack of understanding regarding sonography student documentation. They suggested better training for clinical staff and reduced workloads could provide better experiences for both students and clinical supervisors, but this is difficult to achieve in practice. Work patterns also impacted on learners as clinical practice lists are often mixed to reduce risk of workplace-related musculoskeletal (WRMSK) injury to sonographers (SCoR, 2019), but for students, a dedicated training list provided better consistency and flow for their learning.

St5: I don't want to be wasting time … I don't want to push this sonographer behind on the list. But with the teaching list it's nice to have that relaxed amount of time between scans.

Sr5: always got that demand and the waiting list and people breathing on you, asking you to squeeze things in

Due to service demands, some services were prioritised over others, which impacted on training capacity and availability of staff for training, and it was evident from all participants that the staffing shortages were a significant stressor in practice. Time constraints are recognised as inhibiting good clinical learning in radiology departments (O'Connor, Lunney, Rainford, Grehan, 2023), and stakeholder participants were aware of the lack of available time for discussion and feedback for students. The negative impact of workload on clinical training, and lack of sufficient discussion or reflection time impacted on the quality of learning experiences, and the development of student confidence and progression. There appeared to be a conflict between the students' need for support and time to learn, and the need for sonographers to manage large workloads and work at full capacity within departments.

Sr3: It's like training fatigue … sonographers in practice at … they're struggling to be able to give more. They want to. And I think that creates a real challenge for them, because they know they're not giving maybe as well as they want to, but they haven't got the capacity to do that either because of the workload or the pressures they're under.

This is similar to findings by Harrison & Beardmore (2020) who identified a variety of issues impacting on sonographers' ability to teach, including working at capacity, competing demands, insufficient staff, lack of experienced mentors, and lack of funding. Workforce pressures negatively impacted on both staff and students, and several participants described feelings of guilt for not doing better. Educators recognised that more trainees are needed to address workforce shortages, but clinical departments do not have capacity to increase the number of students, and existing trainees are not feeling nurtured.

Sr3: I think there's like a guilt thing going on both sides … you've got your sonographers that are under pressure that feel guilty because they're not giving the students, and the students don't want to put the sonographer under pressure.

Sonography students find it difficult to get enough hands-on experience, and pressures in practice made it difficult to provide tailored, individualised high-quality training for students. However, stakeholders doubted that simulation could provide sufficient learning to significantly relieve the pressures in practice.

St6: I basically tried to run before I could walk. I needed to go back to the beginning: I can't just play all this music, I've got to learn the notes, before I can put everything together

Although there is potential to use simulation-based learning to support students, long term workforce deficits impact negatively on the development of new or innovative strategies for teaching sonographers; even if there were opportunities to incorporate more simulation, there were not enough staff (or enough expertise) to implement this in practice.

Stakeholders reported that some clinical departments felt unable to accommodate any trainees, since the extreme pressures on their staff made provision of an appropriate learning environment impossible.

> *Sr5: … 50% of our staff are bank staff … it's quite difficult*
>
> *Sr1: I've spoken to one manager recently who doesn't want to bring trainees, they feel like they have a duty of care to their trainees not to bring them into those environments where they may get substandard training.*

Stakeholders also felt that the quality of applications for training posts was declining, but perhaps workloads in practice placed unrealistically high expectations on new trainees. Clinical placements that provide high quality learning opportunities and effective feedback can encourage the development of intrinsic motivation for students (Khine, Harrison & Flinton, 2024), and dedicated clinical educators could offer a possible solution to improve student experience and reduce demands on clinical staff through effective use of simulation to support clinical placement learning.

> *Sr3: Even departments where they've always been able to give a lot of time and support to students are now struggling.*
>
> *Sr7: it's hard, especially when you're starting out, to get enough exposure to getting your hands on … to learn all those basic skills.*
>
> *St7: I know for me there's definitely some days where I get less hands-on than others and … you've kind of just been put in a room with somebody because there's nowhere else for you to go.*

Stakeholders suggested that only departments with staff deficits engage with training, and that there was a need to review training capacity nationally, rather than each department planning training independently. However, this might be challenging as it is unlikely that every department could support training in the same way due to the costs and training time required. Traditional one-to-one clinical training models are not producing enough graduates to impact on longstanding staff shortages, and although some participants suggested potential ways to increase training capacity, such as training pairs or groups of students, this is not yet commonplace in ultrasound practice.

Sr4: In other professions … they've implemented different methods where two might be doing something else … a one-to-two model or a one–to-five model, and implemented different tasks rather than all being with one patient in the room. So, in terms of sonography two might be writing a report and viewing some cases that are relevant to what they're scanning; one might be observing, one might be scanning for example.

Other educational models, such as integrated small group learning and simulation to supplement clinical learning has been successful in other healthcare students, and resulted in improvements in critical thinking, reflective practice, teamwork, communication skills and an increased awareness of patient safety (Levinson et al., 2016). Dyad learning in pairs has been successful in nursing education, providing a supportive environment for learning in a community and developing teamworking skills, which ultimately improved patient outcomes (Ruth-Sahd, 2011). Interprofessional dyads had further benefits of widening student perspectives, which led to more holistic understanding of patient care (Torben Baek et al., 2020). In sonographer training, consideration of testing this model of dyad training, or adopting multi-professional working between sonographer and radiologist trainees could benefit learners, potentially increase training capacity, and reduce one-to-one training pressures for clinical staff.

Use of simulation learning could supplement clinical learning, and one educator felt this could increase placement capacity, but this would require additional time from educators within HEIs, or a dedicated clinical educator within clinical departments to provide simulation learning and support, teaching and mentoring students in practice. However, lack of time due to work pressures means that existing resources are not being used to their full capacity.

Sr4: Sim provides peer support, access to it to be able to when they go into the department already have some of those skills that are needed so they're not so worried or concerned about having to develop the very basic skills and deal with a patient … in some circumstances they can be very demanding … it can be a very tense situation.

Nightingale et al (2021) emphasised the importance of staff retention in maintaining radiographer workforce supply and ensuring continuity, however, sonographers were leaving their roles due to WRMSK injury, lack of flexible working, poor CPD opportunities, burnout, and lack of role recognition. Staff retention and career development opportunities are also key elements of the NHS Long Term Plan (2019), so widespread introduction of clinical educator roles could provide a partial solution to these issues. Although this would require funding, it could have a positive impact on staff retention and potentially increase the number of trainees and newly qualified staff.

4.4.2. Educator pressures

Educators showed interest and enthusiasm for simulation use, but they described high workloads and limited time and resources available for developing their programmes or innovating in their educational practice. The relatively small cohorts on ultrasound programmes compared to other health professions, meant that educators sometimes felt overlooked, and unable to implement change within complex HEI organisational structures. Educators reported frustrations with the complex internal processes and time taken to enact change within HEIs, and they felt exhausted and powerless to change this. Time was also a major barrier to developing innovative strategies for simulation-based education for sonographers. There was a lack of individual ownership of the need to change or enhance teaching and learning for students, which may be due to a lack of time, lack of expertise or lack of confidence.

E2: We run out of time and have to prioritize the lectures ... simulation comes almost last in our thoughts.

E2: Time is a massive barrier … we keep saying our next year will be better, but actually we are all just flying by the seat of our pants!

E3: this is something I haven't fully conceptualised for myself.

Integration of different modes of simulation into curricula varied, with models, phantoms and task trainers commonly discussed, but there was little use of other types of simulation as described by Jones et al. (2015), such as standardised patients, patient simulators or screen-based computer simulators. Educators lacked awareness of the potential variety of approaches to simulation learning, with most focused on practical skill development and task trainers. This is mirrored in the evidence base, with many articles focused on technical skill development using task trainers, and the impact of these on student confidence (Burden, Preshaw, White, Draycott, Grant & Fox, 2013; Byford, Janssens & Cook, 2021; Tantrige et al., 2023; Tolsgaard et al., 2015), but many existing studies evaluate training of radiologists or other professionals, and they are not specific to sonographer education. Furthermore, much of the evidence base has focused on the development of point-of-care ultrasound skills and the use of ultrasound as a clinical tool for medical staff, rather than a complete diagnostic imaging examination undertaken by sonographers (Alexander et al., 2023; Dromey et al., 2021; Nti & Pillarisetty, 2020; Sidhu et al., 2012).

Educator participants demonstrated a willingness to share knowledge, and aspirations to learn and improve were evident, particularly from participants who have access to a variety of sim equipment and those have introduced new educational routes, but they acknowledged that time was a limiting factor. Educators were supportive of this study, and keen to learn from the outcome. There is a clear need for a forum for discussion and sharing of experiences of simulation-based learning.

E2: It's always useful chatting to other programme leaders

St4: think we just need to keep that recognition, promote, showcase what can be achieved through simulation and digital technology

The unanticipated COVID-19 pandemic forced educators to review and adapt their approach to sonographer education, moving to a more online or flipped classroom environment (Lo & Hew, 2022). However, the move to online education limited opportunities for teaching practical skills or using task trainer simulation, and educators missed opportunities for face-to-face interaction with students, impacting negatively on the use of simulation learning for sonographer training. Some participants felt they had reached saturation point with online learning and virtual environments; educators described working under pressure and feeling overwhelmed and exhausted, which meant motivation and time for innovation was limited.

E6: They're not coming in as frequently as we used to see students coming in

E5: COVID did different things to us … I felt we (stopped) using the simulator

St4: I felt isolated … we didn't necessarily see each other as students.

In theory, simulation could reduce pressures on understaffed clinical departments and provide high quality learning experiences for students in a safe and supportive simulated learning environment. However, the reality for educators was that integration of simulation increased their workloads, and they lacked time, experience, and facilities to develop or facilitate high fidelity varied simulation experiences for students.

E2: It's just having the time to actually sit there and get your head round it yourself. I mean I could spend the whole week working through the packages on a Scantrainer … we haven't got time to sit there and do that

E1: There was a lot going on about virtual reality, and we had a team just developing resources for that … there wasn't the expectation that you had to do all that yourself.

E2: I think in theory it's meant to free up some tutor time, but we found it's made more work.

E1: I've just tracked onto the path of least resistance

This meant some participants demonstrated apathy towards embedding simulation-based learning and they saw this as a problem for someone else to resolve, rather than an opportunity to develop innovative ways to embed simulation in their curricula. Similarly, Wallace (2023) reported a diverse variety of resources were used in the delivery of simulation-based education (SBE) in radiography, but there was a lack of feedback and training for facilitators across various health professions, and limited resources and time were barriers to training and development of SBE.

A participant working as a practice educator discussed using simulation to regularly support groups of sonography trainees, which was well received by their students and reduced pressures on clinical staff. The positive impact of a practice educator role was also acknowledged by several stakeholders who had a practice educator to support workforce development in their ultrasound departments.

Sr2: We're quite lucky, if I can't free up a room, we do have a training machine that … that I can show them technique on … the feedback from the last cohort is that they find that really useful … they're really keen to practise their skills in that way … because it's quite informal and working as a group I think they get a lot out of it.

Sr1: the clinical educator role … it's essential to be able to increase the workforce capacity for training … I think that it will have a direct bearing on that, because they'll be some form of coordination and overview. I also believe that it's … about developing our entire workforce.

Sr3: in some clinical departments so they've got practice educator funding … to support people working in those areas.

Sr5: In our trust we've just appointed a full-time practice educator role … (to) lead on the training which we found really hard to balance as clinical leads to be responsible for all the training whilst also having our other responsibilities and duties and scanning as well.

Similarly, Dickson & Kay (2024) also found that learners benefitted from the support of practice educators to support their clinical education, but most practice educators in their study had experienced times where they have felt inadequate in this challenging role owing to competing demands. When combined with an academy model for clinical education, practice educators were reported to provide protected learning opportunities for students, with additional time to fully engage in experiential learning within the comparatively structured, non-acute healthcare environment (Dickson & Kay, 2024), however their model did not appear to use simulation learning as part of their teaching. Further review of the practice educator role, cost effectiveness, and the potential of practice educators using a variety of simulation learning to support student learning is recommended.

4.4.3. Student pressures

Workforce pressures meant that students found it difficult to gain experience in clinical practice and learning in front of a "real" patient was challenging. Consistent support from supervising staff or tutors was important to students, as they felt their learning needs were better understood. In clinical practice, this consistency was difficult, as there were many sonographers rotating through different areas of large clinical departments. Khine, Harrison & Flinton (2024) described important characteristics of supervising staff, including professional attitudes, being approachable, kind, and fair, and empowering the student to learn. Unfortunately, it was evident from participant reports that not all sonographers were "*good*" teachers in practice.

St5: [some] people make me nervous, or they are in quite senior roles, so … I've got to be on my best behaviour … all that pressure…then, I don't know what I'm looking at and I feel … So, I do find it hard with different people

Sometimes, students felt that they were an inconvenience to staff, and were worried about making mistakes or asking questions in practice and sometimes felt overlooked. These findings were similar to those of Khine, Harrison & Flinton (2024), who reviewed experiences of clinical learning for sonographers, and emphasised the importance of an inclusive, safe, and welcoming environment for learners. Students indicated that feeling 'cared for' was key to a positive clinical learning experience. In higher education, the notion of belonging, feeling at 'home' and feeling safe has been defined as a basic human need (Strayhorn, 2018; Yuval-Davis, 2006). A strong sense of belonging is associated with student academic attainment and improved wellbeing (Ahn & Davis, 2020; Winstone et al., 2020) and is a fundamental thread within higher education practice and research (Gravett & Ajjawi, 2021). Unfortunately, this is not always easy to achieve, particularly for diverse groups of students who are part time learners.

Characteristics such as patience and willingness to teach were not universal, and student participants felt that there was a lack of awareness from clinical staff about student academic work and what the expectations of their learning practice should be.

Clinical learning accounts for most of a sonography students time, and their experiences impact on their learning, and decisions related to where they choose to work after graduation (Rowland & Trueman, 2024). Experiences of learning for students in this study varied considerably, depending on who they were working with in practice and on their individual learning needs. A positive learning experience could improve recruitment and retention of newly qualified sonographers, as a sense of feeling appreciated and recognized in the workplace were significant factors in radiography workforce retention (Nightingale et al, 2021).

St6: I could have carried on doing that in practice and nobody actually notices, or is too scared to tell me

St4: You feel a bit competitive. … the others … were taking to it much quicker than I was. I was a bit self-conscious.

St3: (It's) really stressful, because I don't want to fail, and I don't want to get anything wrong

For some students, clinical learning experiences were more positive, especially where a clinical educator supported their clinical learning, and provided regular support and group and simulation-based learning within clinical departments. Some students had access to training lists with extended examination times which was beneficial for their learning. This still required them to learn on a "real" patient, where consequences of a mistake are high, and open dialogue between supervisor and students may not be appropriate. Students particularly valued opportunities for group learning in their own environments with the guidance of an experienced clinical educator. This helped them to overcome fears of missing something or making a mistake in clinical practice where implications of an error are potentially damaging to a patient and to their developing professional reputation. Students felt more comfortable asking questions during simulation-based practical learning with a trusted tutor, and this provided valuable opportunities for learning, and constructive feedback regarding their progression.

St6: … (university tutors) know what we've done, and who we are, and where we are up to … see us progressing. Whereas in department, we may not have the same person for a few weeks … it could be like 6 months before we scan with them again, so I think that bit is tricky, the consistency of everything.

St3: in practice I think it is really useful to have consistency with people, … I find sometimes if I scan with somebody I'm not used to, they don't tend to let you do as much, they just have no idea where you're up to with your scanning. So, I think they've got less confidence in you …you do have to build a relationship with people and keep them updated on where you're up to.

Khine, Harrison & Flinton, 2024 highlighted that low student motivation in a clinical setting is often a challenging issue and advocated that students should be responsible for and actively participate in their own learning. Perhaps low motivation was inevitable since student participants were just expected to learn through observation and "*having a go*" at scanning, without the benefit of formal or structured training. It was evident from participants in this research that student motivation was enhanced when they felt less isolated and were well supported and felt integrated as part of the team. Student participants valued support and guidance, and felt benefited from group learning, tutor supported workshops, and peer support during simulation-based learning experiences. Unfortunately, this is not standard practice, and the ongoing work pressures in practice made this difficult to achieve for all learners.

St4: being able to review an area again without the pressure of the patient being there helped … because I've had a moment to reflect, review something and then decide

Sr2: Most prefer the workshop … students … get quite a lot out of those kind of sessions ... because it's a group session and it tends to be fairly relaxed, and they can discuss things … I think it probably makes them feel better that everybody else is struggling with the same … they get tips from each other.

The difficulties experienced in practice by students were common, and educators were aware that "*actual teaching*" was sometimes lacking in practice. Learning in stressful clinical environments was often difficult for sonography students, who admitted that they struggled. Supervising staff sometimes showed impatience and irritation with students during their learning, and the additional pressure of learning in the "*real*" world in front of patients, made questioning and discussion more difficult.

St1: … when you are with a real-life patient it's a completely different situation, there's certain things that you want to say, there's certain things you want to vocalise to your mentor that's standing next to you, but you can't …

Some clinical departments have introduced a dedicated clinical educator role to try to increase training capacity and improve sonography student experiences. Participants in this research indicated that this is proving beneficial as students feel better supported and have access to personalised and group workshop learning (including simulation using live models for some areas of practice). Wider implementation of clinical educator roles will need financial investment, but initial indications are that this is likely to lead to better student experiences, and review of student attainment and staff retention should be reviewed to verify the effectiveness of this role in practice.

4.4.4. Attitudes and assumptions

Most sonography students are postgraduates, and many have healthcare backgrounds. Assumptions were commonly made about the abilities and skills of part time postgraduate students as they are qualified health professionals, and there were high expectations of student ability and skill development from their supervising clinical staff. Several participants mentioned that students to not always meet these high expectations. Participants assumed that students had sufficient communication skills, and basic image interpretation skills, but for students, the skills required by sonographers were significantly different to their previous practice as radiographers or other professionals.

Although simulation learning was not a mandatory activity for most students, there were high expectations that adult postgraduate learners would learn quickly and engage with available self-directed learning opportunities with little support. But scanning skills are not acquired at the same rate (or with the same ease) for all learners, and some found simulation-based learning easier than others. This suggests that educators should consider if their programmes meet student needs, and if a wider variety of uses for simulation learning could help student development.

> *Sr4: I think there's also some, not reluctance but some scepticism is perhaps the word in terms of some sonographers have perhaps not seen the benefits and had exposure to some of the simulation equipment and some of the opportunities, learning opportunities that are available to us to train the future workforce.*

Many participants perceived simulation was not essential for training, and that it had little impact on training capacity. Participants felt that clinical staff were sceptical and not well-informed regarding opportunities for simulation learning, and there was a lack of confidence that simulation could adequately supplement clinical learning. Student attitudes are important factors in expanding the use of simulation for sonographer education: if students do not see any value in simulation learning, then they are unlikely to engage with these learning experiences. Although some students appreciated the benefits of simulation learning, they need the support of an educator who is enthusiastic and well trained in simulation learning.

Sr4: The sonographer profession and, you know, no disrespect but I think some sonographers are very entrenched in this is how we do it, this works, why are we changing it. Going back to the culture shift, we need to change attitudes, we need to change those perceptions.

St7: I think it enabled me to get stuck in straightaway in the calmer environment … you don't always feel like you can take your time in practice

Consistent leadership is required to advocate for the benefits of simulation learning, but this cannot be achieved by a single individual. Some stakeholders felt that professional acceptance and a limited understanding of the benefits of simulation-based learning were limiting the adoption of simulation within sonographer education. Support with training, securing funding, knowledge sharing, and promotion of simulation-based learning in sonography is also required. It is postulated that higher quality and wider variety of simulation-based learning could improve student engagement, but educators and stakeholders need support to enable them to implement and evaluate effective and varied simulation-based learning.

4.5. Subcategory B2: Technology and funding

Use of technology enhanced learning and gaming in medical education has rapidly accelerated over the past few decades (Harder, 2009; HEE, 2020; Owen, 2018). Educators wanted varied and flexible equipment and acknowledged the need for further developing approaches to simulation learning in sonography. However, several educator participants commented that they did not feel knowledgeable about ultrasound simulation, and they were unsure where to source reliable independent information on available equipment and opportunities. As technology advances and becomes more commonly available, attitudes to simulation-based education have started to evolve, but some participants felt that simulation was still perceived as an inferior choice of ultrasound training, which was provided as a token gesture, rather than a core element of planned learning and development.

Sr5: people don't particularly feel the desire to do it. They don't see the need.

4.5.1. Technology enhanced learning

Most participants felt that improvements were needed before simulation could reach its full potential, as the facilities for simulation currently available had limited scope. The complexity of structures and funding within HEIs caused difficulties for educators wanting to develop their programmes to include more simulation learning. There was varied equipment available within clinical departments depending on the size, budget, and priorities within each organisation. This made it difficult to ensure consistency in student experience and learning and may partly explain why students progressed at different rates. Once students had acquired initial skills, participants felt that the scope of simulation was limited, and because of the lack of variation offered, students quickly anticipated what was happening next within simulation learning. Because of these perceived limitations, simulation was not compulsory for learners, and is not used regularly; stakeholders feel that once learners start to scan "real" patients, there is little value in continuing to use simulation.

Sr1: I think it's got to be so early on because it doesn't simulate patients, it's just getting used to that probe movement.

St7: For me, right at the beginning… it was just amazing

Usability and reliability of simulation equipment was an important factor for educators who had experienced a variety of issues with integrating task trainer systems with internal IT systems. Participants found task trainer systems complex and difficult to set up and use, and regular experiences of technical issues negatively affected educator confidence and student experience. The lack of reliability affected educator choices with some selecting the use of models and phantoms with an ultrasound machine as more reliable for their teaching.

Technical issues with equipment, and the complexity of simulator design can result in disengagement or ineffective use of sim within sonographer training programmes.

E1: we've been let down by it so many times and had to do something different, that we have almost lost faith in it.

Digital education can include various types of interventions that can be characterized differently according to delivery tools, content, learning objectives, pedagogical approaches, or settings of delivery (Sangra et al., 2012). Participants reported some use of digital education tools, which they felt were useful, but these were limited. Examples included online learning resources provided with their Scantrainer, the use of virtual reality system VERT for learning anatomy, and games during teaching sessions. Students enjoyed these challenges, and the fun of interactive learning with their peers.

E7: …there used to be some quite good videos with the IPL type learning … I used to think they were good.

Sr2: I do think the physics modules on the simulators are quite helpful, especially initially

E2: those sorts of practical activities are useful to get students to think

St3: The anatomy. I'm not good at 3D, so that sort of thing is really good for me to work out where I'm looking.

Online learning and technology enhanced learning are now widely used in higher education, but digital education is a broad construct describing a wide range of teaching and learning strategies that are exclusively based on the use of electronic media and devices as training, communication, and interaction tools (Sangra et al., 2012). Digital education can also include offline and online computer-based education, serious gaming and gamification, massive open online courses, virtual reality environments, augmented reality, virtual patient simulations, psychomotor skills trainers, and mobile digital education (mLearning) among others (Dunleavy et al., 2019). Dunleavey et al. (2019) showed mobile learning was at least as (or potentially more) effective than traditional learning, but they found a lack of studies in general among allied health professionals, and the use of mLearning interventions was more common in medical and nursing education.

Tools like mLearning are a novel educational strategy that is rapidly developing in the field of health professions education. McCurdy et al. (2019) found that when used in combination with hands on learning and guidance from experienced practitioners, resources like these could provide effective basic ultrasound training in transvaginal ultrasound skills (McCurdy et al., 2019). Use of self-paced multimedia tools, such as those available on Scantrainer task-trainers, are a relatively less time-consuming option for educators, and these are easily implemented and capable of establishing knowledge. Mobile digital education (mLearning) has been mooted as a potential solution to increase the delivery of health professions education as it offers the opportunity for wide access at low cost and flexibility with the portability of mobile devices (Dunleavy et al., 2019), and modern task trainer simulators already offer some useful digital online resources for student learning (Intelligent Ultrasound, 2024).

Participants were optimistic that as technology develops, opportunities for ultrasound simulation will expand, and some examples of technology enhanced learning were mentioned by participants in this research study, but their main focus was the use of high-fidelity task trainers. Participants observed a growing demand for ultrasound simulation equipment (task trainers) across a variety of professional groups; the limited number of UK sonography courses restricted the potential market for simulation equipment, the equipment available was not specifically tailored to sonographer learning needs.

There were some indications of other technologies used in sonographer training, such as digital resources, and one participant mentioned use of an online simulation system, but this was viewed as an introductory tool only.

Sr6: we use … an online interactive platform that steps through scans and steps through all the different things that they can look at … it's really only good as an introduction.

Camilleri & Camilleri (2022) reported that online technologies provided new development opportunities for educators and were effective as remote learning tools which allowed interactive conferencing and helped to create rich social and positive learning environments for students. Video conferencing technologies have potential to allow educators to easily monitor progress, facilitate online interactions, in real time, and enable them to obtain immediate feedback from their students, but this could be time consuming for busy educators. Given the participant focus on self-directed task trainer learning, this is not currently a learning strategy has been widely explored in sonography education. Learning management systems are useful tools for educators, but investment in online learning infrastructures, appropriate resources (including staffing) and excellent facilitation are required if these are to be used effectively for delivery of high-quality education (Camilleri & Camilleri, 2022).

A significant barrier for educators and learners is adjusting from the generally accepted method of traditional lecture-based learning (Richardson, 2014). Shah et al. (2020) reviewed the technological changes imposed by COVID-19 on healthcare education, and found that although some might be positive, objective review of the changes is required to ensure ongoing improvement of health-care education. The usefulness of distance learning technologies and simulators became more obvious because of the pandemic, but there are a variety of limitations including cost and accessibility to these resources (Chalouhi, Mouanness, Abu-Rustim & Tolsgaard, 2021). In ultrasound education, to ensure optimal student experiences and best patient care, long term planning and robust structured assessment of technology enhanced learning is still required.

Beyond sonography education, other technologies used in radiology education include gaming concepts such as audience response systems (ARS), and use of multiple gaming strategies like Jeopardy and Pictionary (Awan, Fotos & Powell, 2019) to supplement the more common didactic traditional learning. Educational gaming is goal-oriented; specific objectives to master educational content are implicit. Different types of games can be appropriate tools for education, (e.g., board game, physical game, video game, etc.), since they have specific mechanics that result in excitement, encouragement, and punishment.

Ahmed et al., (2015) strongly advocated using gaming concepts in medical education, but their use remains limited. Feizabadi et al. (2019) found that while various games could be applied in diverse educational settings, only 13 of the 6917 articles related to radiology education, with none relating to ultrasound education. Feizabadi et al. (2019) reported that games increased learners' behaviour, commitment, and motivation, as well as improving knowledge and skill acquisition. Games attempt to give players/trainees pertinent knowledge or skills necessary for their success, and they are inherently interactive, prompting users to make complex decisions and develop skills such as image interpretation

(Awan, Fotos & Powell, 2019), therefore there is potential here to develop these for use this as a tool in sonographer education. However, creating an effective educational game requires technical ability and careful consideration of learner's characters and educational goals (Feizabadi et al., 2019), so careful design and effective facilitation is important to ensure a meaningful student experience. Applying science gaming in radiology can improve patient safety and standardize education. As educators seek new ways to revamp curricula, gaming provides a unique learning paradigm with potential benefits for developing attitudes, behaviour, and knowledge. While gaming is an innovative teaching method, it remains relatively unexplored in sonography education.

Researchers have trialled other emerging technologies which may have future applications in sonographer education. Gallagher, Smith and Sheppard (2020) reviewed ultrasound teaching for medical trainees and found that there is potential for the use of 3D printed task trainers as an economically viable tool for learning basic ultrasound skills, however the technology is yet to be perfected, and may be a simple substitute for existing task-trainer systems which are already available to most sonography educators.

The effectiveness of digital learning is not certain and further research is needed to assess whether technology enhanced learning is applicable more broadly across the health professions fields and in sonographer education. Development of technology enhanced learning requires significant resources: time commitment (development, implementation time), costs (initial purchase, maintenance, upgrades), equipment, software, and built-in safety features allowing access within the institution's security network.

Nestel & Kelly (2018) predicted that over the next 20 years, the use of healthcare simulation will grow, with tools like gaming and 3D Printing becoming more commonplace. Developers must ensure simulation design is informed by current clinical practice, effective implementation of simulation requires training and careful planning (NHS, 2011). Darzi (2024) noted that although the NHS has made significant investments in digital technology and training of staff, it is still in the early stages of digital transformation, and more training is needed to maximise the benefits of information technology. Similarly, the findings of this research suggest that although there is a myriad of opportunities to develop technology enhanced learning in sonography education, this has not been fully explored for sonography. Perhaps in future, wider use of technology enhanced learning will expand, but the use of these systems for sonographer education is currently limited.

4.5.2. Financial considerations

Educators were concerned about the high cost of simulation equipment and doubted the value of expensive task trainer equipment. The financial and time constraints mentioned by participants are likely to be a significant barrier to their use in sonography education. Participants had fears about ensuring large expenditures was beneficial to learners, and they did not feel well informed about the equipment, or upcoming developments by manufacturers. Costs of these systems was significant, and their use was largely limited to one learner at a time for practical skill development. For some, task trainer simulators were viewed as an expensive "novelty", which was difficult to fund.

E2: I think it it's definitely seen as a very expensive novelty, and it's one that they keep changing regularly, so it's very hard to keep up with it financially.

Current task trainers lack portability, and updates or additional content sometimes had significant additional associated costs. Participants described a range of funding streams, and there were marked differences in their experiences of accessing these to support the development of simulation learning in healthcare. A wide variety of institutional priorities affected funding for infrastructure or staff development, and stakeholders felt that accessing funding was difficult. Internal processes for funding were complex and funding was not always easily available for what educators felt was required. Some educators felt there was a lack of equity for allocation of funding through HEE funding schemes as some HEIs had gained significantly more funding than others. For those successful in acquiring funding, the process was complex and required considerable time to complete and to justify equipment purchases. Following the purchase of scan-trainer systems, stakeholders and educators expressed concerns about how they would keep up with costs of technology updates.

E1: I know that some HEIs have been given a lot of money by Health Education England, and others have been given virtually none.

Sr5: … the upgrade (cost) is something ridiculous … I think that cost is a huge issue.

Stakeholders recognized that high costs of task-trainers meant simulators were not regularly replaced, leading to concerns about outdated technology. Justifying these costs required significant effort, and some felt the expenditure provided poor value for money. Funding at HEIs often did not meet educator needs, with limitations on funding and space. Educators were frustrated by complex internal processes and the lack of equivalent funding for staff to use the equipment effectively. Additional funding applications were difficult to access, and stakeholders were frustrated with the process and timescales. Limited budgets in healthcare organizations and HEIs meant high costs of task trainers were not a priority. The costs, complex processes, and timescales for acquisition of equipment and space were barriers to further development of simulation for sonographer learning.

E6: if we look at how much some of these simulators cost and the staffing time, some of them are extortionate in how much they cost

E7: the equipment's quite expensive and if we're going to have a tutor there all the time or whenever, it does make it difficult.

E2: I've not been massively impressed with the equipment considering the price we paid for it.

E2: there is a limit to how much the University has to spend on equipment, and the ultrasound courses aren't generally the most profitable, because they are relatively small programs.

Small cohorts on HEI ultrasound programmes, make it difficult to justify the high costs associated with simulation facilities. The limited availability of equipment and space is limiting innovation in simulation use within sonographer education. Stakeholders also had concerns about how they could generate enough income to make investments sustainable. High investment costs are associated with high expectations, but for several participants their expectations were not met when they purchased expensive task trainers. Perhaps expectations were too high, or conversely limited training and limited experience of effective simulation facilitation contributed to their disappointment. A systematic review by Dalwood et al. (2020) reported that simulation was an effective training method, and although there is potential to expand, the cost and value has not been fully evaluated. Given financial pressures on HEIs and NHS trusts, careful consideration of available approaches is required.

Comparisons between traditional sonographer training and options for simulation were difficult, since traditional training is mainly provided in the clinical environment, where students were expected to adapt to available opportunities. Some educators felt that the high costs of task trainers were not justifiable, and other forms of simulation using phantoms and volunteer live models was felt to be more effective. However, student experience is also an important consideration, although students were aware the equipment was expensive, most felt that the benefits were significant and outweighed the costs for simulation equipment.

Current reliance on expensive task trainer equipment makes simulation learning appear as an expensive option, but if simulation is used in a wider variety of forms, the cost effectiveness might be significantly improved. Further research, improved collaboration, equitable investment, and training are required to enable educators to maximise opportunities for simulation-based learning.

Some participants felt that available opportunities for simulation were not being used to their full potential and reported that simulation was not integrated into the curriculum or used consistently throughout the year. The cost effectiveness of ultrasound simulation is not well understood, and wide variations in practice between institutions makes this difficult to measure accurately. Change is required if educators are to provide the consistent, focused, and well-planned simulation learning needed by students. To achieve this, they need easier access to funding, as well as training and time to develop their skills as simulation facilitators.

4.6. Subcategory B3: Governance and guidelines

Complex structures and processes within organisations affected how educators worked and impacted on opportunities for collaboration and innovation. Educators and stakeholders felt overwhelmed by complexities of internal processes and governance, and this seemed to be hampering innovation in providing clinical experiences and simulation learning for students.

Most participants were unaware if their organisations had any simulation strategies in place, or of any available national guidance for using simulation in healthcare education.

4.6.1. Regulation and accreditation

The lack of professional regulation and associated lack of a national college of sonographers (or equivalent) was viewed as a major issue in sonography education; multiple organisations are currently involved in production of standards and guidelines relating to UK sonography practice and education (including BMUS, SCoR, and member organisations of CASE). A report by the Professional Standards Authority for Health and Social Care (PSA, 2024) recognised that the risks for sonography practice were sufficiently high, and potential impacts on patient safety sufficiently great, to recommend government consideration of whether current accredited registration provides sufficient assurance, or whether additional regulatory oversight might be needed.

E3: … you need assurance, you need a regulatory framework to make sure it's safe … (but) we have no regulation

BMUS and SCoR currently produce regular updates for professional guidelines for clinical practice, with CASE responsible for producing the educational guidelines and accreditation of HEI sonography programmes. Although course structures vary, the clinical competencies should be consistent nationally for any sonographer courses validated by CASE. Current CASE recommendations (2019) encourage innovation by educators, but there is no specific guidance on the types or amount of simulation which should be included within ultrasound programmes. Guidance on how simulation might replace some current clinical placement hours for sonographers could be beneficial. However, the involvement of numerous professional organizations in ultrasound education, along with significant variations in the availability and accessibility of simulation facilities and expertise nationally, increases the complexity of developing a clear national consensus on effective use of simulation for sonographer learning.

There are no current guidelines or recommendations regarding simulation for sonographer education or how it should be implemented, although participants reported that formal guidance would benefit the sonography profession. Current educational requirements for sonography programmes (from CASE) focus on quantity of learning over the duration of the course. Other professional organisations such as the NMC (2024) formally recognise simulation placement hours, but this is not the case for accreditors of ultrasound education, which is likely to be a barrier to implementation of simulation learning in the curriculum. The current lack of consensus and national and regional variations in allocation of funding has resulted in a lack of consistent practice.

E7: I think it is good to work to guidelines and things that are proven to work

Although there is considerable enthusiasm for the potential of simulation learning, the pressures and workloads of educators and stakeholders mean that simulation is not their main priority. Professional organisational guidance and consensus is needed to guide how and when simulation might be used effectively within curricula for sonography education.

4.6.2. Guidelines for simulation in healthcare education

Participants felt that guidelines for the use of simulation in sonographer education would be useful to inform their teaching and ensure basic standards of ethics and training are met. However, there was a lack of awareness of existing national guidance and organisational frameworks for good practice in healthcare simulation. Some educators agreed that recommendations might be useful but relied on practical experience for teaching clinical skills. They were either unaware of available frameworks and guidance or felt these were not useful to their practice, possibly due to a lack of time to engage with these and develop their understanding of simulation pedagogy.

Educator participants were not well informed or unaware of the available guidelines or recommendations for simulation design and delivery, and there appeared to be little use of existing frameworks related to simulation-based learning in healthcare education. Instead, there was a reliance on designing simulation learning based on reproduction of clinical experiences, mirroring the clinical environment. This facilitated some skill development, but the known benefits of pre-brief, debrief, and the opportunity to allow students to identify and address their own individual learning needs may be lost.

E1: a lot of it is coming out of a clinical environment … following guidelines, making it evidence based, and making it appropriate for the level that you are teaching

E4: I've seen poor practice as well as really good practice; hence … we've just done the regional guidelines (to ensure) the standard is consistent across four hospitals

Stakeholders and educators acknowledged a lack of expertise in facilitating simulation and although participants agreed more specific guidance might be useful, they typically used a trial-and-error approach to practical learning or relied on purchased "training packages" provided with their task-trainers. However, it should be noted that these complex systems were not specifically designed for sonographer education, and a stakeholder commented that there is a larger market demand for ultrasound training for medical professionals.

E6: currently we just use the pre-set (Scantrainer learning packages)

Sr7: I know that tutors are really busy and so if they can just plug something in and get started that's what we mainly see

Sr7: … point of care ultrasound's growing faster than sonography-based education.

There appears to be a lack of ownership and engagement by educators, perhaps due to lack of time or lack of awareness of the range of opportunities for simulation learning. Educators indicated that they wanted someone else to design their simulation lesson plans, rather than doing this themselves; they reported a reliance on a limited number of manufacturers' pre-set learning activities, using training "packages" provided with their task-trainers. Where there was no pre-designed package, they tended not to use sim in their teaching delivery.

E2: it's lacking for MSK and vascular, as there just isn't the packages available yet.

E3: if they're working through the training package on the unit, then actually doing it themselves

In many clinical areas (apart from intimate examinations) it is possible to use phantoms and ultrasound machines, and even hybrid simulation with live models combined with phantoms. Examples of this are found widely within the literature for medical education.

However, there is a lack of experience and time for educators to develop simulations, leading to a reliance on manufacturers' pre-set learning activities.

Sr7: (product design) comes from current customers … from talking with potential customers, professional groups that we work with or … new protocols that are coming out

Educators acknowledged that they would benefit from having guidance or a framework for simulation in ultrasound education, but they would like this to be specific for ultrasound training. The lack of use of appropriate frameworks, and lack of simulation education (regarding design and debrief) may be limiting the potential of simulation in sonographer education. There was limited awareness of specialist simulation groups from educators or stakeholders, and no formal use of simulation frameworks or guidelines for best practice in healthcare simulation (ASPiH, 2023; INACSL, 2021).

Some stakeholders had written strategies for simulation within their own institutions, but this is not consistent practice. For those with existing institutional strategies, they found that support and advice was difficult to obtain because their task trainer differed from other available simulation training.

There are a variety of published principles for simulation in healthcare education, which should be useful to inform practice. The Association for Simulated Practice in Healthcare (ASPiH, 2023) standards for guiding simulation-based practice in health and care recommend that all faculty involved in simulated practice should be trained and possess competence in simulation as well as appropriate content knowledge. The International Nursing Association of Clinical Simulation and Learning (INACSL) standards for facilitation of best practice in healthcare education (INASCL et al., 2021) also emphasise the importance of a facilitator who has the education, skill, and ability to guide, support, and seek out ways to assist participants in achieving expected outcomes from simulation learning. This requires specialist education, which participants lacked, and educators appeared to have little confidence in their knowledge of simulation equipment or their skills as effective facilitators.

Ed4: from my experience … our approach has always been practical.

Partner, England, Young, Shiner & Bridge (2023) surveyed simulation use in radiography education and recommended integration into the international simulation community, and that existing guidance such as INACSL and the Healthcare Simulation Dictionary could be more consistently used (Merguerdichian et al., 2022). Dedicated conceptual frameworks were recommended and should be developed by leading international organisations, but these focus on radiography education, and not on the specific needs of sonographers.

4.6.3. Occupational standards and sonographer career framework

Current national occupational standards (Skills for Health, 2019) specify the minimum standards of anyone performing, interpreting, and reporting ultrasound examinations at all levels. Publication of a tiered sonographer career framework (HEE, 2022) further defined a variety of roles in sonographer practice, however these have yet to be widely adopted in routine practice. There is potential to use simulation across a variety of areas of the professional ACP framework to enable sonographers to develop a wider range of professional knowledge, behaviours, and clinical skills, but if this is to become a reality, national consensus must be reached between a range of stakeholders. Unfortunately, for a relatively small professional group who are short staffed and under immense workforce pressure, this may be difficult to achieve. Challenges include clinical practice pressures, professional protectionism, lack of awareness of the new career framework, and the logistics of changing department structures to introduce new roles and more trainees. There is some appetite for change, but widespread representation of all levels of the career framework in practice is yet to be realised.

Ed6: … it probably would be useful to start providing some guidance as to how it could be utilised

Not all participants identified a need for change from traditional training. Because a stakeholder had learned mainly in clinical department, they did not see the need for or benefits of change or supplementing learning with simulation. Some participants agreed that consensus on best practice, and shared resources which are specific to sonographer learning needs would be useful to allow sharing of expertise. Darzi (2024) highlighted the importance of continuous education, training, and adherence to good practice standards to ensure the NHS can effectively meet current and future challenges. For simulation to achieve its full potential, training, coordination, and investment are required; effective implementation of simulation for learning, teaching or assessment of sonographers cannot be achieved by an individual person or organisation. However, the competitive nature of higher educational institutes, high workloads and limited financial support are barriers to introducing this. It would be beneficial for stakeholders, educators, and students to have opportunities collaborate and contribute to the evidence base. This could encourage more effective and wider implementation of simulation learning for sonographer education across a range of occupational standards of practice to improve learning experiences and maintain best practice.

4.7. Summary Category B: Influences on simulation use

There are significant pressures on educators, clinical staff, stakeholders, and students. These negatively impact the adoption of technology enhanced learning in sonographer education.

Financial constraints, alongside limited time available to a workforce in crisis, mean that learning experiences for students in practice have unwarranted variations, and students' experiences are sometimes poor. Although this research did not initially aim to investigate student wellbeing, this was a significant consideration for student participants in this study, and there are some indications that the psychological safety of learners is not consistently assured. Further research into this topic is strongly advised.

Although there are many existing guidelines relating to the effective use of simulation in healthcare education, these were not well known to participants, and some felt they were not relevant or not specific enough to be used in sonographer education. Further research and collaboration are required to ensure that simulation can effectively support student learning, across all levels of practice.

Category C: Experiences, identity, and culture

This category will explore participant experiences, identity, and culture, with three subcategories: experiences of learning, professional identity in sonography, and the need for collaboration and education (See Table 4.5).

Table 4.5: Summary of subcategories Category C

Core Category		Subcategory	Content summary
C	Experiences, identity, and culture	**Experiences of learning**	• Understanding learner needs • Engagement • Wellbeing and psychological safety • WRMSK disorders* • The patient perspective
		Professional identity	• Sonographer identities • Becoming a sonographer
		Collaboration and education	• Cooperation and consistency • Interprofessional and multi-professional learning • Educator education and research • Leadership

* Work-related musculoskeletal disorders

4.8. Subcategory C1: Experiences of learning

Ultrasound services are under pressure, and it can be difficult to prioritise student learning for a variety of professionals alongside meeting service demands. Khine, Harrison & Flinton (2024) reported that effective teaching and learning within the clinical environment is crucial to enable learners to acquire and develop the required competence and confidence. Consideration of participant experiences of teaching and learning are important to inform curriculum development. The amount of time spent in practice does not necessarily equate to more learning: the quality of the learning experience is important. The impact of training burdens on recruitment and retention of staff is also important.

4.8.1. Understanding learner needs

Participants described a variety of approaches to sonographer training, but inconsistent opportunities for simulation learning meant that most students relied heavily on learning in the clinical environment, including for complex cases. Students' experiences in practice were variable, which impacted on the quality of their learning. Students reported that some clinical staff were not aware of their learning needs and sometimes had unrealistic expectations of their performance, which created additional pressures in their learning experiences. This was particularly noted by students on new routes including the undergraduate apprenticeship, where students felt additional responsibility for informing clinical staff about their learning needs.

St3: Because people were used to training people coming from the other route … they couldn't get their heads around it even though I tried to explain.

An optimal learning environment is important for a positive clinical experience (Khine, Harrison & Flinton, 2024), but in this research, pressures during clinical learning negatively impacted learning experiences. Student participants often worked in different hospitals, different departments, and with a wide variety of staff. They were often the only trainee in unfamiliar and pressured clinical environments, with little peer support. This lack of consistency meant that students felt their learning needs were not always well understood in practice, and they felt pressured to do things differently to meet the varied expectations of supervising sonographers.

Sr3: the students don't want to put the sonographer under pressure. So, they're not necessarily getting the time and the support that they need.

St 4: I did feel a bit self-conscious … thinking I might get this completely wrong

Similar clinical competences were consistently used for assessment between departments, yet sonography students were often isolated and working within different cultural environments, with differences in local leadership and service delivery practices influencing their learning experiences. These pressured clinical environments made optimal learning difficult, and students reported feeling pressured, uncomfortable, and lacking in confidence in practice. Students felt that they were not well equipped to deal with negative experiences because they were unfamiliar with their environment and sometimes felt intimidated by existing relationships and cultures within their clinical departments.

St6: got to know what I'm doing

E7: I think they're always cautious aren't they that they're going to say something and somebody's going to say no you're wrong.

St1: … you feel like if you ask a question, they're going to think oh my gosh, are you stupid?

Not all clinical staff had the same level of training or dedicated time for teaching, and there are challenges for supervisors, who must manage multiple tasks of patient care, leadership, mentoring and assessing student progress (McClintock et al., 2022). Students valued a supportive non-judgemental relationship with clinical supervisors, but it is recognised that work-related pressures could interfere with this (Khine, Harrison & Flinton, 2024) since supervising staff were potentially overworked or affected by burnout (Skelton et al., 2023; Younan et al., 2022). Students should understand where to seek help, even if this feels uncomfortable, but this can be difficult in a busy clinical environment. Unfortunately, service demands within clinical environments negatively impacted clinical training in sonography, and some student participants felt there was lack of emphasis and focus on their training needs.

St4: often that kind of vibe would be coming from someone that had recently qualified as well and then I didn't get that, why they weren't as empathetic, or they weren't as good a teacher

St5: … some people just do not want to be with students

Consideration of learner experience and stage of learning is crucial, since students from non-health care backgrounds, those at different educational levels, or at different stages of learning have different learning needs, and if simulation is not used effectively, they may not see any value in simulated learning experiences. Equipment standards in practice are important for optimal image quality and this impacts on student confidence. Because of the difference in environment and equipment at HEIs, students found that learning in their own environment using simulation was particularly helpful as this had higher authenticity for them, but this was not consistent for all students.

St2: I don't feel like I would have been at a loss if I hadn't have had it.

It is important that students have realistic expectations of themselves and the difficulties of learning the skills required by sonographers. Participants acknowledged the challenge of adapting to new roles as trainees and establishing their place within unfamiliar teams, and they feared getting things wrong, both in simulation learning and in their clinical environments.

Sr1: (students) feel like they're holding the list up somehow … then performance slips a little bit and that undermines confidence

Opportunities for tutor and peer support ensure students feel valued, supported, and nurtured, which enables them to learn in a more supportive and less pressured environment. Relationships between learners and their teachers impacts learning and meaningful engagement, with collaboration and respect essential to foster positive learning experiences, also recognised by Khine, Harrison & Flinton (2024). Trust between learners and tutors is important to ensure confidentiality and setting clear expectations during learning is essential. Supervising staff were in a position of power and their feedback (negative or positive) hugely impacted on student experience and confidence. Students needed assurance that discussions remained confidential, but they sometimes felt that staff had little trust in them or their skills, which negatively impacted their learning and confidence. This aligns with other literature, which found that students who learned in an environment where they felt well supported were less self-conscious, better able to concentrate on the task at hand, felt empowered to ask questions, and had reduced anxiety about failure and performance (Edmondson, 2018; McClintock et al., 2022).

St2: you've got to have a sonographer who is patient, who is willing to teach and impart that knowledge … be transparent and polite about it because your confidence can get knocked.

St6: people make me nervous, or they are in quite senior roles, so then I'm a bit like, I've got to be on my best behaviour.

St5: We've had one student recently who, it didn't go well at all … I hope they don't think I'm going to be like her and there's that paranoia that you're not good enough

Clinical supervisors should ensure sonography students receive high-quality learning and support during their clinical placements (Khine, Harrison & Flinton, 2024). Positive role models and appropriate supervision of learners is an essential element of the NHS England safe learning environment charter (NHS England, 2024c), which emphasises the need for dedicated time and space for feedback, reflection, and debriefing. Unfortunately, these goals are not being consistently met for sonography learners in practice, and work pressures are known to interfere with learning and the relationships between students and supervisors (Khine, Harrison & Flinton, 2024). A good understanding of individual student needs can provide tailored and effective learning experiences; participants who had the support of a dedicated clinical educator to support their learning and offer in-situ simulation group learning reported enhanced student experiences. However, this is not standard in all ultrasound departments.

E6: one of the students was working individually because they have a student support plan … that they are dyslexic, so they really struggled …I think it's important that we recognise that some students won't fit that norm and we need to adapt

St4: Having that training lead … you feel more nurtured as a student when you've got a manager that is looking after that role … that has helped.

In contrast to learning in the clinical environment, simulation provided opportunities for questioning, feedback, and discussion. Students highlighted the importance of simulation in providing a safe learning environment where they can question, experiment, reflect and share learning. Several participants highlighted the importance of peer support and a community of learning, which are more easily established during practical simulation and group learning. These communities of practice for students fostered communication, trust and collaboration based on shared simulation experiences, helping to build student confidence.

St7: it'd be nice to kind of have somebody just if you've got any questions and if you're having a bad day

St4: a group environment … helped.

Regular use of high-quality simulation learning, alongside good support systems for students could greatly improve student experiences, but task trainers alone are insufficient and, as previously discussed, students do not always enjoy or gain optimum benefit from self-directed learning. Simulation learning as a group was particularly important to students, as it allowed them to build a community of learning for peer support.

S3: they didn't want to be using the simulator at the end of the day, they're exhausted.

St1: I would choose the group peer learning together over a simulator, because when you are scanning with each other the feedback is dynamic

These findings align with the work of sociocultural learning theorist Wenger-Trayner (1998), who described a powerful kind of learning occurring when trainees work in a group pursuing the same goals. Communities of practice oriented around mutual engagement, joint enterprise, and shared repertoire (Wenger-Trayner, 1998) is a learning approach that has been embraced across a range of fields to improve collection and dissemination of knowledge (Hodson, 2019). Siddique et al. (2024) also reported positive benefits of group engagement, enabling individuals from a variety of backgrounds to alleviate feelings of self-doubt and isolation. Clear expectations and a code of practice are recommended to ensure students understand the expected behaviours and confidentiality of discussions during practical learning group sessions, which emphasises the need for debrief to identify learning and enhance the impact of simulation for sonography students.

The importance of peer support for sonography students was evident, with one student explaining how they relied on the peer support and feedback from their university cohort, rather than from staff in their clinical department. For some students, this was only available when on campus at their HEI, but some learners had set up informal virtual communities for peer support, reducing isolation and providing opportunities to ask questions, share experiences and recognize their limitations.

St5: …you feel like you're not on your own. So that's been really important, that support network.

St5: you've done something wrong it's more than likely that at least one other person in that room has done the same thing as you and it makes you feel quite normal and that mistakes are going to happen, but there's nothing wrong with that

Sr5: … no one's perfect, everyone's going to make a mistake, or there's always a way to get better. It's more important to recognise that and actually it's more dangerous to think that you're perfect and nothing will ever go wrong.

Simulation can lead to deeper learning, improved performance, and allows exploration of complex healthcare systems and care, however implementation will be influenced by a wide variety of factors. Nestel & Kelly (2018) reported that it is unlikely that there will ever be a unified theory of simulation, but instead new frameworks which reflect evolving clinical practices will emerge. There is a clear need to carefully consider the best approach to supporting sonography learners, drawing upon relevant learning theories. Maslow's pyramid of needs (Maslow, 1943) identifies what is required for individuals to reach their full potential, with each level of the pyramid leading to the development of the next. However, more modern theories suggest that these needs co-exist, and that humans can still possess higher order needs even if their rudimentary ones are not met. A modern revision of Maslow's work was produced by Hale et al. (2019), where needs are no longer hierarchical, but instead form an integrated framework (Figure 4.3). Given the challenges of sonographer learning experiences identified in this study, simulation (if done well) has potential to positively impact sonographer learning across all levels of the framework proposed by Hale et al. (2019) (See Figure 4.4). This could provide an ideal learning experience, but further work is recommended to explore how this model might be applied to sonography education.

Figure 2.4.3. A modern revision of Maslow's work Hale et al. (2019): (Reproduced with Publisher Permissions 2024).

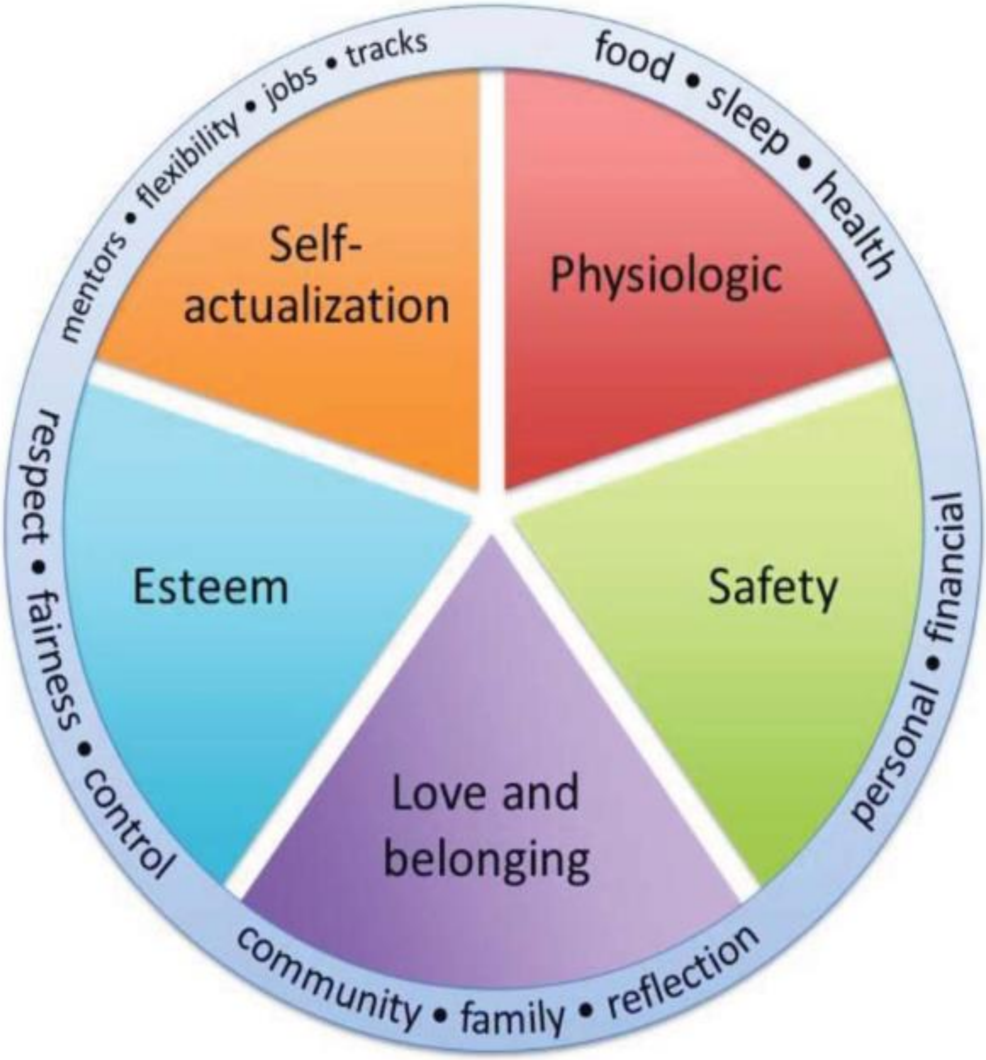
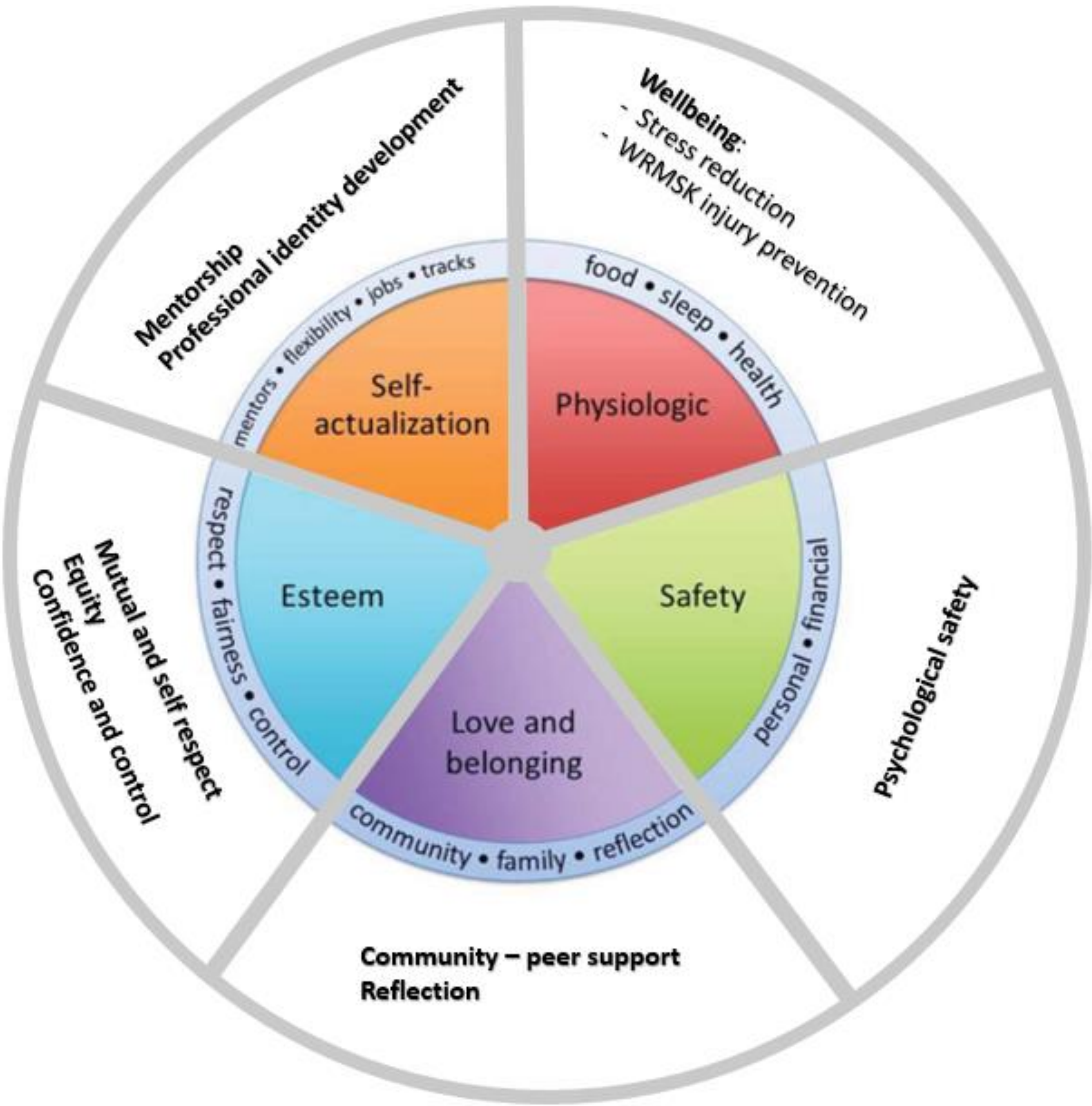


Figure 3.4.4: Simulation learning in sonographer education could support all elements of this integrated wellbeing framework. (Adapted from Hale et al. (2019))



4.8.2. Engagement

Student engagement with simulation varied. Self-directed learning activities were seen as ineffective, since students might not be aware if they are making repeated mistakes, and there were no opportunities for questioning or discussion. Some educators were frustrated that students were not engaging with simulators, and limited student engagement diminished educator enthusiasm for further use of simulation.

E3: You could have loads of really good ideas, but it's very variable whether the students engage with these. You know they're not engaging with everything we put there for them.

There were wide variations in use of simulation between different courses, tutors and modules and educators appeared to influence the level of student engagement through their attitude to simulation learning. Simulation learning was not compulsory for most participants and was seldom promoted by educators, leaving many students unconvinced that simulation learning was essential, seeing this as just an "*added extra*". To improve engagement, simulation must be recognised as valuable to students, and regular use of well-designed simulation learning throughout the curriculum may improve overall engagement. Limited availability of facilities was negatively impacting the ability of educators to achieve this in practice.

E1: I mean it's difficult with the amount of equipment that we've got … if you have got 60 postgraduate students and two ultrasound machines and two simulators, then it's very difficult to give them a meaningful time on those

Participants acknowledged that students have different personalities and different needs in terms of what support works best for them. Teachers' proactive and reactive classroom management strategies are a significant component of teaching effectiveness (Alasmari & Althaqafi, 2021). Reactive approaches in education can foster cooperative and collaborative approaches to learning, which may increase students' motivation and engagement in the instructional process (Dellatola et al., 2020). However, a more proactive approach could help create more effective classroom learning environments through consideration of curriculum design and delivery, establishing positive relationships and ensuring engaging learning experiences (Garrett, 2014). The timing of learning to maximise learning opportunities is an important factor in student engagement, with some students seeing simulation as a hurdle to overcome, rather than a beneficial learning experience. This was particularly evident for activities which involved either role play or being a scanned as a model.

E7: … more and more we're getting students who don't wish to be models … they feel a bit vulnerable … I have to say that I think the students are much more reluctant now ... so I think that makes it more awkward.

St2: I don't find it helpful … if you were to put me in a situation where we roleplayed me giving bad news in early pregnancy assessment, that doesn't help me; I'd feel so just like embarrassed trying to do roleplays with people.

The benefits of simulation were not well understood, yet some stakeholders felt that there was potential to use more simulation in a structured way. Some educators valued simulation more, had more access, and understood effective implementation of simulation. Educators influence the level of student engagement through their attitudes by setting expectations, formative assessment, and regular use as part of the core curriculum for all students. If simulation learning is not developed and promoted by educators, then it is unlikely that students will fully engage with this method of learning. Students perceived that simulated learning in their postgraduate learning was detached and "cold", and it lacked the nurturing approach they experienced as an undergraduate learner. This may be because their experience of simulation in ultrasound was limited to largely self-directed or peer supported learning of technical skills, with little development of communication or decision-making skills which are core to ultrasound practice. Many participants believed that in its current form simulation held little value or had little impact on learning. It is unlikely that simulation learning has reached its full potential in sonographer education.

St2: looking at my own experience it has played a marginal role

Sr2: having used the simulator a little, I think once you get your hand on a patient, a simulator doesn't really feel lifelike.

Using simulation as a formative assessment tool as part of the core curriculum could increase engagement with simulation learning. On some programmes, students were required to pass a formative simulated assessment before being allowed on placement, which is likely to incentivise students to engage more with simulation learning. On other programmes, simulation use was minimal as students on part time routes often had access to scanning patients prior to starting their university programme. For these students, the need to learn additional systems such as scan trainers merely added to student pressures, with little perceived benefit to their learning.

4.8.3. Wellbeing and psychological safety

The safe learning environment charter (NHS England, 2024c) aims to develop safety cultures and continuous learning in NHS environments to strengthen the workforce. The report emphasised the importance of emotional and psychological safety so that learners feel respected and valued. Unfortunately, student participants in this research regularly felt that they were perceived negatively and felt that they were "*being an inconvenience*", or they described examples of experiencing demeaning behaviour which made them feel "*stupid*". There was acknowledgement from stakeholders and educators that learning ultrasound is difficult, yet student accounts of their learning experiences were concerning, particularly where students are fearful of asking questions or worried that they will be laughed at.

St4: I think they were stressed or had different issues

St5: sometimes you maybe feel like an inconvenience

St3: … after the initial excitement, it was really awkward, and I just felt really rubbish really

Negative experiences of clinical placement are widely reported for healthcare students, and students often do not feel valued (Rowland & Trueman, 2024). They sometimes experience negative behaviours from staff and patients, including criticism, incivility, harassment, bullying, and racism (Capper, Muurlink & Williamson, 2021; Codd, Ramlaul & Trivedi, 2024; Morrison et al., 2023; Walsh et al., 2024). CASE Standards for sonography practice (2022) specify a need to ensure the physical and psychological safety and wellbeing of all individuals in the immediate work environment, and professional registers such as the HCPC (2017) (where many sonographers are registered as radiographers) also require a safe and supportive environment for learners. Some aspects of professional culture amongst radiographers were previously seen to be potentially damaging to patient care and the perception of the profession by others (Strudwick, 2015), and it appears that this negative culture may still be affecting sonography students. This is not an effective learning environment, and the challenges of learning in a pressured environment could be linked to the lack of confidence described by students.

Sonography students in this study reported experiences of learning in pressured and varied clinical environments, and feelings of isolation and stress were common. Students described high workloads which meant they often feel nervous, rushed, pressured and panicked in practice. They worried about failing an assessment, failing to meet the expectations of clinical staff, and the implications of these failures on their employment and career progression. Their learning needs were not always well understood by supervising staff in clinical departments, which caused difficulties with access to hands on experience, and feelings of uncertainty, guilt, and fear that they were not meeting expectations. Sonography students also worried about making a mistake in practice, and reported self-imposed pressures, feelings of competitiveness between learners, and additional pressures from the academic development and assessments which were a core part of their course.

St4: You feel a bit competitive … the others were taking to it much quicker than I was. I did feel a bit self-conscious thinking I might get this completely wrong

St2: I'm like oh, you're not going to be as good as everyone else at this and then they're all going to see that you're not as good.

Consideration of student wellbeing is important in higher education, and a meta-analysis of postgraduate student wellbeing reported average rates of 34% for depression (Guo et al., 2021). Prevalence of depression, anxiety and psychological distress are particularly high in medical and health-related students (Almansoof et al, 2024; Pacheco et al., 2017; Pacheco et al, 2023). Hardie et al. (2022) defined student psychological safety as a student's belief regarding whether it was safe for them to take interpersonal risks, such as asking questions, sharing an idea for improvement, or speaking up to maintain patient safety. Learning was enhanced when students perceived they were in a psychologically safe environment (Hardie et al., 2022) where they could express concerns, ask questions, or acknowledge mistakes without fear of humiliation, retaliation, blame, or being ignored (Edmondson, 2018).

St5: I witnessed them talking about this student being awful …. I don't want sonographers saying things about me behind my back

Although the sample size in this study was small, it was apparent that sonography students' psychological safety was not consistently assured in practice, which impacted negatively on their learning. Student participants felt they needed to be on their *"best behaviour"* and sometimes felt like an outsider and a burden to busy supervising staff. Comparisons can be made to a study by McClintock et al. (2022) who reported that medical students faced multiple challenges of providing patient care, and developing competences, and they considered it risky to reveal deficits, ask for help or giving an incorrect answer to questions. McClintock, Kim & Chung (2022) evaluated the role of educators in ensuring psychological safety in medical students and found this was improved with high-quality relationships among team members at all levels of training, emphasis on teamwork, and leaders who invite, listen to, and respond respectfully to perspectives and input from traditionally lower ranking team members (Edmondson, 2018).

Effective teaching and learning of clinical skills can empower learners, and ensures they develop the required knowledge, skills, and confidence in their practice. However, long term workforce shortages in sonography make it difficult to consistently provide effective learning for students. As previously discussed, burnout (psychological response to long term exposure to occupational stressors) is a significant issue for sonographers and other health professionals (Hardicre et al, 2021; Khammissa et al., 2022; Younan et al, 2022). High levels of sonographer burnout are due to high workload, clinical environment, and lack of career progression (Cohen, Childs & Maranna, 2021; Younan, Walkley, Quinton & Alphonse, 2022), and this makes it difficult to provide optimal learning and support for students. There is limited data relating to sonography student burnout, however it is evident from the literature that occupational stress extends beyond the training period. All participant groups were aware that there is a need to improve student experiences and ensure that student wellbeing is maintained.

Sr3: We need to make sure we nurture the sonographers we have got; because if we don't do that, we're going to have an even bigger workforce crisis.

St1: training in the NHS needs to change. We need to focus a lot more on people's health and wellbeing and mental health.

Participants valued simulation learning to help them to learn what to say, how to act, and to improve their understanding of patient perspectives. Simulation provided opportunities for learning in a "safe" environment, and there is potential to increase the use of simulation to provide supportive learning environments, which encourage participation, and provide constructive feedback. Learning environments which promoted openness, inclusivity, effective communication, and collaboration between students were more likely to provide a psychologically safe learning experience for students (Hardie et al., 2022), which may partly explain why some student sonographers found simulation learning so beneficial. Meaningful simulated learning experiences can contribute to building resilience in learners and can potentially provide opportunities to observe best practices from skilled, experienced professionals (Monks et al., 2020). It is therefore surmised that providing an unpressured environment for simulation learning could have a significant positive impact on student wellbeing.

St5: … the opportunity to take as long as we need and …to ask those questions in a relaxed environment where you know you're not going to get judged

St1: Learning in a non-intimidating environment… you are a bit more brave

4.8.4. WRMSK disorders

Sonographers have long been recognised as high risk for WRMSK injury (Society of Radiographers, 2002), and WRMSK disorders are common amongst sonographers (Murphey, 2017). Bolton (2023) reported a general awareness amongst sonographers of the risks of acquiring a WRMSD, but despite this, they appeared conflicted between knowing they need to change their practice and being compelled to carry on regardless of the risks. Bolton (2023) also highlighted concerns that there is a lack of effective consideration of WRMSD risk and prevention among students in the initial stages of their training.

If simulated learning is not well designed and appropriately supervised, there is potential for students not to recognise their mistakes, to develop bad habits, or potentially develop symptoms of WRMSK injury during simulation learning. For some participants in this study, simulation experiences (using live models and ultrasound machines, or in situ simulation within their clinical departments) provided opportunities for students to develop a better awareness of their posture and movements, and what worked best for them, and they developed strategies to apply in their practice to reduce their risk of injury. There is potential to develop further to ensure they are better informed on safe practice and WRMSD prevention.

St6: I'm more aware of it now in practice, so it's good to see what your negatives are, like what you shouldn't do, and then to put that into practice, and hopefully you won't pick up any bad habits.

Sr2: if we can try and instil that in that kind of environment where there's no pressure it becomes a natural instinct … because you've done that in simulation

St5: and getting to know my body and how I need to see it ergonomically and how to be comfortable while scanning … it's just getting my head round what's best for me

For a few participants, simulation provided some opportunities for better awareness of posture, but they criticised the lack of authenticity of simulation learning and poor ergonomic design of task trainers. Students who completed self-directed learning on task trainers felt that they developed poor ergonomic practice due to poor equipment design and set up. WRMSK injury is a well-known risk of sonography practice (Bolton, 2023), so it is concerning that participants criticised the lack of authenticity and poor ergonomic design of task trainers. Indeed Gibbs (2015) reported that some trainees reported musculoskeletal discomfort, which is concerning, and manufacturers, trainers and learners must ensure that ergonomic practice is safe, and that equipment is suitably adjustable.

St1: The design of the equipment, it was just unnatural, because the way it, it almost taught you the wrong way of scanning in terms of ergonomics.
E6: …their ergonomic practice … that's something that we really want to emphasise with students…we are hearing of an increasing number of people within the local region who are struggling with RSI issues

Simulation training could potentially provide effective opportunities for individual risk assessments and strategies for reducing risk of MSK injury in sonography students, which could have long term benefits for students by ensuring they develop good practice and injury prevention strategies at an early stage of their careers. There may be opportunities here for educators to use simulation to ensure students adopt good posture and teach the principles of safe ergonomic practice in an unpressured environment, but this approach has yet to be explored for sonographers. Khan et al. (2020) tested methods of promoting ergonomics in endoscopy training, using a dedicated ergonomics curriculum using a combination of lecture, a 5-minute video of expert performance and a checklist for individualised feedback for trainees. They found that trainees without any training unknowingly adopted unfavourable postures as they were focused on technical skill development to complete the procedure. Although a different technique, this can be compared to sonography practice, with similar requirements for complex skill development, a high procedural volume for practitioners, and risk of WRMSK injury in practice. In their study, Khan et al. (2020) found that introducing a focused curriculum which included individual risk assessments was effective in increasing awareness and reducing rates of MSK injury in their trainees. Exploration of this approach with sonography learners could also have a positive impact on their posture and awareness of injury risk in practice.

4.8.5. The patient perspective

Understanding the patient perspective is an important element of clinical learning, and several participants (students and educators) commented on the value of simulation in allowing trainees to experience "being the patient". Participants reported few issues with students gaining permission to scan patients in clinical practice, with occasional refusals linked to sonographer gender relating to intimate examinations or linked to cultural or religions reasons. Students valued the opportunity to experience a patient perspective in simulations to inform their practice.

St7: understanding how it felt to be scanned … experiencing being that patient and how you kind of want to be treated is really useful

St7: having never had a scan myself, having somebody else have a go on me, that was really useful as well just to know kind of how it feels and that it doesn't hurt if you're pressing.

Healthcare professionals need a deep understanding of the processes of patient care (WHO, 2011) however this can be difficult to teach. A systematic review of educating students to portray patient roles found some positive impacts on student communication, confidence, self-efficacy, and patient empathy, and recommended further investigation into this learning approach (Dalwood et al., 2020). It is important that appropriate training in patient portrayal is completed to ensure accuracy in the learning experience, otherwise there may be a negative impact on learning, so a framework for students for role preparation, accurate patient portrayal, realism and maintaining character is essential (Dalwood et al., 2020).

In radiography education, an interactive clinical simulation tool proved useful for teaching patient-centred care in imaging practice (Matthews et al., 2024), and if the case studies like these were tailored to sonographer practice, this could also prove to be a valuable tool in sonographer education. This could be developed further through adding the perspective and involvement of service users and their families could greatly enhance simulation learning and provide opportunities for students to strengthen their understanding of patient and family perspective in a variety of areas of practice.

4.9. Subcategory C2: Professional identity

There are few studies which examine the professional culture in radiography practice (Strudwick, 2015), and even fewer related specifically to sonography. Educator and stakeholder participants viewed sonographers as being unique, using terms like "*different*", "*elite*" and "*special*". This meant that sonographers were sometimes perceived as protective of their roles and reluctant to teach other professional groups.

E4: I think ultrasound is not like other specialities

Sr6: maybe we're a bit precious about our profession … guarded about teaching ultrasound to non-sonographers

4.9.1. Sonographer identities

There is no specific way to explain what makes or defines a profession, or to decide if a job type is a profession (McKnight, 2023). In the UK, radiography practitioners and professional bodies generally describe radiography as a profession, however sonographers are not recognised by an equivalent protected title and, in practice, sonographers are potentially on a variety of professional registers such as the HCPC or NMC (Society of Radiographers, 2023). This makes it difficult to define sonography as a profession and this may explain the variety of views and experiences expressed by participants in this research. Sevens (2017) highlighted deep issues relating to professional identity amongst sonographers and called for change to enable them to achieve professional identity and professionalisation; although progress is evident, her recommendations for professional registration and national leadership are yet to be realised. Participants viewed themselves as a uniquely skilled group, yet they felt that sonography was not well understood, with a lack of recognition of the high level of skill required in clinical practice. Sonography has been portrayed as a challenging and rewarding career that demands individual initiative, clinical judgment, critical thinking, and a commitment to ongoing professional development in a rapidly evolving field (Hagen-Ansert & Billick, 2023). However, lack of professional registration for sonographers meant that participants sometimes felt undervalued and unrecognised by the public.

Sr4: We seem to be a long way down the recognition hierarchy for the general public ... [because] we don't have a specific professional body promotion and regulatory status.

In this study, sonographer culture and identity were strongly developed within qualified participants, but frustrations were evident, with some suggestion that sonographers are not meeting their full potential as advanced clinical practitioners. Pressures in practice mean that sonographers are required to spend much of their time on clinical scanning, which leaves little time for them to be able to engage in activities for the other three pillars of advanced practice. The potential for sonographer professional development is hindered by chronic staff shortages and high workloads, and recruitment advertisements for sonographer roles do not portray a true presentation of the realities of the role of the average sonographer in practice.

Sr5: I find it difficult in recruitment: I'm not always happy with how departments advertise … They're selling the grass is greener over here [but] I think every department's the same

E3: Clinical staff are absolutely exhausted and are just trying to get through the work as fast as possible … with the best will in the world a lot of them aren't going to want to do training

Mitchell & Nightingale (2019) reported occupational protectionism amongst sonographers, who defended their need for professional recognition; emotional factors such as anxiety were linked to a perceived loss of value and dilution of their professional identity. McKnight (2023) identified similar issues for radiographers where there were tensions at the boundaries of professions; to protect the profession as a credible entity, she recommended replacement of the concept of profession with that of a 'field'. This concept of a network of occupants with common attribute could also be applied to sonography.

Interestingly, in this research sonographer participants described varied professional identities, and labelled themselves differently within various organisations. Sonographers working within HEIs appeared more likely to describe themselves as teachers, educators, or academics, whereas clinical staff within training academies or NHS Trusts used a variety of terms like trainer, supervisor, sonographer, mentor or educator. These internal professional divisions were evident across educator and stakeholder participants groups. Educator participants described "we" and "they", and some appeared to see themselves as separate to those teaching students in clinical departments, whilst others maintained a strong identity as a clinical sonographer.

E1: I think of myself first and foremost as a clinical person rather than an academic.

In addition to varied clinical and academic sonographer identities, participants also described multiple distinct professional groups within clinical ultrasound departments, including roles such as sonographer, clinical educator, radiologist, support staff and student learners on different training routes. Some role conflict and competition for training time was evident between groups. This aligns with findings of Mitchell (2018), who reported that professionalism and sonography identity was heavily influenced by clinical departments, and the multi-professional nature of sonography may lead to territorial behaviours, protectionism, and professional jealousies.

Sr2: even the registrars, they scan lists, but although they need the same sort of skillset, it's not to the same degree a sonographer needs it … we are an expert in that field, … having viewed consultant scans even, you can see that they don't have the skill that a sonographer has in getting and presenting an image like a sonographer would.

This confusing mixture of professional identities in sonography practice mirrors findings by Dace et al. (2022), who reported that clinicians working in medical education can struggle to manage dual identities of clinician and teacher. In this research, competitiveness and conflicts between different individuals and groups extended beyond the clinical versus teacher divide to include students studying at different educational levels, on different programmes in various HEIs, and with varying levels of clinical experience.

Competition for training between professional groups was also reported, with both registrars and sonography students competing for practical training in the same departments, yet their professional backgrounds, training programmes, assessments, funding streams and availability of equipment varied considerably. Some participants felt frustrated and excluded from accessing available ultrasound training resources and therefore felt that simulation equipment within their departments (or within local academies) had little impact on sonographer training.

E7: I've always found it very frustrating, as you know, we've got an academy for radiology and we're not allowed to use it

Professional protectionism in sonography was linked to resistance to change and fear of loss of value and status (Mitchell & Nightingale, 2019). These views persist in practice, and impact negatively on student learning. This unique culture, workforce shortages, varied professional roles and identities, growing service demands, and complex roles make this a difficult environment in which to teach and learn. Sonographers continue to work and train students in pressured environments, and long held cultural beliefs and resistance to change noted by Mitchell (2018) remain evident. One stakeholder described "*growing up*" in an obstetric department, learning only through observation and real-life experience. If stakeholders have not experienced simulation (and are not aware of the potential benefits), they are less likely to utilise this teaching strategy.

4.9.2. Becoming a sonographer

Professional identity formation is a complex, multidimensional, ongoing, and transformative process which requires individuals to combine their pre-existing knowledge, skills, values, and behaviours with those they perceive as key to their chosen career (Mount et al., 2022). Professional identity is difficult to teach, as it encompasses intangible factors that are attributed to the cognitive, social, and moral development of individuals into health professionals (Keshmiri et al., 2020). Although many student participants had worked in various roles within radiology departments prior to their sonography training, participants felt they did not really understand the role of the sonographer prior to their training, and some had underestimated how difficult the role could be. Student participants reported that their transition from being an experienced health professional to being a "student" again was difficult.

St4: I had to humble myself and become a student again … that was quite challenging and … I think it did become all very overwhelming.

St4: Being in a different clinical environment, different hospital site, different department, I was really out of my comfort zone.

Most students acknowledged that they found it difficult to join unfamiliar departments, and they took time to understand their new roles and relationships within a new department. The established cultures within departments meant that students sometimes felt excluded and found joining a close-knit sonographer community challenging. Complex department hierarchies were confusing as students adjusted to their new roles and responsibilities. Challenging clinical learning experiences can make professional identity development difficult for students.

St5: I don't know how I'm going to act because I've gotten so used to being below the sonographers; there's still those little cliques … they're all friends with each other, they all keep to themselves

St7: All I kept hearing on the grapevine was [the sonographers] moaning about us. And I took that quite personally.

Students were required to achieve competencies in a wide range of skills in practice, but the high demand for clinical skills, resulted in less emphasis on the other pillars of advanced practice such as research, education, and leadership. Students described experiencing a wide variety of pressures when learning in clinical departments, including patient needs, time constraints, workloads, working with a variety of staff (who don't know them or their learning needs well), lack of consistency of support and mixed worklists. Students were expected to quickly adapt to their trainee role, but for some students this was challenging, and feelings of isolation, pressure, imposter syndrome and inadequacy were common. Imposter phenomenon (IP) is experienced as debilitating self-doubt, which can lead individuals to attribute their success to luck or external factors and is common in goal-oriented environments such as healthcare (Siddique et al., 2024). Imposterism can lead to emotional exhaustion, and is associated with increased rates of depression, anxiety and burnout, so the prevalence of this in student participants is particularly concerning.

St4: I didn't really get what it was that I was actually going for or might apply for or how hard it really is … it looks easy but it's not. I don't think being able to scan is that easy… sonographers make it look easy

Professional identity develops as students begin to feel more authentic as sonographers, reflecting on how this impacted on their *'sense of self'* (Cruess et al., 2019). However, the varied professional identities described by educators and stakeholders in this research meant it was difficult for students to develop a clear understanding of what their new identity should be. Hill & White (2022) explored the transition of newly qualified vascular sonographers into practice, and identified similar challenges such as doubts, waning motivation, and dissatisfaction.

There is potential to use simulation in a wide range of ways to support learning for sonography students, but traditional approaches of learning in practice persist, and use of simulation for developing complex skills is more commonplace for other professional groups. Simulation provides opportunities for repeatable and consistent learning experiences and has potential to offer opportunities for students to develop a sense of belonging, self-confidence, mutual respect during their learning experiences. For student participants, a key benefit of simulation learning was the opportunity to observe, discuss and practice behaviours in a safe and supported environment with the support of trusted peers and tutors. Simulation helped students to understand their new roles and development of a new professional identity. Group learning enabled students to explore their professional roles and responsibilities in a safe environment with trusted peers and tutors, which helped them to develop their new sonographer identity.

St5: We've become more aware of what's expected from a sonographer and what makes someone a good sonographer … because you're working in a different capacity than you've ever worked before. It's [simulation] helped find that professional identity

Surprisingly, professional identity development was not mentioned by any of the educators or stakeholders as a benefit of simulation learning, instead their focus was largely on skill development, with little consideration of how learners might develop their new sonographer identity, or how they might support this (with or without simulation). Students were surrounded by a variety of roles and identities in a pressured working environment, however students at a later stage in their studies seemed more confident in their roles and took pride in promoting sonography as a profession.

St1: educating the public on what we do as a profession … it's widening our presence.

Little research exists on professional development in sonographers. The need to support professional identity development is also acknowledged in other health professionals (Dace et al., 2022), however empirical evidence identifying effective ways in which educators can address this in curricula is scarce. Comparisons can be made between professional identity development in sonographers and physicians. Holden et al. (2012) described a similar primary focus on practical training in medical education, but they also emphasised the importance of professional identity development for future healthcare staff.
Monks et al. (2020) explored how simulation-based learning aids professional identity formation in medical students. The study found that simulations offered safe environments,

providing them with opportunities to create relationships, take responsibility, and practice independence, enhancing learning and professional identity development (Monks et al., 2020). Most students agreed that simulation activities enabled them to better understand their role as a doctor, and valued opportunities to engage in reflective practice as part of the simulation debrief (Monks et al., 2020). Bowman et al. (2022) reviewed sonography student professional behaviours following simulation, but this was assessed by observers and did not explore professional identity formation from a student perspective. They recommended incorporating preclinical professional behaviour education with simulated practice into the core curriculum for Australian sonographers to improve clinical outcomes and increase patient safety in practice. In UK education, their recommendations are likely to be more achievable for undergraduate sonography routes, since UK postgraduate students often spend significant periods of time in their clinical department prior to starting their university course.

Sociocultural learning theorist (Wenger-Trayner, 1998) proposed a landscape of practice as a model for how learner identities develop, where part of the educator's role is to guide students and help them to develop the knowledge required to establish their professional identity, but this theory is yet to be explored in medical or sonographer education (Hodson, 2019). Toubassi et al. (2023) explained that professional identity development was possible when students had structured experiences with clear goals. Students with a better sense of belonging, and a feeling that they mattered, had lower anxiety, better resilience, and improved wellbeing. Simulation could provide guidance and controlled challenging experiences to help students cope with the previously discussed pressures in practice, impacting on professional identity development and student wellbeing. Further exploration of the experiences of students, stakeholders and educators is required to develop a better understanding of student needs from a holistic perspective.

Effective design of simulation-based educational activities that allow for safe exploration of role identities was important to students, who face stress and burnout in their sonography careers. Supporting professional identity formation could strengthen well-being and enhance resilience by helping students find meaning and purpose in their work (Toubassi et al., 2023). Simulation learning has potential to create a dedicated space to support identity formation, encourage reflection, and develop communities of practice. From a student perspective, simulation can create a unique experience that provokes the development of professional identity through memorable learning. Each experience provides a framework for students to build, develop, and redefine their professional identity and understanding of self and their professional roles. Simulation could also be used to explore how lapses in professionalism might occur and reflective ability can be strengthened in learners.

4.10. Subcategory C3: Collaboration and education

Educators need to create a supportive and equitable environment for their learners and enable them to benefit from peer support, but an overloaded system means this is difficult for sonographers to achieve. Among other initiatives, the NHS Long Term Plan (NHS, 2019) outlines a strategy to increase the NHS workforce through training, requiring more clinical placements, and more routes into the NHS. The NHS in England has acknowledged the need for more collaborative working to address workforce shortages and declining quality of care (NHS Professionals, 2019), but they also acknowledge that workforce collaboration is in its infancy. If their vision is to be realised for sonographers, support for new educational routes, and embracing new ways of training (including simulation) are required to address chronic workforce shortages.

E1: If we could work collaboratively and have a plan of how that looks, then that should work. I think that would be really helpful, so those who have gone before can help plan that.

Collaboration between educators and stakeholders is required to ensure that simulation is planned to meet student training needs, and that students understand the purpose and benefits of simulation learning throughout their training. A more consistent national approach with clear integration within the curriculum to align with learner needs could be beneficial, but educators noted that not all learners gain skills at the same rate, which may make design and implementation of simulation learning challenging.

E3: I would love to know how other people are using it … that would be the most valuable thing

It is inevitable that training impacts on productivity, with an Australian study estimating that a novice student can reduce a supervising sonographer's productivity by 50% in the first few months of training, and 25% over the 2-year period of training (Victoria State Government, 2016). Given that the role of the sonographer in Australia does not include the same autonomous reporting responsibilities as UK sonographers, and with the increasing demand for ultrasound imaging (SoR, 2022), the impact of a trainee on sonographer productivity may be even higher than previously estimated. Simulation based learning has potential to provide consistent learning experiences without impacting on productivity in busy clinical departments, and some stakeholders felt more access to simulation using task trainers would be beneficial for students, particularly with increasing numbers of students, as this would relieve pressures in their departments.

4.10.1. Cooperation and consistency

Peer support is not only important for students. Opportunities for sharing and peer support were also beneficial to stakeholders and educators, but the findings from this research suggest that these were limited. Participants reported wide variations in practice and facilities for sonographer training. There was a lack of consistency between geographical regions, and educators expressed frustrations and concerns regarding the complexities of sonographer training and the difficulties experienced within sonographer education. Ideally, all learners should have a high-quality clinical education, and although one student commented that they felt lucky to have good access to hands on scanning experience, they indicated that this was not the case for everyone in their cohort. New training routes may be particularly challenging, with the potential for opposition from some clinical staff and leadership teams.

Sr3: you've got disparate sort of setups. Even with your education providers, you've got different amounts of equipment, but you've also got a highly pressured situation where academic staff are under pressure and haven't got time to deliver that kind of upfront clinical skills training.

St3: here were lots of whisperings and things like people didn't want to do this

St6: to start with it felt very hard, nobody knew where we were, or what we were supposed to be doing

The challenges of providing adequate clinical training for a variety of learners in busy departments can be stressful for trainers, managers, and students. Not all clinical staff had the same level of training or dedicated time for teaching, with clinical educator roles only mentioned by a few participants. Funding and availability of equipment varied which made it difficult to provide equitable learning experiences in different geographical areas. These difficulties are not limited to sonography, and McClintock et al. (2022) reported that medical teams had difficulties in building high-quality relationships with learners due to high workloads, limited time, and little continuity with their students.

Sr1: I feel like it's a bit of a shambles at the minute, nobody's got anybody at the helm. I feel like everybody's pulling in different directions

While most participants were enthusiastic about the potential of simulation for sonographer education, there is little sharing of expertise between institutions, which may be due to time pressures, lack of opportunities, or perhaps the competitive nature of higher educational institutions. National and regional funding streams were allocated inconsistently, with some participants noting that regional academy schemes were "*shrouded in secret*". The current approach to funding sonographer training appeared chaotic, with a lack of coordination nationally, and little sharing of resources or experience between these organisations. Collaboration and clearer communication are required to ensure better understanding and wider opportunities for sharing of resources and best practice.

Sr3: central funding went out to regions and regions have all done different things and that's not helped in terms of looking at consistency of education

E1: some HEIs have been given a lot of money by Health Education England, and others have been given virtually none

Educational practice and attitudes have evolved and are continuously changing. Educators and students both described a lack of understanding of educational requirements by clinical staff, who are working in pressured, understaffed environments. Since time spent at HEIs was limited, students welcomed opportunities for simulation-based education within clinical departments, though this is difficult to provide as sonographers have multiple areas of responsibility alongside supervision of students. Clinical departments and HEIs could collaborate more to improve understanding and communication regarding training needs for mentors and students, which would inform development of an effective simulation strategy for sonographer training.

E1 … giving them that consistency of support in a room separated off from the main hub of a normal clinical department

Participants acknowledged the importance of providing consistent learning opportunities for their students. Although there was collaboration between some organisations and individuals, participants felt there were inadequate opportunities for sharing experience and learning to improve practice. Stronger links are required between key stakeholders (Khine, Harrison & Flinton, 2024) to reduce the current variations in educational practice, and to explore the potential for effective and consistent use of simulation within sonography education nationally.

4.10.2. Interprofessional learning

Interprofessional learning aligns with the NHS Long Term plan for developing a well-trained multi-professional workforce through simulation-based education (NHS, 2019). However, there were few inter-professional learning opportunities discussed by participants in this study, either in clinical environments or using simulation. Stakeholder participants felt that although there were opportunities for interprofessional learning, this proved difficult, since ultrasound use by different professionals varied widely in practice. Although educators felt that multi-professional simulation could be beneficial, the costs and logistical issues made this difficult to plan and implement.

Sr4: Looking potentially at the bigger picture, not just hands-on ultrasound … there are other things that they could do multi-professionally and inter-professionally

Hannides et al. (2024) designed and implemented an interprofessional simulation for allied health professionals, which highlighted benefits and barriers to students learning, but this did not include sonographers or radiographers. The varied standards for ultrasound practice for different professionals (e.g., sonographers and radiologists) created challenges in designing interprofessional learning. Distinct groups of learners were evident in participant responses, with some indications of competition between different groups of trainees. There appeared to be an “us” and “them” environment, rather than a unified learning culture for sonographers, registrars and others learning ultrasound skills.

Sr2: [The academy] it’s registrar-based … we don’t share training facilities

Perhaps this lack of cohesion can be partially explained by the different funding routes for staff training in organisations, which inhibits development of a more collaborative approach to supporting training and learning. This is not new, as Mitchell (2018) previously noted the multi-professional nature of sonography created territorial behaviours and fostered protectionism and professional jealousies amongst the sonographers.

Lack of opportunities to share expertise or facilities is unlikely to be efficient or cost effective. Improved collaboration is needed between organisations (HEIs, Academies and Trusts) and within organisations where ultrasound training is required by multiple professional groups. Smith et al (2020) evaluated sonography student led point-of-care ultrasound training, and found that this increased physician respect for sonographers, and increased interest in future interprofessional collaboration. However, continuing service pressures, workforce shortages and financial pressures hinders the development of multidisciplinary learning. This may be a missed opportunity as enhanced collaboration may improve patient outcomes, which makes this an important area for future exploration.

4.10.3. Educator education and research

The NHS Framework for Technology Enhanced Learning (HEE, 2011) highlighted the need for technology to be patient centred and service driven, educationally coherent, innovative, and evidence based. Educators require appropriate training to ensure effective facilitation to ensure students can achieve maximum learning (Nestel, Krogh & Kolbe, 2018). One leading manufacturer offered pre-recorded self-directed training packages for their users, but participants acknowledged that a lack of time meant they were not familiar with available resources. The previously discussed lack of faculty expertise, alongside the pressures experienced within educator roles is likely to be a significant limiting factor to further development of simulation for sonographer education.

Ed3: There's a huge volume of resources … but it's just a lack of time.

Ed7: HEIs have the bare minimum of staff. And the … work is large and increasing.

Participants reported a lack of coordination between clinical placement sites and HEIs, with a lack of awareness amongst clinical staff relating to what sonography students were required to do, or how best to support their learning. This aligns with findings from Khine, Harrison & Flinton (2024), who reported that supervisors were not always well prepared for their role and may not have adequate training. Educators largely relied on replicating their clinical experiences using a trial-and-error approach to simulation, and they were aware of the skills gap in their expertise in facilitation and design of simulation learning. Although they wanted to try new things, educators lacked the time, training, funding, or facilities to provide effective simulation learning for their students.

E3: trial and error is how I've got to where I am now with it … I think there might be a better way.

E3: It feels like an unsurmountable mountain to climb

Most educators lacked confidence in their skills to plan and offer simulation-based learning. This made them less likely to have incorporated this as a learning approach in their teaching, and less likely that their students understood the value of simulation in their learning. This may explain why simulation was often seen as an "adjunct" to sonographer training, rather than a core part of the curriculum. The lack of use of appropriate frameworks, and lack of time to support development of simulation training (re design, implementation and debrief) may be limiting the potential of simulation in sonographer education.

E7: … making sure that we use it properly

E4: this is a very new toy for us … we're learning it ourselves before we pass it on to trainees designing and delivering simulation-based learning.

Sr4: I think there is a gap in the knowledge and the skills to be able to utilise simulation and simulation activities and equipment

There was enthusiasm about simulation learning using task trainers, yet there was a lack of confidence to look beyond these for effectively embedding a variety of simulation learning experiences into training programmes. Educators showed willingness to learn and wanted to expand the use of simulation in their practice but were hindered by a lack of opportunities for specialist training or sharing experiences, and felt they were having to "learn" to use the simulation equipment with little support or guidance.

E2: we are like swans … paddling frantically underneath the surface: we look like we are absolutely cool and professional, and know what we're doing but actually, no, we don't! We literally are flying by the seat of our pants

E7: I would like loads more simulation … [like] immersive technology … I think that makes it more exciting, more interesting. It needs to be not a bolt-on, it needs to be embedded in the curriculum.

Staff involved in clinical teaching are essential to student success, and the need for training and accreditation to demonstrate skills to undertake the role of a clinical educator is widely advocated (HCPC, 2017; CoR, 2022). Wallace (2023) reviewed the use of simulation-based education for radiography courses and reported a lack of feedback, training, and reassurance for facilitators, with most participants lacking any formal simulation training. There is potential to develop simulation learning experiences that focus on professional development in the areas of teamwork, building a sense of community of practice, self-reflection, and resilience learning at an appropriate level of difficulty to support student development (Monks et al., 2020). Expanding the use of simulation for sonography education will require educators to collaborate with simulation experts to design effective and varied simulation learning experiences. To adequately prepare learners for clinical practice through simulation learning, it is essential to provide training and support for educators to ensure consistency and effectiveness in their approach.

4.10.4. Leadership

Effective leadership and good relationships between healthcare professionals are essential to ensure high quality patient care (Hill & White, 2022). At a local level, effective leadership is essential to manage pressures on clinical departments. Participants reported frustrations with regional variations in funding for specialist equipment and dedicated training leads. Participants felt that a dedicated clinical educator and simulation leads within organisations were essential to the development of effective and coordinated approaches to using simulation within training programmes.

St4: [my clinical educator] arranged for workshops … she'd guide us through and the rest of us would watch and take in and then we'd take it in turns. So that was nice to do.

The growing demand for imaging services (NHS England, 2019) is likely to further compound pressures for training the sonography workforce. Effective and efficient training programmes are essential to meet workforce demands, and simulation is likely to be a key component within sonographer training. This will require equitable national funding for practice educators to effectively support students and coordinate with simulation experts to ensure effective use of simulation learning.

Sr3: You've got disparate sort of setups … we need to think more strategically

Sr3: workload pressure is a massive factor. Sonographers are overwhelmed … students are struggling.

Lack of national leadership for sonographers has been previously reported by both Mitchell (2018) and Sevens (2017), with inconsistencies in guidance between professional bodies and sonography managers creating uncertainty. Since then, there have been some positive changes nationally, but long held cultural beliefs and resistance to change observed by Sevens (2017) and Mitchell (2018) are still present, with stress and apathetic tendances noted within the workforce and educators within this study.

Ed2: somebody needs to take an ownership of it and drive it forward and force us all into it.

Sr3: I think it's having the right leadership, you know, then the vision.

Strong leadership is essential to develop the potential of simulation within sonography education. For change to be managed and implemented effectively, national leadership and better consistency is needed in sonography education. Unfortunately, the multidisciplinary diverse leadership team suggested by Sevens (2017) is still not a reality, and wide variations in sonographer training persist. The division of responsibilities for accreditation and professional guidance among several key national bodies makes the development of consistent guidance on optimal use of simulation challenging. A variety of stakeholders are involved in accreditation, funding, setting professional standards, and decision making in sonographer education. This includes CASE (made up of 9 separate organisations), BMUS, SCoR, NHS England, The Institute for Apprenticeships, training academies, and a variety of HEIs and integrated care systems. This makes consistency and identifying a single organisation to provide leadership difficult to achieve. Establishing a specialist interest group could foster a collaborative approach to leading the development of a simulation strategy for sonographer education, which must be flexible to accommodate technological advances and to encourage innovation.

4.11. Summary Category C: Experiences, identity, and culture

Simulation has potential to provide high quality learning experiences, but to date the focus has been largely on psychomotor skill development in the early stages of student learning. Opportunities for using simulation to develop teamworking, communities of practice and resilience are unexplored in sonographer education. Simulation was seen as an adjunct rather than a core part of sonographer training, impacted by time pressures and resultant lack of educator training and engagement with existing simulation guidance and frameworks. Opportunities for peer support for students, stakeholders and educators are important, but these are limited, and there was no discussion of opportunities for simulation in interprofessional learning.

Wide variations in practice and facilities for sonographer training exist in different organisations, and students did not have equal access to high quality clinical training. The complexities and inconsistencies in sonographer training nationally posed challenges for educators, who lacked time and confidence in embedding simulation throughout the curriculum. Training and support for those involved in sonographer training is essential to ensure consistent and effective learning.

Simulation learning was mainly limited to academic learning in HEIs, and although there was enthusiasm amongst participants, there were limited opportunities to share experiences and knowledge relating to simulation-based education. Participants reported simulation within clinical departments and funding for roles like practice educators benefited learners. Better support and training for clinical staff could improve supervision, and clinical educators should be available to all students.

High workloads impacted on the ability of educators to design and develop effective simulation, and this also affected relationship building between educators, stakeholders, and clinical educators. Clinical departments, academies and HEIs should collaborate to develop effective simulation strategies for sonographer education. This could provide opportunities to improve provision of consistent learning opportunities and could establish stronger links between stakeholders to reduce variations in educational practice.

However, there is no consistent approach to this nationally, and although CASE recommendations (CASE, 2018) for accreditation of ultrasound programmes include the need for innovation, there is little specific guidance for educators on effective use of simulation in sonography programmes. Stakeholders viewed simulation as an added extra (or something to use when no scanning lists were available), whereas some students seemed to place higher value on opportunities for simulation learning. Coordination and leadership are required to guide the development of simulation within sonography education. The multiple organisations involved in sonographer education, limitations of time and available funding, and professional guidance increases the complexity of developing clear national consensus. Newer training routes provide opportunities for change, but there is lingering opposition to these routes and the new career structure in sonography culture in which they sit.

Long term workforce shortages, an ageing workforce, occupational risk of workforce injury, career advancement and increasing demand for imaging services, all impact on clinical training experiences and learning opportunities in clinical departments. Inconsistency in national and regional funding streams creates challenges in providing equitable training experiences. Strong leadership is essential to develop the potential of simulation within sonographer education. National coordination of the many organisations involved in sonographer education is recommended to ensure provision of consistently high-quality education for students. Establishing a specialist interest group could foster a collaborative approach and lead the development of a simulation strategy for sonographer education.

Chapter 5: Conclusions and Recommendations

5.1. Conclusion

This research investigated the role of simulation in sonographer education from a variety of perspectives to inform recommendations for optimal learning. A constructivist Grounded Theory methodology was used to collect rich, in-depth data from educators, students, and key stakeholders. An initial literature review set the context for the research, focusing on three main areas: sonographer education, factors impacting the use of simulation for ultrasound training, and clinical skills development in sonography. Limited evidence exists to inform sonography educators as to the most appropriate simulation strategies and their effectiveness. There were indications that simulation learning can be effective however widespread implementation is yet to be achieved, and its use is likely to continue to develop (Harrison & Beardmore, 2020; Shanks et al, 2010). These findings informed the development of the research aims and initial interview schedule.

The core categories that emerged from the final analysis were related to contemporary literature, allowing for practical recommendations for educators, stakeholders, and students. As the research developed and theory emerged, it became evident that although there was huge potential for development, there were many barriers, limitations, and challenges affecting simulation use. Most participants recognized the need for well-planned simulation learning, but limited educator expertise, time, and financial constraints hindered effective implementation.

In the context of sonography simulation, participant enthusiasm was high, but current educational practice must evolve and adapt to ensure that simulation is not just high fidelity, but also meaningful and fit for purpose. Simulation has significant potential to meet the educational needs of modern sonographers, offering opportunities for increased training capacity and high-quality training experiences, but it's use is currently limited and not keeping pace with other professional groups or industries.

Simulation must be designed to meet the needs of learners at different educational levels, supporting students to develop skills, behaviours, and professional identity in a safe environment, which will ultimately ensure high-quality patient care. Although there is huge potential to use simulation in a variety of ways for sonography education, implementing this is hindered by limited time, training, funding, and confidence. As a result, there is no consistent approach to using simulation within UK sonographer education.

Sonographers require a complex set of skills to meet the requirements and challenges of autonomous practice, but longstanding workforce deficiencies and changes to educational and career models are impacting on training quality and capacity for sonographers. Simulation learning has potential in many areas, however national practice variations and limited exploration of simulation-based sonographer education persist. Development of basic scanning skills using simulation is reasonably well established in sonography training, but variability exists, and a wider range of sonographer skills could be enhanced through simulated learning experiences. For simulation to reach its' full potential, a variety of simulation learning should be consistently embedded throughout curricula.

The resulting theory revealed the potential for using simulation in various ways in sonographer education but achieving this requires changes in practice, educator training, dedicated clinical educator roles, and increased funding and facilities. There is no consistent approach to this nationally, and specific guidance on effective use of simulation is lacking.

Simulation learning has potential to increase training capacity, and quality of learning experiences. However, there is limited evidence to guide educators on the most appropriate simulation types, timing, teaching, and assessment strategies as well as the short, medium, and long-term effectiveness of simulation in sonographer education. Increased use of well-designed simulation learning experiences could enable students to adopt a strategic approach to learning, reduce current reliance on training in pressured clinical environments, and therefore increase training capacity with high quality student learning experiences.

Long-term workforce shortages, an ageing workforce, occupational risks, career advancement and increasing demand for imaging services lead to high levels of work-related injury and sonographer burnout, negatively impacting clinical training. Although this research did not initially aim to investigate student wellbeing, it emerged as a significant consideration for participants, and there were some concerning indications that the psychological safety of learners is not consistently assured. The importance of simulation to enable student opportunities for professional identity development was also an unanticipated finding in this study.

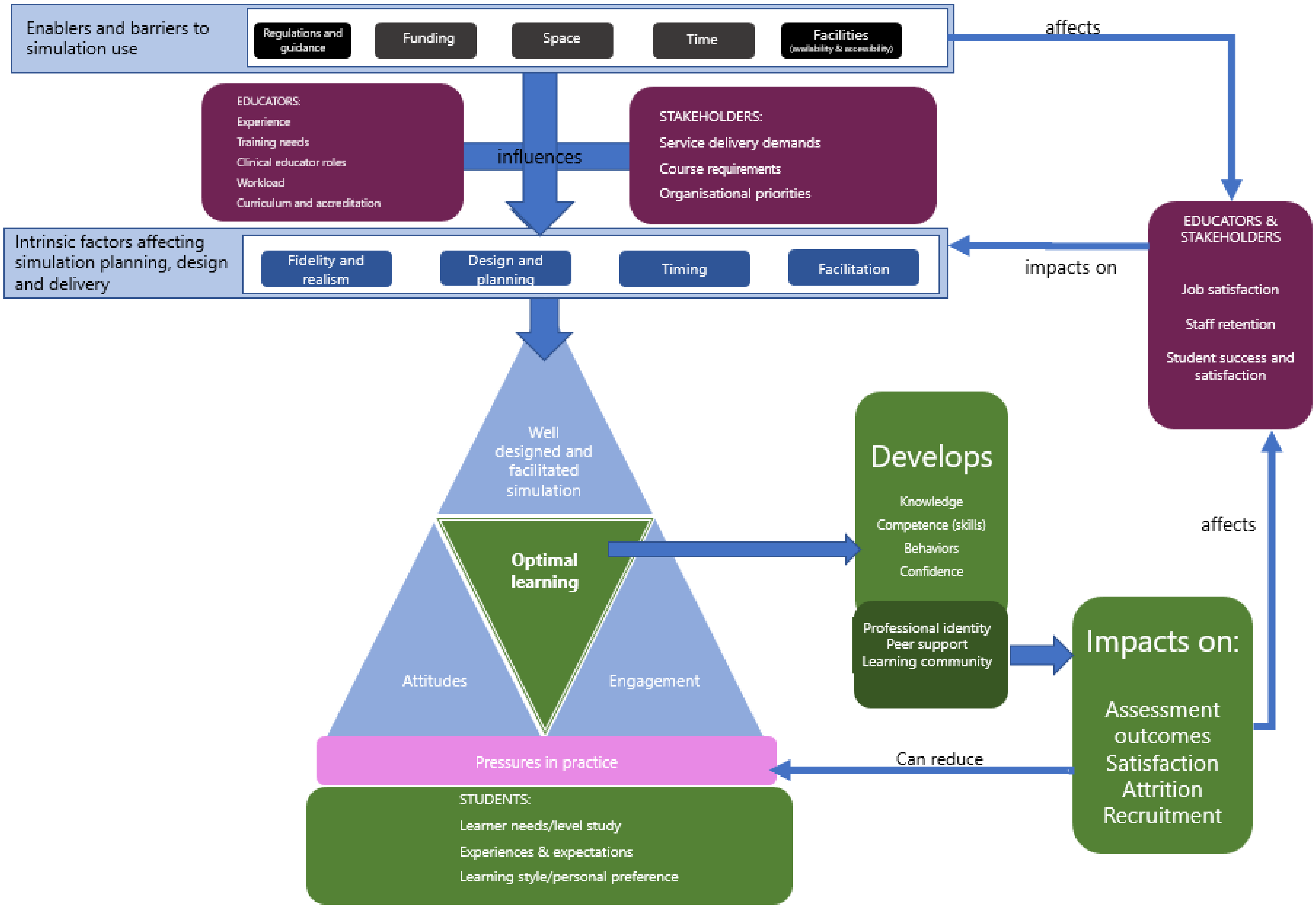
Coordination and leadership are required to develop a clear national consensus on the effective use of simulation in sonography education, and to justify the need for more funding and facilities. Further research is required to fully evaluate simulation use in all aspects of training. Educators were eager to learn and share their experiences. Exploring best practice relating to the use of simulation learning in clinical education and engagement with the international simulation community can better inform and develop simulation use across various areas of sonography practice.

Planning, design, and delivery of simulation within sonographer education have multiple influences which impact on the integration of simulation into curricula. Further training to develop expertise in facilitation of simulation, alongside better awareness of guidance related to simulation design in healthcare education could increase the positive impact of simulation for sonography trainees. Consideration of the limiting factors of funding, space, time and availability and accessibility of facilities is also important. Offering simulation only within HEIs is not sufficient for students who are part time learners, and development of specialist clinical educator roles who can facilitate simulation in clinical practice environments should be explored. If educators are not confident in their skills to plan and offer simulation-based learning, then they are less likely to incorporate this as a learning approach in their teaching.

Variation in equipment design and functionality, and the requirement for regular updates to software packages, make it difficult to achieve consistency in delivery of learning. Improved student outcomes are desirable, and improved student attainment could relieve some of the current pressures experienced during clinical practice learning; unfortunately, a lack of awareness and engagement with guidance, and reliance on a trial-and-error approach to teaching is limiting the potential of simulation learning for sonographers.

The factors influencing the use of simulation for sonographer education are varied, and interdependent. A summary of the developed theory, which illustrates links and influences between different factors is summarised in Figure 5.1. Multiple factors require consideration to ensure that simulation is used effectively, and to ensure that students have an enjoyable and safe learning experience to develop knowledge, skills, behaviours, and confidence. Simulation can also provide valuable opportunities for students to understand their professional responsibilities which will inform the development of their professional identity as a sonographer. Learning experiences are further enhanced through implementation of guidelines, group learning, development of communities of learning and support networks (both tutor and peer support). Effective simulation could positively impact on assessment outcomes, student satisfaction, attrition rates and student confidence.

Figure 5.1: A summary of the interrelated concepts identified as part of this research



5.2. Recommendations

The developed theory shows that better design and regular use of SBE could improve student outcomes and has led to a variety of recommendations.

5.2.1. Using Simulation in Sonographer Education

Simulation design should be reviewed to determine what is most beneficial and most cost-effective. Consideration of how available funds are best used and determining which SBE methods are most effective is essential. Upgrading equipment and implementation of innovative approaches to training can be costly, therefore further investigation into the cost-effectiveness of a range of simulation-based training is required. Careful consideration of costs, and training and time for educators to innovate are essential, but this is challenging for a relatively small professional group. Utilizing existing resources more effectively could improve cost-effectiveness, though this is currently hindered by wide variations in practice and available resources.

To enhance learning experiences for students, it is crucial to ensure consistency with supervising staff, avoidance of assumptions, and fostering a better understanding of learner needs. Facilitated simulation-based learning can play a significant role in this process. Regular access to and use of simulation in HEIs and clinical environments is necessary to expand knowledge, skills, and confidence among educators and students. However, clear student understanding of the role and benefits of simulation learning is required to ensure high engagement with SBE learning opportunities.

It is imperative to ensure fundamental aspects of simulation-based education are implemented, before integrating more advanced techniques. There is significant scope to expand beyond the current use of simulation and explore a wider variety of simulation-based education methods, such as simulated patients, virtual reality (VR), augmented reality (AR), artificial intelligence (AI), hybrid simulation, gaming, and digital tools. Existing task trainers are becoming more realistic and user-friendly, with increased variation in cases and available tools, but there are a multitude of other opportunities for simulation learning. Educators should explore the potential for simulation to support learning across all four pillars of the Advanced Clinical Practitioner (ACP) framework, as well as supporting preceptorship and capability development for sonographers in practice.

5.2.2. Educators

Educators need access to specialist training and time to develop expertise in design and facilitation of effective simulation learning. Improved understanding of best practices in simulation delivery, including effective use of pre-brief and debrief techniques is especially important. Incorporation of healthcare simulation guidelines for good practice alongside curriculum review could ensure simulation is appropriate for educational level and designed to ensure high quality and consistent learning. Further training and support for innovation to move beyond task trainers and self-directed learning is important to provide learning which is valued and offers opportunities for peer support and development of communities of learning. Educators need time and training to develop expertise in simulation-based education for HEI staff and clinical mentors to facilitate exploration of a range opportunities for simulation learning.

Regular use of well facilitated simulation-based learning helps students to learn and gain confidence, but this requires fostering positive attitudes to maximise engagement. Engagement with clinical staff and students in development of sim learning, to ensure better design of simulation-based education and exploration of a wider range of simulation based educational opportunities. This study recommends moving away from reliance on self-directed task trainer learning to more expertly facilitated simulation experiences. Effective use of group simulation learning can provide safe and supportive learning environments, where students can establish a community of learning. To ensure students understand the expected behaviours and confidentiality, it is recommended that educators set clear expectations and establish “a code of practice” during pre-briefs. Educators must also ensure they provide adequate debrief processes to maximise learning opportunities for their students.

Consultation with students is essential to clarify expectations, roles and learning outcomes could provide more tailored learning, and improve student engagement with simulation learning and to meet their training needs.

An inclusive and effective learning environment is essential, and application consideration of psychological safety and needs of learners is critical. Sonography educators need to engage with the growing simulation community to ensure the curriculum is relevant and efficient in producing the future workforce. There is a need for opportunities to share, learn to grow confidence to enable educators to take ownership and innovate in their teaching.

5.2.3. Clinical mentors/practice educators

Clinical educators require adequate training and time to get to know students, and consistent supervision provided better student support, and an improved understanding of individual student learning needs. The desirable attributes of clinical mentors and educators should be considered, recognizing that not everyone is naturally adept at teaching, and that student learning styles can vary considerably. Clinical mentor accreditation through professional organizations such as the Society and College of Radiographers could be beneficial. Consistency with supervising staff, and the avoidance of assumptions facilitates a better understanding of student needs. Support and training for clinical mentors, and funding to enable wider introduction of clinical educator roles should be considered nationally to ensure consistently high-quality student experiences. Further review of the impact and cost effectiveness of the clinical educator role is required.

Adapting from traditional one-to-one training to alterative training models would offer opportunities for feedback and peer support. Testing alternative training models, such as dyad or group learning with consistent use of simulation learning, could help reduce pressures and enhance the overall educational experience.

5.2.4. Stakeholders

Engagement in the design and implementation of simulation-based learning needs to be prioritised by all relevant stakeholders, including accrediting and professional bodies, commissioners, clinical services, support leads, individual practitioners, and patient groups. Stakeholders should support the wider introduction of clinical educator roles, which could reduce workforce pressures and provide better learning experiences for students.

Access to simulation learning in clinical departments for students can be beneficial, therefore current use of simulation mainly within HEIs needs to change. Provision of dedicated training lists with additional time for teaching and feedback, alongside effective simulation throughout learning would benefit development of student knowledge, skills, and confidence.

Implementation of effective strategies to assure the wellbeing of all staff and students must be prioritised. Effective preceptorship programmes for qualified staff could improve morale and teaching skills, and therefore have a positive impact on student experiences. Integration of student sonographers into teams is also essential to improve their sense of belonging is essential, and consideration of individual training needs is important.

5.2.5. Governance, guidance, and funding

Consensus on the effective use of simulation-based learning, and recommendations from accreditors regarding the use of simulation in curricula would be beneficial. Effective leadership is essential for training, funding, and researching simulation-based learning opportunities. However, the large number of organizations involved in sonographer education and professional practice makes the development of guidance complex, necessitating clear leadership.

Furthermore, occupational standards must be fully aligned with the career framework and the multi-professional career framework for advanced practice. This could enable a wider exploration of how simulation could support all levels of practice and for different educational routes. Although time, money, and innovation are required, this is challenging for a relatively small professional group.

Clearer guidance would lead to more consistency between organizations. Developing and approving a strategy for implementing simulation in sonography education requires input from various stakeholders. There is a need for collaboration and consensus amongst interested parties nationally, which requires coordination and leadership, but it is important to define who should produce this guidance. A multi-professional Delphi study and establishment of a national special interest group (SIG) could provide consensus and support the development of a detailed guidance document defining effective strategies for using simulation for sonography.

5.2.6. Collaboration

A coordinated approach and national leadership are required to foster a collaborative approach to sonographer education and to optimize resource use and learning experiences for students. Specialist training for all those involved in delivering simulation learning is essential, and collaboration with simulation experts within organizations. Opportunities to share and learn will enable educators to take ownership and innovate in their teaching.

Although some guidance and training are available, engagement is varied and limited due to time constraints, finance, and competing work demands. Adopting available ASPiH and NASCL guidance would improve simulation-based education delivery for sonographers. These guidelines could be simplified or modified to be more specific to sonographers. Engagement with the growing international simulation community would also help sonography educators ensure that the use of simulation-based education remains relevant and efficient in producing the future sonography workforce.

A variety of educational routes and wider adoption of all levels of the career framework requires change, and effective integration of simulation learning could benefit all learners. To ensure consistent and high-quality simulation implementation in sonographer education, it is crucial to prioritize the development and design of guidance and simulated learning experiences. This requires the input of wide range of stakeholders, including accrediting and professional bodies, commissioners, clinical leads, sonographers, and students. Closer collaboration between organisations and individuals involved in sonographer education is needed to ensure students experiences are consistent, and opportunities for sharing and collaboration among educators are essential to build confidence and encourage innovation in teaching. Listening to and considering student feedback and engaging with clinical staff and students in the development of simulation learning, can improve student outcomes and engagement.

5.3. Limitations of the study

Constructivist grounded theory is a powerful tool which provides rich, detailed insights into participant experiences and perspectives. The flexibility of the methodology allows for the development of new insights, but the approach has some limitations. Symbolic interactionism, a key theoretical underpinning of constructivist grounded theory, emphasizes the subjectiveness of social reality (Blummer, 1969; Charmaz, 2014). This subjectivity introduces complexity and uncertainty which critics argue undermines the rigour of the research method.

Co-construction was an essential element of this research; however, it can introduce subjectivity and bias. Denscombe (2010) argued that the lack of objectivity in interpretivist research could lead to competing research outcomes form different researchers, each claiming that they have validity. Critics of interpretivism dislike the degree of uncertainty and open-endedness contained within explanations of the social world – the subjectivity of understanding how people construct their social world introduces complexity and uncertainty – this does not fit with traditional scientific approaches to research (Denscombe, 2010). In the view of critics, interpretivist research lacks rigour due to the lack of statistical analysis and the possibility of emergent research design, however Charmaz (2014) argues that good interpretivist research is systematic and rigorous in its approach to exploring social phenomena and is strengthened by using reflexivity.

Data analysis in constructivist GT is iterative, and since the analysis was limited to one researcher (with supervisory team oversight), this may influence the resulting theory (Birks et al., 2019). Member checking and supervisory oversight were employed throughout the research to enhance credibility and trustworthiness. Although participants did not make changes to the transcripts, their involvement demonstrated transparency in the research process. Peer feedback played an important role in the development of theory, initially through informal discussions, and formally through supervision processes and feedback following conference presentations. This provided opportunities for objective review and was an important process to inform theoretical sampling decisions. Although the researcher used theoretical sampling to ensure a diverse participant group, not all organisations involved in sonographer education participated, and this may have influenced the theory development. Future research should aim to include a broader range of organizations to enhance the representativeness and robustness of the developed theory.

The methodology is time-consuming and complex, and care was taken to ensure consistently throughout the research process. The COVID-19 pandemic impacted on student access to simulation learning, therefore the initially planned timescale of the data collection was adjusted. Following the initial stages of the pandemic there was an increased interest in simulation learning, which may have influenced participant responses.

Patient and public involvement is viewed as an essential part of health and social care research and has been shown to improve quality and impact (Health Research Authority, 2025; NIHR, 2025). The omission of “patient” voice in the participants was a conscious decision, as the “service user” in this educationally focused research was the student. Student participants reported few issues with gaining patient consent in practice, therefore patient voice was not sought during theoretical sampling. Qualitative research has been criticised for lack of justification of sample size decisions, but this is highly variable, depending on the topic under investigation, and the paradigm under which the research is being conducted (Boddy, 2016). Thompson (2011) reported that the average sample size in a constructivist grounded theory study was 25, but this can vary considerably depending on the complexity of the topic and when theoretical saturation is reached. Although a sample size of 21 in this study limits the generalizability of the findings, the research aimed to achieve theoretical saturation to ensure an in-depth understanding of the role of simulation in sonographer education. Theoretical saturation is a key concept, where the researcher focused more on participant position and professional experience, and perhaps more consideration of ethnic and cultural diversity might have been beneficial. Larger sample sizes across each group of participants may have yielded more varied results, however it was felt that it was more important to obtain views from a diverse range of participants, rather than focus solely on one group.

5.4. Contribution to knowledge

This research has provided valuable insights into the role of simulation in sonographer education, including barriers, limitations, opportunities, and challenges. While simulation has the potential to enhance learning experiences, effective implementation requires leadership, collaboration, and sufficient time, training, funding, and engagement.

The high level of specialist skills required by sonographers means clinical training is lengthy, and students highly value opportunities for well-designed and supported simulation learning. However, long-term pressures in practice negatively impact training capacity and experience. Effective use of simulation could improve learning experiences and serve as a useful tool throughout learning. National leadership and collaboration are required to establish consistent practice. If used effectively, simulation could improve training quality and increase training capacity.

Dissemination of the research findings at multiple local, national, and international conferences underscores the value and relevance to sonography education (See Appendix 3). These included proffered papers (Hynes, Nightingale & Collins, 2022; Hynes, Nightingale & Collins, 2024; Hynes, 2024a (June); Hynes, 2024b (Nov)), and two invited speaker presentations at British Medical Ultrasound Society Annual Scientific Meetings (Hynes, 2022; Hynes, 2024c). Following completion of this thesis, key findings will be submitted to a professional journal for wider publication.

5.5. Opportunities for future research

The role of simulation and immersive learning technologies cannot be ignored. HEE (2020) predicted that simulation will play a key role in underpinning both the patient safety strategy and syllabus for healthcare education. Simulation within sonographer education is in its infancy but already provides engaging learning opportunities which inform safe practice. Simulation is primarily used for developing psychomotor skills and familiarizing students with ultrasound images, yet could easily be used for developing communication skills, clinical decision-making, professional identity development and ensuring access to peer support and learning communities. Although initial indications are positive, further research into the wider use of simulation in sonographer education and further assessment of skill transferability are required.

Regular, dedicated time for teaching and learning is invaluable. The role of dedicated clinical educators with expertise in facilitation of clinical simulation appears beneficial, but the role requires further evaluation.

Addressing staff burnout and ensuring psychological safety for learners is crucial, and the potential role of simulation in facilitating professional identity development and assuring student psychological safety is recommended.

Consistent and high-quality simulation implementation requires prioritization by all relevant stakeholders. There is a need to explore the potential for simulation to be integrated into curricula at all levels and across all four pillars of advanced practice. Changes in career frameworks and educational routes may challenge existing practice structures, therefore further investigation is needed into the role simulation across all elements of the career framework for developing advanced and interventional skills for advanced practitioners. Educational provision needs to evolve to align with new frameworks and professional structures. National professional regulation could improve standardization in practice, but until this is a reality, review of current occupational standards and educational frameworks is needed to ensure they provide consistent and detailed guidance which adequately reflects technological advances and all levels of the sonographer career framework. Wider exploration is also needed to evaluate the effective use of simulation as an assessment tool, which is especially relevant to planned end point assessments in sonography apprenticeship provision.

To reach consensus on the essential elements of sonography education and effective use of simulation, a multi-professional Dephi study involving a wide range of stakeholders is required.

Chapter 6: Reflexivity

People inevitably make assumptions about reality which influence their views and actions; therefore, researchers are obliged to be reflexive about what they bring to the research, what they see, and how they see it, to avoid preconceptions of their data (Charmaz, 2014). This chapter is largely presented in the first person, as it is the researchers' personal account of their research journey.

6.1. Theory of reflexivity

Researchers must acknowledge that individuals have varied social views, emotions, and preferences, therefore there is no absolute truth and complete objectivity is not possible (Denscombe, 2010). Reflection allows researchers to gain insights about themselves and their research, but reflexivity goes beyond this through examination of the wider context, by questioning assumptions, and allowing researchers to examine their subjectivity and their role in the research process (Sirris, 2022). Reflexivity is an essential element of constructivist grounded theory to ensure that researchers are aware of how they interpret the world, and the impact of this knowledge on their actions and understanding (Charmaz, 2014). Reflexivity throughout my research process was critical, and any potential influences of the researcher were documented as part of the constant comparative process and throughout theory development (Charmaz, 2014).

Since researchers make assumptions about what is real, researcher influence on any qualitative study is inevitable (Denscombe, 2010), but reflexivity ensures critical awareness and transparency are maintained to ensure high quality research processes. Reflexivity forms an important element of qualitative research as it enables researchers to explore their beliefs, to question the obvious and take nothing for granted (Denscombe, 2010). Reflexivity is particularly important in constructivist grounded theory as it ensures exploration of researcher preconceptions, promotes honesty, and informs ethical processes in research practice (Charmaz, 2014). A grounded theory approach allowed for a fluid and interactive research process, where the researcher formed part of the study, rather than being an objective observer. Awareness and acknowledgement of my own positionality, preconceptions and potential biases were an essential element of the research process. The opportunity for co-construction was an appealing element of the methodology, but my previous professional experience and personal views were carefully examined to ensure the integrity of the research process. According to Charmaz (2014) researchers are part of what they study rather than separate from it, but there is an obligation to be reflexive about my own values and processes, and how this impacted on the research (Urquhart, 2023).

Being a reflexive researcher takes time, and the process can be difficult, as critical self-appraisal can be uncomfortable and reveal biases or preconceptions which may be emotionally challenging. Reflexivity can evoke feelings of discomfort, frustration, and vulnerability, especially in new researchers (Probst, 2015). Maintaining honest transparency about researchers' background, values, and beliefs, while also navigating the boundaries between personal and professional, was sometimes challenging. Keeping a research diary during the research process to record feelings and impressions during the research helped me to take a critical look at myself and allowed monitoring of stress levels during the research process (Corbin & Strauss, 2015). This allowed more self-awareness of assumptions, biases, and insight into behaviour (Corbin & Strauss, 2015). This was particularly important, given that the COVID-19 pandemic (which started in March 2020) had a significant impact on the researcher, participants, and the world during the data collection phases of this research.

6.2. Key reflections on the research journey

This study developed from my own interests and my master's dissertation, which raised more questions than answers about the effective use of simulation for sonographer education. As a health professional, I had spent many years following principles of research informed practice, yet as an educator I felt there was a lack of appropriate evidence to inform my teaching, particularly around the use of simulated learning for sonographer education.

6.2.1. Researcher background, biases, and assumptions

Qualitative researchers must consider how they are perceived by their participants, and the effects of personal characteristics and familiarity between researcher and participant (Britten, 2006). Having spent many years working as a radiographer, sonographer and lecturer in the UK, I was known to many of the participants, and although assurances were made as part of gaining consent, and care was taken to be aware of interviewer influence on responses.

My position and professional background inevitably influenced the collection and analysis of the data, which is why the co-construction typical of constructivist GT was felt to be the most appropriate method to employ. Others may look at the data and see things differently, but for me, the bracketing required in interpretive phenomenological analysis (IPA) was unachievable, and the opportunity to explore co-construction and to include my own voice in this research was important. From the early stages of the research, constructivist GT felt the best fit for my research aims, but the complexities of the method, and the varied approaches to grounded theory research were initially confusing.

There is a need to examine researcher influence on the data generated, since how participants identify the researcher influences their responses, and participants are likely to adhere to expected etiquette rules within their communities (Charmaz, 2014). The professional community in UK sonography is small, and my roles as a sonographer and educator were considered, as this may have introduced some bias and influenced the participant responses. However, I feel that my professional reputation had a positive influence on recruitment, with few invitations to participate being declined. This also helped to ensure that participants felt comfortable during interviews, as discussions were friendly, with a feeling of trust between myself and participants.

Individuals bring their own characteristics to their research, which are influenced by worldviews, assumptions and biases (Corbin & Strauss, 2015), and this can have a great impact on the research design and analysis. It is difficult to separate who we are as a person from the research and analysis that we do, therefore reflexivity is required to explore how researchers and the research process affect each other (Charmaz, 2014; Corbin & Strauss, 2015). It must be acknowledged that perception and meaning can change over time, and my world view and my ability to be reflexive has evolved during this PhD research.

6.2.2. A research diary

Researchers cannot realistically know the full extent of their biases, but they can Although reflexivity is an important tool for researcher self-awareness (Probst, 2013), as a novice researcher I found it difficult to objectively assess the adequacy of my own reflexivity during the research process. Imposterism and lack of confidence in myself were common feelings during this PhD journey.

A research diary helped to explore and document researcher thoughts and responses to events on the research journey. This was especially important during data collection and research to check meaning and acknowledge experiences, biases and decisions to limit their impact on the research process (Corbin & Strauss, 2015). Feeling overwhelmed, fatigued, and torn between multiple responsibilities is common on every PhD journey, and this can affect how the researcher responds to data, and a research journal is important in documenting this (Corbin & Strauss, 2015). During data collection, developing categories were reviewed for any signs of bias or assumptions, with regular review of the emerging theory by the project supervisors (Corbin & Strauss, 2015).

Cutcliffe (2003) argued that researchers can have difficulty in accounting for all levels of their consciousness, and the time and level of importance assigned to maintaining self-awareness varies between researchers. However, reflexivity is a valuable tool to allow examination of the impact, position and presence of the researcher and promote rich insight into personal responses and interpersonal dynamics (Corbin & Strauss, 2015). Corbin & Strauss (2015) describe research as a biographical journey, where researchers influence, and are influenced, by the process. In my own research, the use of a reflexive diary allowed exploration of thoughts and feelings, and how these might have influenced the decisions and analysis during the research process. Fear of making a mistake, and fear of not generating a theory which was "grounded" enough in the data were sometimes overwhelming. Particularly during the pandemic and lockdowns, elements of the researcher reflexive diary were dominated by negative emotions and a sense of hopelessness, with no obvious path forward with the work, and a sense of being lost. Once data collection resumed, there was a return of enthusiasm and motivation to continue with the work.

6.2.3. The interview process

Researchers and participants give meaning to events in light of their own experience according to gender, time, place, and cultural and professional backgrounds (Corbin & Strauss, 2015). There are many influences on interviews, including professional status, power dynamics, age, gender, participant experience, preconceptions, and impressions of the interviewer (Charmaz, 2014). Interviewers must acknowledge how their participants perceive them, as identities may influence the character and content of the interview (Charmaz, 2014). Power dynamics were a particularly important concept to consider during student interviews, and care was taken to ensure that participants were either from other institutions, or not part of the researcher's groups for teaching or assessment. Even if interviewers say very little, their body language, gaze, and murmured "*mmm*" or "*oh huh's*" can affect the flow of the discussion. Interviews should be conducted with skill and sensitivity (Charmaz, 2014), as a participant may wish to please the researcher by saying what they think the researcher wants to hear, so this can prove difficult for novice researchers (Britten, 2006).

For new researchers, one of the most difficult aspects of interviewing are periods of silence. I am aware of my own tendency to talk a lot and was conscious of resisting the urge to jump in with questions or comments during interviews and allowing the participants time to think about their responses. The need to allow silences should be balanced though, as some participants may be initially uncomfortable or shy, so asking a few questions or providing some sense of direction can build trust between the researcher and participant (Corbin & Strauss, 2015), but pauses are important to allow the participant time to think. As a naturally "chatty" person, I did make a conscious effort to facilitate discussion without leading, and to listen carefully without influencing responses in any way. In a few interviews, it was evident that participants were looking for agreement from me to validate their responses, and I was careful to maintain a neutral expression. To try to minimise potential bias, careful checking that participants had read information sheets, and encouragement to be honest alongside reassurances that there were no “correct” answers were a key part of the consent process. Some participants were reluctant to give what could be conceived as negative answers, and reassurance was provided during the interview to attempt to encourage honest answers.

Detailed interview field notes were taken following each interview, which highlighted instances of participant reactivity. Although participants usually do not mind being recorded, there may be occasions when some end of interview revelations provide greater insight. Occasionally, participants were conscious of being recorded, so opportunities to speak “off the record” were offered and sometimes resulted in deeper insights into participants’ views and experiences. On these occasions, detailed field notes were taken as soon as possible after the interview was completed (Corbin & Strauss, 2015) to ensure no data was lost.

In some qualitative research, questions are provided in advance of the interview, which can give participants time to consider their responses, and might lead to more detailed responses (Opdenakker, 2006). However, providing questions in advance can reduce the spontaneity of responses, and increases the time commitment required from participants. In this research, the interview schedule was not provided in advance, as it was important to facilitate open discussion of what was important to the participants (and to minimise the possibility of bias that a list of provided questions might have created).

A criticism of interviews is that they consist of retrospective narratives from participants which are their own subjective construction of reality, but it is still useful data, which should be approached reflexively by the researcher (Charmaz, 2014). The retrospective nature of interviews can mean that responses are influenced by time or personal bias, or narratives may be incomplete due to memory gaps or selective recall (this is particularly important when discussing sensitive or complex topics, which was not the case in this research).

The participants seemed keen to give the right answers to the questions - the status of the researcher and the professional relationship between interviewer and interviewee may influence the outcome of the interview. Participants sometimes were reluctant to speak negatively about the use of simulation, and one attended the interview with prepared notes and information, as if they were being tested, and “wanted to give the right answers”. Participant responses reflected each individual’s interpretation of events and context, which were constructed based on their own background, belief, and cultural influences. Pre-interview information to set the context of the research was important to encourage participants to share their individual honest views.

The research initially set out to examine views of educators and students, however during the constant comparison process, it became evident that this was not sufficient to gain a wider perspective. The flexible nature of CGT and theoretical sampling allowed me to explore a wider range of views through recruitment of stakeholders, which resulted in a much more comprehensive research outcome.

6.2.4. Analysis and generating theory

The volume of data generated was sometimes overwhelming, and final theory generation was time consuming and complex. The use of NVIVO software helped significantly with organising and managing the volume of data and ensured consistency with the processes of coding across all transcripts. Data visualisation tools within the software also helped to organise and prioritise different elements of the findings in the early stages of the analytical process. The large volume and varied content of the data set meant that I was sometimes overwhelmed when making comparisons, and sometimes became paralysed by indecision about the “right” thing to do. During the initial stages of writing, I focused solely on the participant voice and wanted to ensure their stories were obvious in the final work. However, inclusion of the researcher voice must also be incorporated into grounded theory studies, and reflexivity and supervisor support enabled me to become more confident in my choices and my own theory development as I got closer to the end of this work. Care was taken to ensure that I had reached saturation with the core categories, although it is acknowledged that further sampling may have added new concepts.

It was important to ensure that any theory emerged from the interview data, and guidance and discussion with supervisors during the analysis were essential. Presentation of early findings to peers, and conference presentations of findings from the first stages of the research helped to focus my analysis, provided fixed deadlines for completing phases of the research, and provided invaluable opportunities for discussion and informal feedback from peers. The process of analysis and theory development were significantly helped by a planned sabbatical from my usual duties as an educator – without this focused time for theory development, the research would have taken significantly longer, and is unlikely to have been such a clear and well-developed theory.

Individual researcher factors influence topic choice, approach to analysis and emphasis on results – another researcher could take the same data and generate a different theory, however this does not negate the validity of the theory, as it still provides insight and understanding into the research topic (Corbin & Strauss, 2015). Relevance refers to the importance of the theory in the real world (Charmaz, 2006), and a theory must hold importance for participants. Part of a PhD journey is to generate new knowledge and start to fill the "gap" in the literature. But for me, it was important that the findings of this study were relevant to real world educational practice for sonographer training, making recommendations which were clear and achievable in the real world.

6.2.5. COVID-19

Completing a part time PhD takes a long time, and it is impossible to ignore the impact of the COVID-19 pandemic on myself as an individual, and my research. Fear of the unknown, home-schooling two children, separation from wider family and social isolation during the pandemic had a lasting impact. Researchers have an ethical responsibility to self, participants, and their profession to produce the highest quality work possible, but researchers cannot achieve this when they are overwhelmed or too emotionally drained to think critically (Corbin & Strauss, 2015).

The research started in 2018, initially planned to be a mixed methods approach. At that time, I planned on using video conferencing for practical and financial reasons, although this was not a widely applied method in research data collection at that time. Since then, there has been a great change in the use and acceptability of videoconferencing applications for both teaching and research. The pandemic impacted on the data collected from the first student participants, and this phase was suspended until students were again engaging with on campus and "normal" clinical learning.

The impact of COVID-19 affected educational practice, and therefore the timing and duration of the data collection was impacted, and it was necessary to delay data collection with students until they regained normal access to their universities and clinical departments. Although this extended the overall duration of the data collection, this delay ensured a richer data set for analysis. A positive impact of the COVID-19 pandemic was the increased familiarity with online conferencing and recording, which simplified the recruitment and data collection phases of the research.

6.2.6. Research impact and value

A successful PhD candidate must prove that they have generated new knowledge. This was an intimidating concept, and I have had doubts along this journey that I would achieve this adequately. Now that I have reached the end of this journey and reflect on the various dissemination activities during the research, I feel reassured that there is genuine professional interest and relevance to my work. I have been successful in presenting proffered papers at local, national, and international conferences (See Appendix 3 for dissemination activities), and in addition to several proffered papers, I have been delighted to attend the Annual BMUS Conference as an invited speaker on two separate occasions during this research journey. These opportunities to disseminate findings have increased my confidence, but more importantly, they have provided invaluable opportunities for discussion with other professionals and provided insights into wider professional issues which have informed and challenged my own work.

6.3. Reflexivity Summary

On a personal level, this journey has been challenging in so many ways. Attempting a part-time PhD with a full-time job and a young family seemed initially ambitious, and at that time, if I had known about the pandemic, perhaps I would never have been brave enough to start. The pandemic had a significant impact on my personal and family life, and during this period was the only time during this journey when I felt I might need to withdraw from the programme. With the unwavering support of excellent supervisors, my husband, and my family, I am proud that I persevered.

Although I had realistic expectations about the challenges of completing a part time PhD, it was impossible to foresee the immense and long-lasting impact of COVID-19 on the world. There were times when the research lay ignored while I dealt with more urgent issues at home and at work. During the lockdowns I felt immensely guilty about my lack of progression and disinterest in the PhD work – but at that time, family, health and maintaining my own sanity had to take priority. Looking back, I did not give myself enough credit for what I did manage to achieve: my RF2 (progression review) was successfully completed virtually during the pandemic, and this was a key step in assuring me that I was doing the "right thing", helped to support key decisions about the work, and reassured me that I was making appropriate progress.

In retrospect, I sometimes prioritised more imminent deadlines over my research, particularly in the earlier stages, and I still have that feeling that I have not done "enough". Determination to succeed was accompanied by fear of failure and embarrassment if I was not successful in completing this PhD. The need to prioritise my own research and sometimes saying "no" to requests for help from others was challenging. During the final write up phase of the thesis, I struggled to be satisfied with the writing, but I have had to accept that there is no place for my perfectionist tendencies in the real world. I could keep writing and re-writing this work forever, but that is not practical. I have accepted that having realistic achievable recommendations for practice based on the data collected can be impactful, and that good qualitative research often raises more questions than answers.

I have learned so much and acquired so many new skills and a new way of thinking since the beginning of this PhD journey, which has been transformational for me as a person, educator, and researcher. On reflection, there is little I would change about the key elements of this research, however in the absence of a pandemic and the havoc that had on my world, perhaps in other circumstances I could have been more efficient and completed the work more quickly. The unwavering support of excellent supervisors, family, colleagues, and friends made it possible to continue when I doubted myself. At times, only fear of failure and the associated embarrassment were what pushed me to continue.

Reflecting on the highlights of this journey, I have developed a new way of thinking, so many new skills, better self-awareness, resilience, perseverance, and I have pushed myself beyond anything I have attempted before. Opportunities to disseminate findings at a variety of conferences allowed me to test theories and enabled me to discuss my progress with a variety of people. The greatest (and most unanticipated) benefit of this PhD was the expansion of my network of friends and colleagues through this research journey. As I move forward, I aspire to help others to grow their own research skills, and to support those undertaking their own research journeys.

Completing a PhD requires focus and some degree of selfishness, which did not come naturally and led to feelings of guilt about how my PhD work impacted family and colleagues. This PhD journey has been long and difficult, and I have probably experienced every possible emotion since I started, from elation, curiosity, pride, excitement, to doubt, confusion, anxiety, and exhaustion. I have learned from all these varied emotions and the highs and lows of being a part time PhD student with a full-time job and two young children.

The ambition to gain a PhD and the work involved has become an integral part of my identity, and I am now very uncertain about what should come next. According to Wolcott (1994), *'Qualitative studies do not have endings, only questions'*, so perhaps the completion of this thesis is more of a new beginning than an ending.

References

Ahmad, R., Alhashmi, G., Ajlan, A., & Eldeek, B. (2015). Impact of high-fidelity transvaginal ultrasound simulation for radiology on residents' performance and satisfaction. *Academic Radiology, 22*(2), 234–239. https://doi.org/10.1016/j.acra.2014.09.006

Ahn, & Davis. (2020). Four domains of students’ sense of belonging to university. *Studies in Higher Education, 45*(3), 622–634. https://doi.org/10.1080/03075079.2018.1564902

AIUM. (2015). *Training guidelines for physicians who evaluate and interpret diagnostic obstetric ultrasound examinations.* https://www.aium.org/resources/viewStatement.aspx?id=59.

Almansoof, A. S., Masuadi, E., Al-Muallem, A., & Agha, S. (2024). Prevalence of psychological distress among health sciences students: A systematic review and meta-analysis. *Quality & Quantity, 58*(4), 37-47. 10.1007/s11135-024-01829-6

Alasmari, N. J., & Althaqafi, A. S. A. (2021). Teachers’ practices of proactive and reactive classroom management strategies and the relationship to their self-efficacy. *Language Teaching Research,* https://doi.org/10.1177/13621688211046351

Alexander, L. F., McComb, B. L., Bowman, A. W., Bonnett, S. L., Ghazanfari, S. M., & Caserta, M. P. (2023). Ultrasound simulation training for radiology Residents—Curriculum design and implementation. *Journal of Ultrasound in Medicine, 42*(4), 755–764. https://doi.org/10.1002/jum.16098

Altmann, T. K. (2007). *An evaluation of the seminal work of Patricia Benner: Theory or philosophy?* Informa UK Limited. https://doi.org/10.5172/conu.2007.25.1-2.114

Anderson, L. W., Krathwohl, D. R., & Airasian, P. W. (2001). A taxonomy for learning, teaching, and assessing: A revision of bloom's taxonomy of educational objectives. In L. W. Anderson, & D. R. Krathwohl (Eds.), (1st ed.). Longman.

Appleyard, R. M., & Coleman, L. (2010). *Virtual environment for radio therapy training (VERT) final project report. Department of Health for England, Cancer Action team.* https://www.researchgate.net/publication/303327287_Virtual_environment_for_radio_therapy_training_VERT_final_project_report_Department_of_health_for_England_Cancer_action_team

ARDMS. (2012). *American registry for diagnostic medical sonography (ARDMS): Accreditation.* https://www.ardms.org/get-certified/rdms/.

ASAR. (2023). *Standards for the accreditation of sonographer courses.* https://www.asar.com.au/public/90/files/ASAR%20Standards%20for%20the%20Accreditation%20of%20Sonographer%20Courses.pdf

ASPiH. (2023). *The ASPiH standards 2023: Guiding simulation-based practice in health and care.* https://aspih.org.uk/wp-content/uploads/2023/11/ASPiH-Standards-2023-CDN-Final.pdf

Awan, O., Dey, C., Salts, H., Brian, J., Fotos, J., Royston, E., Braileanu, M., Ghobadi, E., Powell, J., Chung, C., & Auffermann, W. (2019). Making learning fun: Gaming in radiology education. *Academic Radiology, 26*(8), 1127–1136. https://doi.org/10.1016/j.acra.2019.02.020

Bächtold, M., Montpellier, U., Montpellier, & Bächtold, F. M. (2013). *What do students "construct" according to constructivism in science education?* Springer Science and Business Media LLC. https://doi.org/10.1007/s11165-013-9369-7

Baillie, L., & Curzio, J. (2009). Students' and facilitators' perceptions of simulation in practice learning. *Nurse Education in Practice, 8*(5), 297–306. https://www.sciencedirect.com/science/article/pii/S1471595308000966?casa_token=oSkCUIiUPXQAAAAA:e7R3HO6iI2IGXvnm_nKU7CPQwlYQkfVD7EtKQlXDHFbXQ8YF6miDln5rMLC2Tne2qKzfSEPEXg

Bains, H. Personal communication [*Sonography Workforce].* (May 18th, 2017).

Bajaj, K., Meguerdichian, M., Thoma, B., Huang, S., Eppich, W., & Cheng, A. (2018). The PEARLS healthcare debriefing tool. *Academic Medicine: Journal of the Association of American Medical Colleges, 93*(2), 336. https://doi.org/10.1097/ACM.0000000000002035

Baker, J. (2005). The History of Sonographers. *Journal of Ultrasound in Medicine., 24*, 1–14.

Balsyte, D., Schaffer, L., Burkhardt, J., Wisser, J., Zimmerman, R., & Kurmanavicius, J. (2010). Continuous independent quality control for fetal ultrasound biometry provided by the cumulative summation technique. *Ultrasound in Obstetrics & Gynecology, 35*, 449–455.

Barbaroux, P. (2022). Developing leadership skills through simulation-based training: A research framework and interpretive case study. *Management International, 26*(1), 192–208. https://id.erudit.org/iderudit/1088443ar

Barry, S. (2010, April). MedaPhor launches ultrasound training simulator. *Walesonline* http://www.walesonline.co.uk/news/business/business-news/medaphor-launches-ultrasound-training-simulator-1923924

Bearman, M., Nestel, D., & McNaughton, N. (2018). Chapter 2: Theories informing healthcare simulation practice - healthcare simulation education. In D. Nestel, M. Kelly, B. Jolly & M. Watson (Eds.), *Healthcare simulation education: Evidence, theory and practice*. Wiley Blackwell.

Becker, L. R., & Hermosura, B. A. (2019). Simulation education theory. In S. Deering, T. C. Auguste & D. Goffman (Eds.), *Comprehensive healthcare simulation: Obstetrics and Gynecology* (pp. 11–24). Springer International Publishing. https://doi.org/10.1007/978-3-319-98995-2_2

Benner, P. (1984). *From novice to expert: Excellence and power in clinical nursing practice*. Addison-Wesley.

Bergs, J., Lambrechts, F., Desmedt, M., Hellings, J., Schrooten, W., Vlayen, A., & Vandijck, D. (2018). Seen through the patients' eyes: Surgical safety and checklists. *International Journal for Quality in Health Care, 30*(2), 118–123. https://doi.org/10.1093/intqhc/mzx180

Bilyeu, McDevitt, & Judd. (2023). *A blended approach to developing psychomotor skills in novice learners in a doctor of physical therapy curriculum*. Informa UK Limited. https://doi.org/10.1080/0142159x.2023.2240001

Birks, M., Chapman, Y., & Francis, K. (2008). Memoing in qualitative research. *Journal of Research in Nursing, 13*(1), 68–75. https://doi.org/10.1177/1744987107081254

Birks, M., & Mills, J. (2015). *Grounded theory: A practical guide*. SAGE.

Blickendorf, J. M., Adkins, E. J., Boulger, C., & Bahner, D. P. (2014). Trained simulated ultrasound patients. *Journal of Ultrasound in Medicine, 33*(1), 35. https://doi.org/10.7863/ultra.33.1.35

Bloom, B. S. (1971). Mastery learning: Theory and practice (pp. 47–63). In J. H. Block (Ed.), *Mastery learning*. Holt, Rinehart and Winston.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* David McKay Company.

Blumer, H. (2001). *Symbolic interactionism: Perspective and method*. University of California Press.

BMUS. (2012). *Statement on the safe use, and potential hazards of diagnostic ultrasound.*

BMUS. (2022). Preceptorship and capability development framework for sonographers. https://www.bmus.org/media/resources/files/Preceptorship_and_Capability_Development_Framework_for_Sonographers.v5_A_vmkHHDn.pdf

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research, 19*(4), 436–432. https://doi.org/10.1108/QMR-06-2016-0053

Bolderston, Amanda, BSc, MSc, MRT(T), FCAMRT. (2012). Conducting a research interview. *Journal of Medical Imaging and Radiation Sciences, 43*(1), 66–76. https://doi.org/10.1016/j.jmir.2011.12.002

Bolton, G. C. (2023). *Ideological dilemmas and work-related musculoskeletal disorders in ultrasound practice: An interpretive phenomenological analysis of the lived experiences of sonographers* (Doctoral Thesis).

Booth, L., & Brown, P. (2011). Chapter 6: Research governance and ethics. In A. Ramlaul (Ed.), *Medical imaging and radiotherapy research: Skills and strategies.* (pp. 53 – 64). Churchill Livingstone.

Bouleon, C., Mattatia, L., Minehard, R. D., Rudolph, J. W., Lois, F. J., Guillouet, E., Philippon, A., Brissaud, O., Lefevre-Scelles, A., Benhamou, D., Lemonte, F., Bellot, A., Cruble, I., Philippot, G., Vanderlinden, T., Batrancourt, S., Boithias-Guerot, C., Breaud, J., de Vries, P., . . . Chabot, J. (2022). Simulation-based summative assessment in healthcare: An overview of key principles for practice. *Advances in Simulation,* https://advancesinsimulation.biomedcentral.com/articles/10.1186/s41077-022-00238-9

Bowler, F., Klein, M., & Wilford, A. (2021). Healthcare simulation standards of best Practice: professional integrity. *Clinical Simulation in Nursing, 58*, 45–48. https://doi.org/10.1016/j.ecns.2021.08.014

Bowman, Reid, Bobby Harreveld, & Lawson. (2022). Evaluation of post-simulation sonographer students' professional behaviour in the workplace. *Radiography, 28*(4), 889-896. https://doi.org/10.1016/j.radi.2022.06.010

Bradley, K., Quinton, A., & Aziz, A. (2019). *Determining if simulation is effective for training in ultrasound: A narrative review*. Wiley. https://doi.org/10.1002/sono.12208

Bradley, P. (2006). The history of simulation in medical education and possible future directions. *Medical Education, 40*(3), 254–262. https://doi.org/10.1111/j.1365-2929.2006.02394.x

Braun, V., & Clarke, V. (2022). *Thematic analysis: A practical guide*. SAGE.

Brennan, B. A. (2021). Prebriefing in healthcare simulation: A concept analysis. *Clinical Simulation in Nursing, 56*, 155–162. https://doi.org/10.1016/j.ecns.2021.04.015

Bridge, Gunn, Kastanis, Pack, Rowntree, Starkey, Mahoney, Berry, Braithwaite, & Wilson-Stewart. (2014). The development and evaluation of a medical imaging training immersive environment. *Journal of Medical Radiation Sciences, 61*(3), 159–165. https://doi.org/10.1002/jmrs.60

Britten, N. (2006). Chapter 2: Qualitative interviews. In C. Pope, & N. Mays (Eds.), *Qualitative research in health care, 3rd edition*. Blackwell Publishing Ltd.

Brown, D., & Chronister, C. (2009). The effect of simulation learning on critical thinking and self-confidence when incorporated into an electrocardiogram nursing course. *Clinical Simulation in Nursing, 5*, e45–e52.

Brown, D., & Chronister, C. (2009). The effect of simulation learning on critical thinking and self-confidence when incorporated into an electrocardiogram nursing course. *Clinical Simulation in Nursing, 5*(1), e45–e52. https://doi.org/10.1016/j.ecns.2008.11.001

Bryant, A., & Charmaz, K. (Eds.). (2019). *The SAGE handbook of current developments in grounded theory*. SAGE Publications Ltd. https://doi.org/10.4135/9781526485656

Burden, C., Preshaw, J., White, P., Draycott, T. J., Grant, S., & Fox, R. (2013). Usability of virtual-reality simulation training in obstetric ultrasonography: A prospective cohort study. *Ultrasound in Obstetrics and Gynecology, 42*(2), 213–217. https://doi.org/10.1002/uog.12394

Byford, S., Janssens, S., & Cook, R. (2021). Implementing the transvaginal ultrasound simulation training (TRUSST) programme for obstetric registrars. *Advances in Simulation, 6*(1) https://doi.org/10.1186/s41077-020-00152-y

Capper, T., Muurlink, O., & Williamson, M. (2021). Social culture and the bullying of midwifery students whilst on clinical placement: A qualitative descriptive exploration. *Nurse Education in Practice, 52*, 103045. https://doi.org/10.1016/j.nepr.2021.103045

Carolan-Rees, G., & Ray, A. F. (2015). The ScanTrainer obstetrics and gynaecology ultrasound virtual reality training simulator: A cost model to determine the cost viability of replacing clinical training with simulation training. *Ultrasound: Journal of the British Medical Ultrasound Society, 23*(2), 110–115. https://doi.org/10.1177/1742271X14567498

CASE. (2017). *CASE course directory 2017-18.* case-uk.org/course-directory/, from https://www.case-uk.org/course-directory/

CASE. (2018, November). CASE November Newsletter 2018.

CASE. (2019). *CASE - standards for sonographic education.* Retrieved October 15, 2019, from http://www.case-uk.org/information/publications/

CASE. (2022). *Standards for sonographic education November 2022 CASE standards for sonographic education.*

Centre for Workforce Intelligence. (2017). Securing the future sonography workforce: Sonography workforce review. *32*(1), 25–37. https://doi.org/10.1016/j.bpa.2018.04.002

Chaer, DeRubertis, Lin, Bush, Karwowski, Birk, Morrissey, Faries, McKinsey, & Kent. (2006). Simulation improves resident performance in catheter-based intervention. *Annals of Surgery, 244*(3), 343–352. https://doi.org/10.1097/01.sla.0000234932.88487.75

Chalouhi, G. E. (2015). Comment: Re: Sustained effect of simulation-based ultrasound training on clinical performance: A randomized trial. M. G. Tolsgaard, C. Ringsted, E. Dreisler, L. N. Nørgaard, J. H. Petersen, M. E. Madsen, N. L. C. Freiesleben, J. L. Sørensen and A. Tabor. Ultrasound in Obstetrics and Gynecology. 2015; 46: 312-318. *Ultrasound in Obstetrics and Gynecology, 46*(3), 264–265. https://doi.org/10.1002/uog.15659

Chalouhi, G. E., Bernardi, V., Gueneuc, A., Houssin, I., Stirnemann, J. J., & Ville, Y. (2016). Evaluation of trainees' ability to perform obstetrical ultrasound using simulation: Challenges and opportunities. *American Journal of Obstetrics and Gynecology, 214*(4), 525.e–525.e8. https://doi.org/10.1016/j.ajog.2015.10.932

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis.* Sage.

Charmaz, K. (2008). The legacy of Anselm Strauss in constructivist grounded theory. *Studies in Symbolic Interaction.,* (32), 127–141.

Charmaz, K. (1995). Chapter 3: Grounded theory. In J. A. Smith, R. Harre & L. V. Van Langenhove (Eds.), *Rethinking methods in psychology* (pp. 27–49). SAGE Publications. https://doi.org/10.4135/9781446221792.n3

Charmaz, K. (2014). *Constructing grounded theory* (2nd ed.). SAGE Publications.

Charnetski, M., & Jarvill, M. (2021). Healthcare simulation standards of best Practice operations. *Clinical Simulation in Nursing, 58*, 33–39. https://doi.org/10.1016/j.ecns.2021.08.012

Cheng, A., Eppich, W., Grant, V., Sherbino, J., Zendejas, B., & Cook, D. A. (2014). Debriefing for technology-enhanced simulation: A systematic review and meta-analysis. *Medical Education, 48*(7), 657–666. https://doi.org/10.1111/medu.12432

Chernikova, O., Heitzmann, N., Stadler, M., Holzberger, D., Seidel, T., & Fischer, F. (2020). Simulation-based learning in higher education: A meta-analysis. *Review of Educational Research, 90*(4), 499–541. https://doi.org/10.3102/0034654320933544

Chick, N. (2019). *Learning styles*. Retrieved 16/10/2024, from: https://cft.vanderbilt.edu/guides-sub-pages/learning-styles-preferences/

Clark, A. E. (2007). Grounded theory: Conflicts, debates and situational analysis. In W. Outhwaite, & S. P. Turner (Eds.), *Handbook of social science methodology* (pp. 838 – 885). SAGE.

Clarke, A. (2005). *Situational Analysis—Grounded theory after the postmodern turn.* SAGE Publications.

Clarke, A. E. (2019). Situating grounded theory and situational analysis in interpretive qualitative inquiry. In A. Bryant, & K. Charmaz (Eds.), *The SAGE handbook of current developments in grounded theory* (pp. 3–48). SAGE Publications Ltd.

Codd, L., Ramlaul, A., & Trivedi, D. (2024). "I used their criticisms as my weapon to succeed" experiences in the dual learning environment of black, asian, and ethnically diverse therapeutic radiographer undergraduate students - results of a UK survey. *Radiography (London, England), 30 Suppl 2*, 131–137. https://doi.org/10.1016/j.radi.2024.10.026

Cohen, C., Childs, J., & Maranna, S. (2020). Behind closed doors: Are sonographers coping? A literature review of sonographer burnout. *Sonography, 8*(1), 3. https://doi.org/10.1002/sono.12243

College of Radiographers. (2021). *Diagnostic radiography workforce 2021 UK census.*

College of Radiographers. (2022). *Education and career framework for the radiography workforce (4th edition).* . https://www.sor.org/getmedia/b2f6bf07-668f-4155-950a-b9d96c48eae1/12604-CoR-ECF-Interactive-v9a

Corbin, J. M., & Strauss, A. L. (2015). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (4th ed.). SAGE Publications.

Cornford. (1999). *Rediscovering the importance of learning and curriculum in vocational education and training in Australia*. Informa UK Limited. https://doi.org/10.1080/13636829900200072

Corti, L., Van den Eynden, V., Bisshop, L., & Woollard, M. (2014). *Managing and sharing research data: A guide to good practice.* SAGE Publications Ltd.

Cresswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications Inc.

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

Creswell, J. W., (2007). *Qualitative inquiry & research design: Choosing among five approaches*. SAGE.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. SAGE Publications Ltd.

Cruess, S. R., Cruess, R. L., & Steinert, Y. (2019). Supporting the development of a professional identity: General principles. *Medical Teacher.* https://doi.org/10.1080/0142159X.2018.1536260

Cutcliffe, J. R. (2003). Reconsidering reflexivity: Introducing the case for intellectual entrepreneurship. *Qualitative Health Research, 1*(13), 136–48.

D.Abate, F., & La Leggia, A. (2017). Professional standards the role of sonographers: Future professionals across Europe? https://healthcare-in-europe.com/en/news/the-role-of-sonographers-future-professionals-across-europe.html

Dace, W., Purdy, E., & Brazil, V. (2022). *Wearing hats and blending boundaries: Harmonising professional identities for clinician simulation educators*. Springer Science and Business Media LLC. https://doi.org/10.1186/s41077-022-00229-w

Dalwood, N., Bowles, K., Williams, C., Morgan, P., Pritchard, S., & Blackstock, F. (2020). Students as patients: A systematic review of peer simulation in health care professional education. *Medical Education, 54*(5), 377–488. https://doi.org/10.1111/medu.14058

Darzi, A. (2024). *Independent investigation of the National Health Service in England*. Department of Health and Social Care.

https://assets.publishing.service.gov.uk/media/66f42ae630536cb92748271f/Lord-Darzi-Independent-Investigation-of-the-National-Health-Service-in-England-Updated-25-September.pdf

Datta, R., Upadhyay, K. K., & Jaideep, C. N. (2012). *Simulation and its role in medical education*. https://doi.org/10.1016/S0377-1237(12)60040-9

Dave, R. H. (1970). Developing and writing behavioural objectives. In R. J. e. a. Armstrong (Ed.),. Educational Innovators Press.

DeBenedectis, C. M., Gauguet, J., Makris, J., Brown, S. D., & Rosen, M. P. (2017). Coming out of the dark: A curriculum for teaching and evaluating radiology residents' communication skills through simulation. *Journal of the American College of Radiology: JACR, 14*(1), 87–91. https://doi.org/10.1016/j.jacr.2016.09.036

Decker, S., Alinier, G., Crawford, S. B., Gordon, R. M., Jenkins, D., & Wilson, C. (2021). Healthcare simulation standards of best Practice: the debriefing process. *Clinical Simulation in Nursing, 58*, 27–32. https://doi.org/10.1016/j.ecns.2021.08.011

Dellatola, E., Daradoumis, R., & Dimitriadis, Y. (2020). Exploring students' engagement within a collaborative inquiry-based language learning activity in a blended environment. In S. Yu, M. Ally & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum bridging human and machine: Future education with intelligence.* (pp. 355–375). Springer.

Denscombe, M. (2010). *Ground rules for social research: Guidelines for good practice* (2nd ed. ed.). McGraw-Hill/Open University Press.

Department of Health. (2011a). *A framework for technology enhanced learning*. Retrieved from: https://assets.publishing.service.gov.uk/media/5a7cbdc940f0b6629523b843/dh_131061.pdf

Department of Health. (2011b). *Enabling excellence autonomy and accountability for healthcare workers, social workers and social care workers.* https://assets.publishing.service.gov.uk/media/5a7c104240f0b63f7572b1e1/dh_124374.pdf

DePoy, E., & Gitlin, L. N. (2005). *Introduction to research: Understanding and applying multiple strategies.* (3rd ed.). Elsevier Mosby.

Dickson, D. M., & Kay, M. (2024). Postgraduate medical ultrasound learner and practice educator perceptions and experiences of academy model clinical ultrasound training in Scotland. *Radiography, 30*, S26–S33. https://doi.org/10.1016/j.radi.2024.09.056

Dietrich, Lucius, Nielsen, Burmester, Westerway, Chu, Condous, Cui, Dong, Harrison, Koch, Kraus, Nolsøe, Nayahangan, Pedersen, Saftoiu, Savitsky, & Blaivas. (2022). The ultrasound use of simulators, current view, and perspectives: Requirements and technical aspects (WFUMB state of the art paper). *Endoscopic Ultrasound, 12*(1), 38–49. https://doi.org/10.4103/EUS-D-22-00197

DoH. (2012). *Liberating the NHS: Developing the healthcare workforce, from design to delivery*. www.gov.uk/government/uploads/system/uploads/attachment_data/file/216421/dh_132087.pdf

Donaldson, L. (2009). *150 years of the annual report of the chief medical officer: On the state of the public health.* London: Department of Health. https://www.researchgate.net/publication/319998672_On_the_state_of_public_health_Annual_report_of_the_Chief_Medical_Officer_2008

Dromey, B. P., Peebles, D. M., & Stoyanov, D. V. (2021). A systematic review and meta-analysis of the use of high-fidelity simulation in obstetric ultrasound. *Simulation in Healthcare, 16*(1), 52. https://doi.org/10.1097/SIH.0000000000000485

Duke, & Madsen. (1991). Proactive versus reactive teaching: Focusing observation on specific aspects of instruction. *Bulletin of the Council for Research in Music Education,* (108), 1–14. https://www.jstor.org/stable/40318434

Dunleavy, Nikolaou, Nifakos, Atun, Law, & Tudor Car. (2019). *Mobile digital education for health professions: Systematic review and meta-analysis by the digital health education collaboration*. JMIR Publications Inc. https://doi.org/10.2196/12937

Edmondson, A. C. (2018). *The fearless organization: Creating psychological safety in the workplace for learning, innovation, and growth.* John Wiley & Sons, 2018.

EFSUBM. (2009). *Minimum training requirements for the practice of medical ultrasound in Europe*

England, A. (2018). Clinical simulation in radiography education. *OPTIMAX 2018: A Focus on Education in Radiology,* https://www.researchgate.net/publication/331994287_O_P_TI_M_A_X_2_0_18_a_focus_on_Education_in_Radiology#fullTextFileContent

Ennin, C. S., & Satin, A. J. (2010). Training and assessment in obstetrics: The role of simulation. *Best Practice and Research in Clinical Obstetrics and Gynaecology,* (24), 747–758.

Eppich, W., & Cheng, A. (2015). Promoting excellence and reflective learning in simulation (PEARLS): Development and rationale for a blended approach to health care simulation debriefing. *Simulation in Healthcare: Journal of the Society for Simulation in Healthcare, 10*(2), 106–115. https://doi.org/10.1097/SIH.0000000000000072

Etherington, K. (2004). *Becoming a reflexive researcher: Using ourselves in research*. Jessica Kingsley Publishers.

Farmer, D. L. (2015). Soft skills matter. *JAMA Surgery, 150*(3), 207. https://doi.org/10.1001/jamasurg.2014.2250

Federmeier, K. D. (2019). *The psychology of learning and motivation* (First edition ed.). Academic Press.

Feldman, Edwards, Wong, Randolph, Woleben, Nguyen, & Grossman. (2021). The role for simulation in professional identity formation in medical students. *Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare, 17*(1), e8. https://doi.org/10.1097/sih.0000000000000583

Ferris, & Aziz. *A psychomotor skills extension to Bloom's taxonomy of education objectives for engineering education. Proceedings of iNEER Conference for Engineering Education and Research, Tainan, Taiwan, 1-5 March.*

Few, S. (2014). Chapter 35: Data visualization for human perception. In Interaction Design Foundation (Ed.), *The encyclopedia of human-computer interaction, 2nd ed.*

Finlay, L., & Ballinger, C. (2006). *Qualitative research for allied health professionals challenging choices*. John Wiley.

Foley. (2021). Video-based online interviews for palliative care research: A new normal in COVID-19? *Palliative Medicine, 35*(3), 625–626. https://doi.org/10.1177/0269216321989571

Francis, R. (2013). *Report of the mid-Staffordshire NHS foundation trust public inquiry.* https://assets.publishing.service.gov.uk/media/5a7ba0faed915d13110607c8/0947.pdf

Gaba, D. M. (2004). The future vision of simulation in health care. *BMJ Quality & Safety,* (13), i2–i10.

Gabor, P., Dimassi, K., Aabakke, A., Rouveau, R., & Ami, O. (2017). Ultrasound training of trainees in obstetrics and gynaecology in europe: Satisfaction survey. *Ultrasound in Obstetrics and Gynaecology, 51*(4)

Gallagher, P., Smith, R., & Sheppard, G. (2020). Use of three-dimensional printing for simulation in ultrasound education: A scoping review. *BMJ Simulation and Technology Enhanced Learning,* *https://doi.org/*10.1136/bmjstel-2020-000663

Garrett, T. (2014). *Effective classroom management: The essentials*. Teachers College Press.

Gibbs, V. (2015). The role of ultrasound simulators in education: An investigation into sonography student experiences and clinical mentor perceptions. *Ultrasound, 23*, 204–211.

Gibbs, V., & Griffiths, M. (2013). Funding and commissioning issues for undergraduate and postgraduate healthcare education from 2013. *Imaging and Oncology,* , 56–61. http://www.sor.org/system/files/article/201305/I%26O%202013.pdf

Gibbs, V. (2013). The long and winding road to professional registration for sonographers. *Radiography, 19*(2), 164– 167. https://www.radiographyonline.com/article/S1078-8174(12)00100-9/abstract

Gibbs, V. (2014). An investigation into sonography student experiences of simulation teaching and learning in the acquisition of clinical skills. *Ultrasound, 22*(3), 173–178. https://doi.org/10.1177/1742271X14528491

Gibbs, V. (2015). The role of ultrasound simulators in education: An investigation into sonography student experiences and clinical mentor perceptions. *Ultrasound, 23*(4), 204–211. https://doi.org/10.1177/1742271X15604665

Gibbs, V., Cole, D., & Sassano, A. (2009). *Ultrasound physics and technology: How, why and when* (1st ed.). Churchill Livingstone.

Gibson, B., & Hartman, J. (2014). *Rediscovering grounded theory*. SAGE Publications Ltd.

Glaser, B. G. (1992). *Basics of grounded theory analysis.* Sociology Press.

Glaser, B. G. (2002). *Theoretical sensitivity: Advances in the methodology of grounded theory*. Sociology Press.

Glaser, B. G., & Strauss, A. L. (2003). *The discovery of grounded theory strategies for qualitative research*. Aldine de Gruyter.

Gomm, R. (2008). *Social research methodology: A critical introduction.* (2nd ed.). Palgrave Macmillan.

Graham. (2017). Introduction: Data visualisation and the humanities. *English Studies, 98*(5), 449–458. https://doi.org/10.1080/0013838X.2017.1332021

Grant, & Booth. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information &Amp; Libraries Journal, 26*(2), 91. 10.1111 https://doi.org//j.1471-1842.2009.00848.x

Grantcharov, T. P., & Reznick, R. K. (2008). Teaching procedural skills. *BMJ, 336*(7653), 1129–1131. https://doi.org/10.1136/bmj.39517.686956.47

Gravett, K., & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education, 47*(7), 1386–1396. https://doi.org/10.1080/03075079.2021.1894118

Green, J., & Thorogood, N. (2014). *Qualitative methods for health research.* (3rd ed.). Sage.

Greenhalgh, T., Annandale, E., Ashcroft, R., Barlow, J., Black, N., Bleakley, A., Boaden, R., Braithwaite, J., Britten, N., Carnevale, F., Checkland, K., Cheek, J., Clark, A., Cohn, S., Coulehan, J., Crabtree, B., Cummins, S., Davidoff, F., Davies, H., . . . Ziebland, S. (2016). An open letter to The BMJ editors on qualitative research. *BMJ (Online),* , i563. https://doi.org/10.1136/bmj.i563

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods, 1*, 59–82.

Guo, L., Fan, H., Xu, Z., Li, J., Chen, T., Zhang, Z., & Yang, K. (2021). Prevalence and changes in depressive symptoms among postgraduate students: A systematic review and meta-analysis from 1980 to 2020. *Stress and Health, 37*(5), 833–1051. Wiley. https://doi.org/10.1002/smi.3045

Hagen-Ansert, & Billick. (2023). The challenges of educating a cardiac sonography workforce. *Journal of Diagnostic Medical Sonography, 39*(4), 414. https://doi.org/10.1177/87564793231168776

Hale, A. J., Ricotta, D. N., Freed, J., Smith, C. C., & Huang, G. C. (2018). Adapting Maslow's hierarchy of needs as a framework for resident wellness. *Teaching and Learning in Medicine, 31*(1), 109. https://doi.org/10.1080/10401334.2018.1456928

Hallmark, B., Brown, M., Peterson, D. T., Fey, M., Decker, S., Wells-Beede, E., Britt, T., Hardie, L., Shum, C., Arantes, H. P., Charnetski, M., & Morse, C. (2021). Healthcare simulation standards of best Practice: professional development. *Clinical Simulation in Nursing, 58*, 5–8. https://doi.org/10.1016/j.ecns.2021.08.007

Hamstra, S., Brydges, R., Hatala, R., Zendejas, B., & Cook, D. (2014). Reconsidering fidelity in simulation-based training. *Academic Medicine, 89*(3), 387–392. https://doi.org/10.1097/ACM.0000000000000130

Hani, S., Chalouhi, G., Lakissian, Z., & Sharara-Chami, R. (2019). Introduction of ultrasound simulation in medical education: Exploratory study. *JMIR Medical Education, 5*(2), e13568. https://doi.org/10.2196/13568

Hannides, M., Tariq, R., Holland, M., & Nomikos, P. A. (2024). An exploration of student perception toward interprofessional high-fidelity clinical simulation. *Journal of Medical Education and Curricular Development, 11*https://doi.org/10.1177/23821205241249594

Hansen, Pape, Thiesen, & Jakobsen. (2020). Interprofessional versus uniprofessional dyad learning for medical students in a clinical setting. *International Journal of Medical Education, 11*, 191. https://doi.org/10.5116/ijme.5f50.bc76

Harder, N., B. (2009). Evolution of simulation use in health care education. *Clinical Simulation in Nursing,* (5), e169–e172.

Hardicre, Arezina, Mcguinness, & Johnson. (2020). Managing the unmanageable: A qualitative study exploring sonographer experiences of and training in unexpected and difficult news delivery. *Radiography, 27*(2), 369. https://doi.org/10.1016/j.radi.2020.09.015

Hardie, P., O'Donovan, R., Jarvis, S., & Redmond, C. (2022). Key tips to providing a psychologically safe learning environment in the clinical setting. *BMC Medical Education, 22*(1), https://doi.org/10.1186/s12909-022-03892-9

Harrison, G., & Beardmore, C. (2020). Ultrasound clinical teaching capacity in England: A scoping exercise. *Radiography, 26*(1), 3–8. https://doi.org/10.1016/j.radi.2019.09.005

Harrison, G. (2018). *How to become a Sonographer.* Retrieved Oct 17, 2019, from https://www.sor.org/ezines/studenttalk/issue-127/how-become-sonographer

Harrow, A. J. (1972). *A taxonomy of the psychomotor domain: A guide for developing behavioral objectives.* David McKay Co.

Hart, A., & Dixon, A. M. (2008). Sonographer role extension and career development; a review of the evidence. *Ultrasound,* (1), 31–35.

HCPC. (2017). *HCPC standards of education and training.* Retrieved Feb 14, 2024, from https://www.hcpc-uk.org/standards/standards-relevant-to-education-and-training/set/

Health Education England. (2012). *A framework for technology enhanced learning* . Retrieved from: https://assets.publishing.service.gov.uk/media/5a7cbdc940f0b6629523b843/dh_131061.pdf

Health Education England. (2017). *National review of radiology academies*. https://www.hee.nhs.uk/sites/default/files/documents/Review%20of%20radiology%20academies%20-%20summary%20FINAL.pdf

Health Education England. (2018). *Sonography.* Health Education England. Retrieved Oct 18, 2019, from https://www.hee.nhs.uk/our-work/sonography

Health Education England. (2019). *Sonographer career progression and framework.*

Health Education England. (2020). *Enhancing education, clinical practice and staff wellbeing. A national vision for the role of simulation and immersive learning technologies in health and care technology enhanced learning TEL.* https://www.hee.nhs.uk/sites/default/files/documents/National%20Strategic%20Vision%20of%20Sim%20in%20Health%20and%20Care.pdf

Health Education England. (2022, June). *Sonographer career and progression framework V2 (June 2022).* Retrieved Oct 10, 2023, from https://www.hee.nhs.uk/sites/default/files/documents/Sonographer%20Career%20Framework%20-%20V2%20June%202022.pdf

Health Education England. (2023). *Educator workforce strategy.* Health Education England.

Health Research Authority. (2025). *HRA approval.* Retrieved Mar 2, 2025, from https://www.hra.nhs.uk/approvals-amendments/what-approvals-do-i-need/hra-approval/

Heath, H., & Cowley, S. (2004). Developing a grounded theory approach: A comparison of Glaser and Strauss. *International Journal of Nursing Studies, 41*(2), 131–150. https://doi.org/10.1016/S0020-7489(03)00113-5

Heath, H., & Cowley, S. (2004). Developing a grounded theory approach: A comparison of Glaser and Strauss. *International Journal of Nursing Studies, 41*(2), 141–150. 10.1016/S0020-7489(03)00113-5

HEE. (2011). *Guidelines for commissioning technology enhanced learning in the NHS*. https://www.hee.nhs.uk/sites/default/files/documents/Guidelines%20for%20commissioning%20technology%20enhanced%20learning%20in%20the%20NHS.pdf

HEE. (2020). *Enhancing education, clinical practice and staff wellbeing. A national vision for the role of simulation and immersive learning technologies in health and care technology enhanced learning TEL).* https://www.hee.nhs.uk/sites/default/files/documents/National%20Strategic%20Vision%20of%20Sim%20in%20Health%20and%20Care.pdf

HEE. (2024). *Imaging training academies.* Retrieved Feb 22, 2025, from https://www.hee.nhs.uk/our-work/cancer-diagnostics/training-academies/imaging-training-academies

Heitzmann, N., Seidel, T., Opitz, A., Hetmanek, A., Wecker, C., Fischer, M., Schmidmaier, R., Neuhaus, B., Seibeck, M., & Sturmer, K. (2019). Facilitating diagnostic competences in simulations: A conceptual framework and a research agenda for medical and teacher education. *Frontline Learning Research,* https://files.eric.ed.gov/fulltext/EJ1232563.pdf

Hennink, M. M., Kaiser, B. N., & Marconi, V. C. (2017). Code saturation versus meaning saturation: How many interviews are enough? *Qualitative Health Research, 27*(4), 591–608. https://doi.org/10.1177/1049732316665344

Hill, S., & White, A. (2023). Making the transition from student to newly qualified vascular sonographer: An exploration of the domains of professionalism. *Ultrasound, 31*(2), 104–110. https://doi.org/10.1177/1742271X221131479

Hodson, R. (2019). Professional identity formation in medical education: A conceptual framework. *Journal of Medical Education and Curricular Development., 6*, 1–10.

Holden, M., Buck, E., Clark, M., Szauter, K., & Trumble, J. (2012). Professional identity formation in medical education: The convergence of multiple domains. *HEC Forum, 24*(4), 245–255. https://doi.org/10.1007/s10730-012-9197-6

Holloway, I., & Todres, L. (2003). The status of method: Flexibility, consistency and coherence. *Qualitative Research : QR, 3*(3), 345–357. https://doi.org/10.1177/1468794103033004

Holt, P. J. (2024). *Simulated practice learning in preregistration nursing programmes an evaluation of the experience of universities approved to deliver up to 600 practice learning hours through simulation.* https://www.nmc.org.uk/globalassets/sitedocuments/simulated-practice-learning/reports/2024/evaluation-of-simulated-practice-learning-in-pre-registration-nursing-programmes.pdf

Hood, J. C. (2007). Orthodoxy vs. power: The defining traits of grounded theory. In K. Charmaz, & A. Bryant (Eds.), *The sage handbook of grounded theory* (pp. 151–164). SAGE Publications, Limited. https://doi.org/10.4135/9781848607941.n7

Hynes, C. M. (2016). *Perceptions of the use of simulation in ultrasound education.*

Hynes, C. M., & Hood, M. (2024). Medical ultrasound degree apprenticeships – a new route to sonography. Paper presented at the *UK Imaging and Oncology Conference,*

INACSL Standards Committee. (2016). INACSL standards of best practice: Simulation debriefing. *Clinical Simulation in Nursing, 12*, S21–S25. https://www.nursingsimulation.org/action/showPdf?pii=S1876-1399%2816%2930129-3

INACSL Standards Committee. (2021). Healthcare simulation standards of best practice: The debriefing process. *INACSL Standards Committee, Sharon Decker, PhD, RN, FSSH, ANEF, FAAN, Guillaume Alinier,, NTF, Scott B. Crawford, , Randy M. Gordon, , Deborah Jenkins, , Cheryl Wilson, 58*, 27–32. Elsevier

INASCL Standards Committee. (2021). Healthcare simulation standards of best Practice TM. *Clinical Simulation in Nursing, 58*, 66. https://doi.org/10.1016/j.ecns.2021.08.018

INACSL Standards Committee, Penni I. Watts, PhD, RN, CHSE-A, Donna S. McDermott, PhD, RN, CHSE, Guillaume Alinier, PhD, MPhys, PgCert, SFHEA, NTF, Matthew Charnetski, MS, NRP, CHSOS, CHSE, Jocelyn Ludlow, PhD, RN, CHSE, CNE, CMSRN, Elizabeth Horsley, RN, MSMS, CHSE, Colleen Meakim, MSN, RN, CHSE-A, ANEF, Pooja A. Nawathe, MD, FAAP, FCCM, CHSE-A, CHSOS. (2021). Healthcare simulation standards of best practice simulation design. *Clinical Simulation in Nursing, 58*, 14–21.

INACSL Standards Committee, Persico, L., Belle, A., DiGregorio, H., Wilson-Keates, B., & Shelton, C. (2021). Healthcare simulation standards of best practice: Facilitation clinical simulation.*58*, 22–26. https://doi.org/10.1016/j.ecns.2021.08.010

Institute for Apprenticeships. (2019). *End-point assessment plan for sonographer (integrated degree) apprenticeship standard.*

Institute for Apprenticeships and Technical Education. (2019). *Sonographer (integrated degree).* Institute for Apprenticeships and Technical Education. Retrieved Feb 2, 2024, from https://www.instituteforapprenticeships.org/apprenticeship-standards/sonographer-integrated-degree-v1-1

Intelligent Ultrasound. (2024). *BodyWorks eve.* Intelligent Ultrasound. Retrieved Nov 27, 2024, from https://www.intelligentultrasound.com/bodyworks-eve/

ISUOG. (2019). *Online learning module index.* https://www.isuog.org/education/learning-modules.html.

Iversen, A., Pedersen, A. S., Krogh, L., & Jensen, A. A. (2015). Learning, leading, and letting go of control: Learner-led approaches in education. *Sage Open,* , 1–11. https://journals.sagepub.com/doi/pdf/10.1177/2158244015608423

Iversen, A., Pedersen, A. S., Krogh, L., & Jensen, A. A. (2015). Learning, leading, and letting go of control. *SAGE Open, 5*(4), 215824401560842. https://doi.org/10.1177/2158244015608423

James, & Busher. (2009). *Online interviewing*. SAGE Publications Ltd.

Jamniczky, H. A., Cotton, D., Paget, M., Ramji, Q., Lenz, R., McLaughlin, K., Coderre, S., & Ma, I. W. Y. (2017). Cognitive load imposed by ultrasound-facilitated teaching does not adversely affect gross anatomy learning outcomes. *Anatomical Sciences Education, 10*(2), 144–151. https://doi.org/10.1002/ase.1642

Jasemi, M., Goli, R., Khalkhali, H., & Zabihi, R. E. (2022). Educating ethics codes by lecture or role-play; which one improves nursing students' ethical sensitivity and ethical performance more? A quasi-experimental study. *Journal of Professional Nursing, 40*, 122–129.

Johnson, J., Arezina, J., McGuinness, A., Culpan, A., & Hall, L. (2019). Breaking bad and difficult news in obstetric ultrasound and sonographer burnout: Is training helpful? *Ultrasound: Journal of the British Medical Ultrasound Society, 27*(1), 55–63. https://doi.org/10.1177/1742271X18816535

Johnson, J., Kaur, E., Arezina, J., Bryant, L. D., Wallace, R., Harrison, G., Bender Atik, R., Coates, J., Hardicre, N., Sicklen, R., Lardner, T., Horwood, K., Beety, H., Arnold, J., & Pollak, K. I. (2023). Communication coaching for sonographers (CCS): Preliminary evaluation of a novel intervention to improve unexpected news delivery. *PEC Innovation, 3* https://doi.org/10.1016/j.pecinn.2023.100231

Johnson-Russell, J., & Bailey, C. (2010). Facilitated debriefing. In W. Nehring, & F. R. Lashley (Eds.), *High-fidelity patient simulation in nursing education* (pp. 369–385). Jones and Bartlett.

Jones, F., Passos-Neto, C., & Melro Braghiroli, O. (2015). Simulation in medical education: Brief history and methodology. *Principles and Practice of Clinical Research Journal, 1*(2), 56–63. https://doi.org/10.21801/ppcrj.2015.12.8

Kaproth-Joslin, K. A., Nicola, R., & Dogra, V. S. (2015). The history of US: From bats and boats to the bedside and beyond: RSNA centennial article. *Radiographics: A Review Publication of the Radiological Society of North America, Inc, 35*(3), 960–970. https://doi.org/10.1148/rg.2015140300

Kapur, Parand, Soukup, Reader, & Sevdalis. (2016). Aviation and healthcare: A comparative review with implications for patient safety. *JRSM Open, 7*(1), 2054270415616548. https://doi.org/10.1177/2054270415616548

Kaur, E., Arezina, J., Bryant, L., Pollak, K. I., Harrison, G., Bender Atik, R., Coates, J., Hardicre, N. K., Sicklen, R., Horwood, K., Lardner, T., Arnold, J., Wallace, R., & Johnson, J. (2023). Adapting a communication coaching intervention for obstetric sonographers delivering unexpected news: A qualitative study. *Ultrasound: Journal of the British Medical Ultrasound Society, 31*(4), 273–283. https://doi.org/10.1177/1742271X221147860

Kennedy, H., & Allen, W. (2017). Data visualisation as an emerging tool for online research. In Nigel G. Fielding, Raymond M. Lee & Grant Blank (Eds.), *Sage handbook of online research methods*. SAGE Publications. https://doi.org/10.4135/9781473957992.n18

Keshmiri, F., Farahmand, S., Baharamnezhad, F., & Hossein-Nejad Nedaei, H. (2020). Exploring the challenges of professional identity formation in clinical education environment: A qualitative study. *Journal of Advances in Medical Education & Professionalism, 8*(1), 42–49. https://doi.org/10.30476/jamp.2019.74806.0

Khamissa, R. A., Nemutandani, S., Shangase, S. L., Feller, G., Lemmer, J., & Feller, L. (2022). The burnout construct with reference to healthcare providers: A narrative review. *SAGE Open Medicine, 10*, 20503121221083080. https://doi.org/10.1177/20503121221083080

Khan, R., Scaffidi, M. A., Satchwell, J., Gimpaya, N., Lee, W., Genis, S., Tham, D., Saperia, J., Al-Mazroui, A., Walsh, C. M., & Grover, S. C. (2023). Impact of a simulation-based ergonomics training curriculum on work-related musculoskeletal injury risk in colonoscopy. *BMC Musculoskeletal Disorders.* https://doi.org/10.1186/s12891-023-06606-4

Khine, R., Harrison, G., & Flinton, D. (2024a). What makes a good clinical practice experience in radiography and sonography? an exploration of qualified clinical staff and student perceptions. *Radiography, 30*(1), 66–72. https://doi.org/10.1016/j.radi.2023.09.013

Kim, Y., & Yoo, J. (2020). The utilization of debriefing for simulation in healthcare: A literature review. *Nurse Education in Practice, 43*

King, N., Horrocks, C., & Brooks, J. M. (2019). *Interviews in qualitative research* (Second edition ed.). SAGE.

Kneebone, K., & Nestle, R. (2015). Feedback in clinical procedural skills simulations. *Feedback in Higher and Professional Education: Understanding it and Doing it Well.* 140–157.

Knowles, M. (1984). *The adult learner: A neglected species* (3rd ed.). Gulf Publishing.

Knudsen, L., Nawrotzki, R., Schmiedl, A., Muhlfeld, C., Kruschinski, C., & Ochs, M. (2018). Hands-on or no hands-on training in ultrasound imaging: A randomized trial to evaluate learning outcomes and speed of recall of topographic anatomy. *Anatomical Sciences Education,* https://doi.org/10.1002/ase.1792

Kolb, A. Y., & Kolb, D. A. (2006). Chapter 3: Learning styles and learning spaces: A review of the multidisciplinary application of experiential learning theory in higher education. In R. R. Sims, & S. J. Sims (Eds.), *Learning styles and learning* (pp. 45–91)

Kolb, D. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education.

Kremkau, F. W. (2016). *Sonography: Principles and instruments*. Elsevier.

Lababidi, H., & AlQahtani, A. M. (2016). Chapter 7 - A simulation hospital as a Model of immersive-based learning: The concept and Challenges. In W. A. Farhat, & J. Drake (Eds.), *Bioengineering* *for surgery* (pp. 125–136). Chandos Publishing. https://doi.org/10.1016/B978-0-08-100123-3.00007-5

Laschinger, S., Medves, J., Pulling, C., McGraw, D. R., Waytuck, B., Harrison, M. B., & Gambeta, K. (2008). Effectiveness of simulation on health profession students' knowledge, skills, confidence and satisfaction. *International Journal of Evidence-Based Healthcare, 6*(3), 278–302. https://doi.org/10.1111/j.1744-1609.2008.00108.x

Lees, C., & Hinshaw, K. (2010). Royal college of obstetricians and gynaecologists ultrasound training recommendations for trainee obstetricians and gynaecologists. *Ultrasound, 18*(3), 108–109. https://doi.org/10.1258/ult.2010.100012

Leonardi, M., Murji, A., & D'Souza, R. (2018). Ultrasound curricula in obstetrics and gynecology training programs. *Ultrasound Obstet Gynecol, 52*, 147–150. https://doi.org/10.1002/uog.18978

Levinson, Kelly, Zahariou, Johnson, Jackman, & Mackenzie. (2017). *Description and student self-evaluation of a pilot integrated small group learning and simulation programme for medical students in the first clinical year*. Wiley. https://doi.org/10.1111/imj.13332

Lewis, N., & Bryan, V. (2021). Andragogy and teaching techniques to enhance adult learners' experience. *Journal of Nursing Education and Practice, 11*, 31. https://doi.org/10.5430/jnep.v11n11p31

Lincoln Guba, E. G., & Lincoln, Y. S. (2006). Competing paradigms in qualitative research. *Business and management research methodologies* (pp. VI216). SAGE Publications Ltd. https://doi.org/10.4135/9781446260906

Lincoln Y, G. E. &. (1985). *Naturalistic inquiry.* SAGE.

Lioce, L. (Ed.). (2020). *Healthcare simulation dictionary*. Agency for Healthcare Research and Quality. https://doi.org/10.23970/simulationv2

Lo Re, G., De Luca, R., Muscarneri, F., Dorangricchia, P., Picone, D., Vernuccio, F., Salerno, S., La Tona, G., Pinto, A., Midiri, M., Russo, A., Lagalla, R., & Cicero, G. (2016). Relationship between anxiety level and radiological investigation. comparison among different diagnostic imaging exams in a prospective single-center study. *La Radiologia Medica, 121*, 763–768. https://doi.org/10.1007/s11547-016-0664-z

Lo, C. K., & Hew, K. F. (2022). Design principles for fully online flipped learning in health professions education: A systematic review of research during the COVID-19 pandemic. *BMC Medical Education, 22.* https://doi.org/10.1186/s12909-022-03782-0

Lopreiato, J. O. (Ed.). (2016). *Healthcare simulation dictionary*

Louise McKnight, K. (2023). Bourdieu's field theory applied to the story of the UK radiography profession: A discussion paper. *Radiography (London, England. 1995), 29*(1), 90–94. https://doi.org/10.1016/j.radi.2022.10.002

Lumivero. (n.d., n.d.). *NVivo12 QDA software.* Retrieved Jan 13, 2025, from https://help-nv.qsrinternational.com/12/win/v12.1.115-d3ea61/Content/concepts-strategies/using-nvivo-for-qualitative-research.htm

Maarouf, H. (2019). Pragmatism as a supportive paradigm for the mixed research approach: Conceptualizing the ontological, epistemological, and axiological stances of pragmatism. *International Business Research, 12*(9). https://doi.org/10.5539/ibr.v12n9p1

Malcom, D. R., Pate, A. N., & Rowe, A. S. (2020). Applying safety lessons from aviation to pre-licensure health professions education: A narrative critical review. *Currents in Pharmacy Teaching and Learning, 12*(8), 1028–1035. https://doi.org/10.1016/j.cptl.2020.04.015

Manningham, R. (1740). Lectures advertisement. *London Evening Post.*

Marshall, A. L., & Wolanskyj-Spinner, A. (2020). COVID-19: Challenges and opportunities for educators and generation Z learners. *Mayo Clinic Proceedings, 95*(6), 1135–1137. https://doi.org/10.1016/j.mayocp.2020.04.015

Masava, Nyoni, & Botma. (2023). Standards for scaffolding in health sciences programmes: A Delphi consensus study. *Journal of Medical Education and Curricular Development, 10*, 23821205231184045. https://doi.org/10.1177/23821205231184045

Maslow, A. (1943). A theory of human motivation. *Psychological Review.* 370–396. https://doi.org/10.1037/h0054346

Mason, M. (2010). Sample size and saturation in PhD studies using qualitative interviews. *Forum, Qualitative Social Research, 11*(3), 19–11

McClintock, A. H., Kim, S., & Chung, E. K. (2022). Bridging the gap between educator and learner: The role of psychological safety in medical education. *Pediatrics, 149 (1*), e2021051441. https://doi.org/10.1542/peds.2021-051441[1]

McDermott, D. S., Ludlow, J., Horsley, E., & Meakim, C. (2021). Healthcare simulation standards of best Practice prebriefing: Preparation and briefing. *Clinical Simulation in Nursing, 58*, 9–13. https://doi.org/10.1016/j.ecns.2021.08.008

McGaghie, W. C., Issenberg, S. B., Petrusa, E. R., & Scalese, R. J. (2010). A critical review of simulation-based medical education research: 2003–2009. *Medical Education, 44*(1), 50–63. https://doi.org/10.1111/j.1365-2923.2009.03547.x

McGhee, G., Marland, G. R., & Atkinson, J. (2007). *Grounded theory research: Literature reviewing and reflexivity*. Blackwell Science. https://doi.org/10.1111/j.1365-2648.2007.04436.x

McIntosh-Scott, A., Mason, T., Mason-Whitehead, E., & Coyle, D. (2014). *Key concepts in nursing and healthcare research*. SAGE.

McMahon, E., Jimenez, F. A., Lawrence, K., & Victor, J. (2021). Healthcare simulation standards of best PracticeTM evaluation of learning and performance. *Clinical Simulation in Nursing, 58*, 54–56. https://doi.org/10.1016/j.ecns.2021.08.016

Meguerdichian, M., Bajaj, K., Ivanhoe, R., Lin, Y., Sloma, A., de Roche, A., Altonen, B., Bentley, S., Cheng, A., & Walker, K. (2022). Impact of the PEARLS healthcare debriefing cognitive aid on facilitator cognitive load, workload, and debriefing quality: A pilot study. *Advances in Simulation (London), 7*(1), 40. https://doi.org/10.1186/s41077-022-00236-x

Mellanby, J., & Theobald, K. (2014). *Education and learning: An evidence-based approach*. Wiley-Blackwell.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation*. Jossey-Bass, a Wiley Brand.

Merrriam S. (1995). What can you tell from an N of 1? issues of validity and reliabilty in qualitative research. *PAACE Journal of Lifelong Learning, 4*(51), e60.

Meuwly, J., Mandralis, K., Tenisch, E., Gullo, G., Frossard, P., & Morend, L. (2021). Use of an online ultrasound simulator to teach basic psychomotor skills to medical students during the initial COVID-19 lockdown: Quality control study. *JMIR Medical Education, 7*(4), e31132. https://doi.org/10.2196/31132

Miller, C., Deckers, C., Jones, M., Wells-Beede, E., & McGee, E. (2021). Healthcare simulation standards of best Practice outcomes and objectives. *Clinical Simulation in Nursing, 58*, 40–44. https://doi.org/10.1016/j.ecns.2021.08.013

Miller, P. K., Waring, L., Bolton, G., & Sloane, C. (2019). Personnel flux and workplace anxiety: Personal and interpersonal consequences of understaffing in UK ultrasound departments. Paper presented at the *UKIO Conference* https://insight.cumbria.ac.uk/id/eprint/4399/1/Miller,%20Waring,%20Bolton%20&%20Sloane%20-%20Ultrasound%20and%20Psychology%20-%20UKIO%202019%20-%20Abstract.pdf

Mitchell, P., Nightingale, J., & Reeves, P. (2019). Competence to capability: An integrated career framework for sonographers. *Radiography (London, England. 1995), 25*(4), 378–384. https://doi.org/10.1016/j.radi.2019.05.008

Mitchell, P., & Nightingale, J. (2019). Sonography culture: Power and protectionism. *Radiography, 25*(3), 227–234. https://doi.org/10.1016/j.radi.2019.02.004

Moak, J. H., Larese, S. R., Riordan, J. P., Sudhir, A., & Yan, G. (2014). Training in transvaginal sonography using pelvic ultrasound simulators versus live models: A randomized controlled trial. *Academic Medicine, 89*(7), 1063. https://doi.org/10.1097/ACM.0000000000000294

Molloy, M. A., Holt, J., Charnetski, M., & Rossler, K. (2021). Healthcare simulation standards of best Practice simulation glossary. *Clinical Simulation in Nursing, 58*, 57–65. https://doi.org/10.1016/j.ecns.2021.08.017

Monks, S., Roberts, C., Smith, J., & Taylor, P. (2020). Simulation-based learning: Building resilience and observing best practices. *Journal of Medical Education and Training, 4*(2), 123–130.

Montero, B. G. (2022). Behaviourism. . Oxford University Press. https://doi.org/10.1093/actrade/9780198809074.003.0002

Morcke, A. M., Dornan, T., & Eika, B. (2013). Outcome (competency) based education: An exploration of its origins, theoretical basis, and empirical evidence. *Advances in Health Sciences Education : Theory and Practice; Adv Health Sci Educ Theory Pract, 18*(4), 851–863. https://doi.org/10.1007/s10459-012-9405-9

Morgan, P. J., Cleave-Hogg, D., McIlroy, J., & Devitt, J. H. (2002). Simulation technology: A comparison of experiential and visual learning for undergraduate medical students. *Anesthesiology, 96*(1), 10–16. https://doi.org/10.1097/00000542-200201000-00008

Morrison, N., Zaman, T., Webster, G., Sorinola, O., & Blackburn, C. (2023). 'Where are you really from?': A qualitative study of racial microaggressions and the impact on medical students in the UK. *BMJ Open, 13*(5), e069009. https://doi.org/10.1136/bmjopen-2022-069009

Mount, G. R., Kahlke, R., Melton, J., & Varpio, L. (2022). A critical review of professional identity formation interventions in medical education. *Academic Medicine, 97*(11S), S96. https://doi.org/10.1097/ACM.0000000000004904

Mulder, N., Van De Velde, M., Dokter,G., Boekestijn, L., Olgers, T., Bauer, M., & Hierck, B. (2023). *Unravelling the skillset of point-of-care ultrasound: A systematic review*. Springer Science and Business Media LLC. https://doi.org/10.1186/s13089-023-00319-4

Munn, Z., Peters,M.D.J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(1) https://doi.org/10.1186/s12874-018-0611-x

Murphey, S. (2017). *Work related musculoskeletal disorders in sonography.* https://www.sdms.org/docs/default-source/Resources/work-related-musculoskeletal-disorders-in-sonography-white-paper.pdf?sfvrsn=8

Murphy, F. J., & Yielder, J. (2010). Establishing rigour in qualitative radiography research. *Radiography (London, England.1995), 16*(1), 62–67. https://doi.org/10.1016/j.radi.2009.07.003

NATCEN. (2016). *National centre for social research: Framework analysis. Retrieved from:* http://www.natcen.ac.uk/our-expertise/methods-expertise/qualitative/framework/?_ga=1.88746907.1069065566.1462887133

Nawathe, P. A., & Herrington, A. (2024). Enhancing healthcare communication education: Standardised patient programmes. *Indian Journal of Anaesthesia, 68*(1), 65. https://doi.org/10.4103/ija.ija_1201_23

Nestel, D., & Bearman, M. (Eds.). (2014). *Simulated patient methodology: Theory, evidence and practice*. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118760673

Nestel, D., & Bearman, M. (2015). Theory and simulation-based education: Definitions, worldviews and applications. *Clinical Simulation in Nursing, 11*(8), 349–354. https://doi.org/10.1016/j.ecns.2015.05.013

Nestel, D., & Kelly, M. (2018). An introduction to healthcare simulation. In D. Nestel, M. Kelly, B. Jolly & M. Watson (Eds.), *Healthcare simulation education: Evidence, theory and practice.* (pp. 3–8). Wiley Blackwell.

Nestel, D., Krogh, K., & Kolbe, M. (2018). Chapter 4: Exploring realism in healthcare simulations. In D. Nestel., M. Kelly, B. Jolly & M. Watson (Eds.), *Healthcare simulation education: Evidence theory and practice* (pp. 23–28). Wiley Blackwell.

NHS. (2011). *National framework for simulation-based education.* https://www.hee.nhs.uk/sites/default/files/documents/National%20framework%20for%20simulation%20based%20education.pdf

NHS. (2019). *The NHS long term plan.* https://www.longtermplan.nhs.uk/wp-content/uploads/2019/08/nhs-long-term-plan-version-1.2.pdf

NHS. (2023). *NHS long term workforce plan.* (No. 235). England. https://doi.org/10.1038/s41415-023-6204-z

NHS England. (2019). *Transforming imaging services in England: A national strategy for imaging networks*. https://improvement.nhs.uk/documents/6119/Transforming_imaging_services.pdf

NHS Employers. (2023). *Sonography and the regulation of workforce.* Retrieved Jun 15, 2024, from https://www.nhsemployers.org/articles/sonography-and-regulation-workforce

NHS England. (2017). *Multi-professional framework for advanced clinical practice in England.* https://www.hee.nhs.uk/sites/default/files/documents/multi-professionalframeworkforadvancedclinicalpracticeinengland.pdf

NHS England. (2022a). *Imaging training academies.* Health Education England. Retrieved Feb 2, 2024, from https://www.hee.nhs.uk/our-work/cancer-diagnostics/training-academies/imaging-training-academies

NHS England. (2022b). *NHS England: The journey to integrated care systems.* Retrieved Feb 2, 2024, from https://www.england.nhs.uk/integratedcare/what-is-integrated-care/the-journey-to-integrated-care-systems/

NHS England. (2023). *NHS long term workforce plan.* Retrieved from: https://www.england.nhs.uk/wp-content/uploads/2023/06/nhs-long-term-workforce-plan-v1.2.pdf

NHS England. (2024a). *Imaging training academies* .Retrieved Nov 25, 2024, from https://www.hee.nhs.uk/our-work/cancer-diagnostics/training-academies/imaging-training-academies

NHS England. (2024b, August). *NHS England: Educator workforce strategy.* Retrieved Jan 30, 2025, from https://www.england.nhs.uk/long-read/educator-workforce-strategy/

NHS England. (2024c, February). *Safe learning environment charter – what good looks like.* NHS England. https://www.england.nhs.uk/long-read/safe-learning-environment-charter/

NHS Professionals. (2019a). *Understanding the key success factors in collaborative working Retrieved Jan 30, 2025, from* https://www.nhsprofessionals.nhs.uk/-/media/corporate/partners/publications/nhsp-thought-leadership-paper_web.pdf

NHS Professionals. (2019b). Understanding the key success factors in collaborative working. https://www.nhsprofessionals.nhs.uk/-/media/corporate/partners/publications/nhsp-thought-leadership-paper_web.pdf

Nicholls, D., Sweet, L., & Hyett, J. (2014). Psychomotor skills in medical ultrasound imaging: An analysis of the core skill set. *Journal of Ultrasound in Medicine, 33*(8), 1349–1352. https://doi.org/10.7863/ultra.33.8.1349

Nicholls, D., Sweet, L., Muller, A., & Hyett, J. (2016). Teaching psychomotor skills effectively in the 21st century. *Ultrasound in Medicine & Biology, 41*(4, Supplement), S21. https://doi.org/10.1016/j.ultrasmedbio.2014.12.127

Nicholls, Sweet, Muller, & Hyett. (2018). A model to teach concomitant patient communication during psychomotor skill development. *Nurse Education Today, 60*, 121. https://doi.org/10.1016/j.nedt.2017.09.004

Nightingale, J., Burton, M., Appleyard, R., Sevens, T., & Campbell, S. (2021). Retention of radiographers: A qualitative exploration of factors influencing decisions to leave or remain within the NHS. *Radiography (London, England: 1995), 27*(3), 795–802. https://doi.org/10.1016/j.radi.2020.12.008

Nightingale, J., Sevens, T., Appleyard, R., & Campbell, S. (2023). Retention of radiographers in the NHS: Influencing factors across the career trajectory. *Radiography, 29*, 76–83. https://www.radiographyonline.com/action/showPdf?pii=S1078-8174%2822%2900158-4

NIHR. (2025). *Putting people first - embedding public involvement in health and social care research.* Retrieved Mar 2, 2025, from https://www.hra.nhs.uk/planning-and-improving-research/best-practice/public-involvement/putting-people-first-embedding-public-involvement-health-and-social-care-research/

Nitsche, Joshua F., MD, PhD, & Brost, B. C., MD. (2013). Obstetric ultrasound simulation. *Seminars in Perinatology, 37*(3), 199–204. https://doi.org/10.1053/j.semperi.2013.02.012

NMC. (2018a). *Realising professionalism: Standards for education and training. Part 3: Standards for pre-registration nursing programmes*. https://www.nmc.org.uk/globalassets/sitedocuments/education-standards/programme-standards-nursing.pdf

NMC. (2018b). *Requirements to enter the NMC register.*

Nti, B., & Pillarisetty, L. S. (2024). Techniques and strategies in ultrasound simulation. *StatPearls.*. StatPearls Publishing.

O'Cathain, Alicia, Murphy, Elizabeth, Nicholl, Jon. (2007). Why, and how, mixed methods research is undertaken in health services research in England: A mixed methods study. *BMC Health Sciences Research, 7*(85) https://www.bmj.com/content/341/bmj.c4587.full

O'Connor, M., Lunney, A., Rainford, L., & Grehan, J. (2023). Recruitment and retention of radiography clinical practice educators. *Radiography, 29*(3), 629–34. https://doi.org/10.1016/j.radi.2023/04/004

Oermann, M. H. (1990). Psychomotor skill development. *Journal of Continuing Education in Nursing, 21*(5), 202–204. https://doi.org/10.3928/0022-0124-19900901-05

Olgers, T. J., Van Os, J. M., Bouma, H. R., & Ter Maaten, J. C. (2022). *The validation of a serious game for teaching ultrasound skills*. Springer Science and Business Media LLC. https://doi.org/10.1186/s13089-022-00280-8

Opdenakker, R. (2006). Advantages and disadvantages of four interview techniques in qualitative research. *Qualitative Social Research, 4*(7) https://doi.org/10.17169/fqs-7.4.175

Owen, H. (2017). Historical perspectives in healthcare simulation: What we still have to learn. In Debra Nestel, , Michelle Kelly, Brian Jolly & Marcus Watson (Eds.), *Heathcare simulation education: Evidence, theory and practice.* (pp. 16–28). Wiley Blackwell.

Pacheco, J. P., Giacomin, H. T., Tam, W. W., Ribeiro, T. B., Arab, C., Bezerra, I. M., & Pinasco, G. C. (2017). Mental health problems among medical students in brazil: A systematic review and meta-analysis. *Brazilian Journal of Psychiatry, 39*, 369−378. https://doi.org/10.1590/1516-4446-2017-2223

Pacheco, J. P. G., Bunevicius, A., Oku, A., Shindel, A., Torres, A. R., Bassols, A. M. S., de Abreu Ramos-Cerqueira, A. T., Fernando, A., Katkute, A., Mayda, A. S., Nair, B., Breyer, B. N., Bakir, B., Kelly, B., Angkurawaranon, C., Sreeramareddy, C., Samaranayake, C., Saravanan, C., Del-Ben, C. M., . . . Tam, W. (2023). Pooled prevalence of depressive symptoms among medical students: An individual participant data meta-analysis. *BMC Psychiatry, 23*(1), 251. https://doi.org/10.1186/s12888-023-04745-5

Page, M. J., McKenzie, J. E., Boussuyt, P. M., Bourton, I., Hoffmann, T. C., Multow, C. D., & et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, https://doi.org/*10.1136/bmj.n71

Palmer, C., & Bolderston, A. (2006). A brief introduction to qualitative research. *The Canadian Journal of Medical Radiation Technology, 37 (1), 16-19. https://doi.org/*10.1016/S0820-5930(09)60112-260112-2)

Parker, & Harrison. (2015). Educating the future sonographic workforce: Membership survey report from the British medical ultrasound society. *Ultrasound: Journal of the British Medical Ultrasound Society, 23*(4), 231–241. https://doi.org/10.1177/1742271X15605344

Parsh, B. (2010). Characteristics of effective simulated clinical experience instructors: Interviews with undergraduate nursing students. *The Journal of Nursing Education, 49*(10), 569–572. https://doi.org/10.3928/01484834-20100730-04

Partner, A., England, A., Young, R., Shiner, N., & Bridge, P. (2023). Post COVID-19 trends in simulation use within diagnostic radiography and radiation therapy education. *Radiography (London, England: 1995), 29*(4), 684–689. https://doi.org/10.1016/j.radi.2023.04.018

Perry, S., Bridges, S. M., & Burrow, M. F. (2021). A conceptual model for clinical psychomotor skill development in an era of simulated and virtual reality. *European Journal of Dental Education,* https://doi.org/10.1111/eje.12699

Persico, L., Belle, A., DiGregorio, H., Wilson-Keates, B., & Shelton, C. (2021). Healthcare simulation standards of best Practice facilitation. *Clinical Simulation in Nursing, 58*, 22–26. https://doi.org/10.1016/j.ecns.2021.08.010

Pilnick, A., O'Brien, R., Beeke, S., Goldberg, S., Murray, M., & Harwood, R. H. (2023). Conversation analysis based simulation (CABS): A method for improving communication skills training for healthcare practitioners. *Health Expectations, 26*, 2461–2474. https://doi.org/10.1111/hex.13834

Plano Clark, V. L., & Ivankova, N. V. (2016). *Mixed methods research*. SAGE.

Polakova, P., & Klimova, B. (2019). Mobile technology and generation Z in the English language classroom – A preliminary study. *Education Sciences, 9*(3) https://doi.org/10.3390/educsci9030203

Pope, C., & Mays, N. (2020). *Qualitative research in health care*. Wiley Blackwell.

Probst. (2015). The eye regards itself: Benefits and challenges of reflexivity in qualitative social work research. *Social Work Research, 39*(1), 37. https://doi.org/10.1093/swr/svu028

Professional Standards Authority. (2019). *Right-touch assurance for sonographers based on risk of harm arising from practice: A report for Health Education England. Retrieved from:* https://www.professionalstandards.org.uk/docs/default-source/publications/right-touch-assurance-for-sonographers---a-report-for-health-education-england.pdf?sfvrsn=b2fd7420_0

Professional Standards Authority. (2022). *Professional standards authority business plan 2022/23. Retrieved from:* https://assets.publishing.service.gov.uk/media/62b9c4ded3bf7f662753cf7b/Professional_Standards_Authority_Business_Plan_2022-23_print.pdf

Professional Standards Authority. (2024). *Decision on whether accreditation is in the public interest: Register of clinical technologists.* Retrieved from: https://www.professionalstandards.org.uk/sites/default/files/attachments/Register%20of%20Clinical%20Technologists%20meets%20Accredited%20Registers%20%E2%80%98public%20interest%20test%E2%80%99.pdf

Purva, M, & Nicklin, J. (2017a). ASPiH standards for simulation based education. *BMJ Stel Doi:10.1136/Bmjstel-2017-000232, 4*, 103–111. https://doi.org/doi:10.1136/bmjstel-2017-000232

Qualitative data analysis: A user friendly guide for social scientists. (2003). Routledge.

Raman, M., & Donnon, T. (2008). Procedural skills education--colonoscopy as a model. *Canadian Journal of Gastroenterology; can J Gastroenterol, 22*(9), 767–770. https://doi.org/10.1155/2008/386851

Ramlaul, A., & Hogg, P. (2010). *Medical imaging and radiotherapy research : Skills and strategies*. Churchill Livingstone.

RCR and SCOR. (2014). *Standards for the provision of an ultrasound service.*

Ribeiro, C. F., Lemos, C. M. C., Alt, N. N., Marins, R. L. T., Corbiceiro, W. C. H., & Nascimento, M. I. d. (2020). Prevalence of and factors associated with depression and anxiety in Brazilian medical students. *Revista Brasileira De Educação Médica, 44*, e021. https://doi.org/10.1590/1981-5271v44.1-20190102.ING

Richardson, M. L. (2014). Audience response techniques for 21st century radiology education. *Academic Radiology, 21*(7), 834–841. https://doi.org/10.1016/j.acra.2013.09.026

Rossler, K., Molloy, M. A., Pastva, A. M., Brown, M., & Xavier, N. (2021). Healthcare simulation standards of best PracticeTM simulation-enhanced interprofessional education. *Clinical Simulation in Nursing, 58*, 49–53. https://doi.org/10.1016/j.ecns.2021.08.015

Rowland, E., & Trueman, H. (2024). Improving healthcare student experience of clinical placements. *BMJ Open Quality, 13*(1) https://doi.org/10.1136/bmjoq-2023-002504

Royal College of Emergency Medicine. (2022). Advanced clinical practice past, present & future: A brief overview & RCEM position. http://president.rcem.ac.uk/index.php/2022/08/30/advanced-clinical-practice-past-present-future-a-brief-overview-rcem-position/

Rutakumwa, R., Mugisha, J. O., Bernays, S., Kabunga, E., Tumwekwase, G., Mbonye, M., & Seeley, J. (2020). Conducting in-depth interviews with and without voice recorders: A comparative analysis. *Qualitative Research, 20*(5), 565–581. https://doi.org/10.1177/1468794119884806

Ruth-Sahd, L. A. (2011). Student nurse dyads create a community of learning: Proposing a holistic clinical education theory. *Journal of Advanced Nursing, 67*(11), 2445–2454. https://doi.org/10.1111/j.1365-2648.2011.05690.x

Salvesen, K. A., Lees, C., & Tutschek, B. (2010). Basic European ultrasound training in obstetrics and gynecology: Where are we and where do we go from here? *Ultrasound Obstet Gynecol, 36*, 525–529. https://doi.org/10.1002/uog.885

Sangrà, A., Vlachopoulos, D., & Cabrera, N. (2012) Building an inclusive definition of E-learning: An approach to the conceptual framework. *International Review of Research in Open and Distributed Learning,* 13(2), 145-159. https://doi.org/10.19173/irrodl.v13i2.1161

Sardo C, S. A. (2019, March). Scaffolding online student success. effective online teaching strategies. Retrieved from https://www.facultyfocus.com/articles/online-education/online-course-delivery-andinstruction/scaffolding-online-student-success/.

Sawyer, T., Eppich, W., Brett-Fleegler, M., Grant, V., & Cheng, A. (2016a). More than one way to debrief: A critical review of healthcare simulation debriefing methods. *Simulation in Healthcare, Vol. 11*(3), 209–217. https://doi.org/10.1097/SIH.0000000000000148

Sawyer, T. L., & Deering, S. (2013). Adaptation of the US army's after-action review for simulation debriefing in healthcare. *Simulation in Healthcare, 8*(6), 388. https://doi.org/10.1097/SIH.0b013e31829ac85c

Scaffidi, M. A., Satchwell, J., Gimpaya, N., Lee, W., Genis, S., Tham, D., Saperia, J., Al-Mazrouri, A., Walsh, C. M., & Grover, S. C. (2020). Impact of a simulation-based ergonomics training curriculum on work-related musculoskeletal injury risk in colonoscopy. *Gastrointestinal Endoscopy, 92(5)*(5), 1070–1084. https://doi.org/10.1016/j.gie.2020.03.3754

Schallware. (2024). *Schallware ultrasound simulator.* Retrieved Nov 27, 2024, from https://www.schallware.de/en/description

Schon, D. (1991). *The reflective practitioner: How professionals think and act.* Avebury.

Schott, C. K., Kode, K. R., & Mader, M. J. (2020). *Teaching vs learning: Impact of deliberate practice and formative feedback on developing point of care ultrasound skills*. Wiley. https://doi.org/10.1002/jcu.22878

SCoR. (2019, 2nd July). *No statutory regulation for sonographers: Society expresses disappointment and dismay.* Retrieved 20/10/2019, from https://www.sor.org/news/no-statutory-regulation-sonographers-society-expresses-disappointment-and-dismay

Society of Radiographers. (2023, June). *SoR leaders in Westminster to raise key issues for radiography professionals.* https://www.sor.org/news/trade-union-ir/sor-leaders-in-westminster-to-raise-key-issues-for. Retrieved 21/09/23.

SCoR & BMUS. (2023). *Guidelines for professional ultrasound practice (8th ed.).* Society of Radiographers and British Medical Ultrasound Society.

Sevens, T. J., & Reeves, P. J. (2019). Professional protectionism; a barrier to employing a sonographer graduate? *Radiography, 25*(1), 77–82. https://doi.org/10.1016/j.radi.2018.11.001

Sevens, T. (2017). *The benefits and challenges of employing new sonography graduates: Key stakeholder views* Available from Dissertations & Theses Europe Full Text: Literature & Language. Retrieved from: https://search.proquest.com/docview/1985544404

Shah, S., Diwan, S., Kohan, L., Rosenblum, D., Gharibo, C., Soin, A., Sulindro, A., Nguyen, Q., & Provenzano, D. (2020). The technological impact of COVID-19 on the future of education and health care delivery. *Pain Physician.* 23(4S), S367-380. https://doi.org/10.36076/ppj.2020/23/4s/s367

Shanks, D., Wong, R. Y., Roberts, J. M., Nair, P., & Ma, I., WY. (2010). *Use of simulator-based medical procedural curriculum: The learner's perspectives*. BMC Medical Education.

Shannon-Baker, P. (2016). Making paradigms meaningful in mixed methods research. *Journal of Mixed Methods Research, 10*(4), p. 319–334. https://doi.org/10.1177/1558689815575861

Sharma, H., Patil, A. D., & Baviskar, A. (2023). Fiction contract: Its importance in simulation-based medical education. *International Journal of Basic and Clinical Pharmacology, 12*(5), 766–770. https://doi.org/10.18203/2319-2003.ijbcp20232579

Shefaly, S., Chan, V., Rajendran, P., & Ang, E. (2021). Learning styles, preferences and needs of generation Z healthcare students: Scoping review. *Nurse Education in Practice, 57. 103217*. https://doi.org/10.1016/j.nepr.2021.103217

Sheffield Hallam University. (2019). *Data management policy.*

Sheffield Hallam University. (2023). *Research integrity.*

Sheffield Hallam University. (2024). *SHURDA - SHU research data archive (SHURDA).* Retrieved Dec 30, 2024, from https://shurda.shu.ac.uk/information.html

Shiner, N. (2018). Is there a role for simulation-based education within conventional diagnostic radiography? A literature review. *Radiography, 24*(3), 262–271. https://doi.org/10.1016/j.radi.2018.01.006

Shiner, N., & Pantic, V. (2019). An overview of the types and applications of simulation-based education within diagnostic radiography and ultrasound at two higher education institutions. *Imaging and Oncology.* https://repository.derby.ac.uk/download/24c6fca04e14b9df04b060f93b6969bc9b446c9c663c0d1aba1fe842f70d388e/5022652/io_2019_lr.pdf

Shinnick, M. A., & Woo, M. A. (2015). Learning style impact on knowledge gains in human patient simulation. *Nurse Education Today, 35*(1), 63–67. https://doi.org/10.1016/j.nedt.2014.05.013

Shorey, S., Chan, V., Rajendran, P., & Ang, E. (2021). Learning styles, preferences and needs of generation Z healthcare students: Scoping review. *Nurse Education in Practice, 57*, 103247. https://doi.org/10.1016/j.nepr.2021.103247

Siddiqui, Z. K., Church, H. R., Jayasuriya, R., Boddice, T., & Tomlinson, J. (2024). *Educational interventions for imposter phenomenon in healthcare: A scoping review*. Springer Science and Business Media LLC. https://doi.org/10.1186/s12909-023-04984-w

Sidhu, H. S., Olubaniyi, B. O., Bhatnagar, G., Shuen, V., & Dubbins, P. (2012). Role of Simulation-Based education in ultrasound practice training. *Journal of Ultrasound in Medicine, 31*(5), 785–791. https://doi.org/10.7863/jum.2012.31.5.785

Silverman, D. (2006). *Doing qualitative research: A practical handbook (2nd Edition)*. SAGE Publications.

Simpson, E. J. (1972). *The classification of educational objectives in the psychomotor domain: The psychomotor domain. Volume 3.* Gryphon House.

Simpson, E. J. (1966). *The classification of educational objectives, psychomotor domain.* Gryphon House.

Sirras, S. (2022). Researchers' role reflexivity when studying values work. In G. Espedal, A. Wæraas, S. Sirris & B. Jelstad Løvaas (Eds.), *Researching values* (pp. 205–224). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-90769-3_12

Skills for Health. (2019). *CI.C.2019 perform, interpret and report on ultrasound examinations.* https://tools.skillsforhealth.org.uk/competence-details/

Skinner, A. A., Freeman, R. V., & Sheehan, F. H. (2016b). Quantitative feedback facilitates acquisition of skills in focused cardiac ultrasound. *Simulation in Healthcare, 11*(2), 134–138. https://doi.org/10.1097/SIH.0000000000000132

Slater, R. J., Castanelli, D. J., & Barrington, M. J. (2014). Learning and teaching motor skills in regional anesthesia: A different perspective. *Regional Anaesthesia and Pain Medicine, 39*(3), 230–239. https://doi.org/10.1097/AAP.0000000000000072

Sloane, D. (2009). Visualizing qualitative information. *The Qualitative Report, 14*(3), 488–497. https://doi.org/10.46743/2160-3715/2009.1407

Smith, C. J., Matthias, T., Beam, E., Pounds, L., Nickol, D., Shope, R. J., Carlson, K., & Michael, K. (2020). A mixed-methods evaluation of medical residents' attitudes towards interprofessional learning and stereotypes following sonography student-led point-of-care ultrasound training. *Journal of General Internal Medicine, 35*(10), 3081–3086. https://doi.org/10.1007/s11606-020-06105-5

Smith, J. A., Flowers, P., & Larkin, M. (2022). *Interpretative phenomenological analysis: Theory, method and research.* (2nd ed.). SAGE.

Society & College of Radiographers. (2019). *Work related musculoskeletal disorders (sonographers).* London: https://www.sor.org/getmedia/d0f41e69-2006-43a8-9c75-1dae2ad04c69/work_related_musculoskeletal_disorders_sonographers-pdf_3

Society of Radiographers. (2022, July). *"No immediate case" to introduce sonographer regulation.* Retrieved 21/09/23, from: https://www.sor.org/News/Ultrasound/Response-to-letter-about-sonographer-regulation.

Society of Radiographers. (2023). *SoR leaders in Westminster to raise key issues for radiography professionals.* SoR. Retrieved Feb 2, 2024, from https://www.sor.org/news/trade-union-ir/sor-leaders-in-westminster-to-raise-key-issues-for

Sonographer (integrated degree) V1. (2019). Institute for Apprenticeships and Technical Education. Retrieved Feb 2, 2024, from https://www.instituteforapprenticeships.org/apprenticeship-standards/sonographer-integrated-degree-v1-0

SoR. (2022). *Diagnostic radiography workforce UK census 2022.* London: Society of Radiographers. Retrieved from: https://www.sor.org/getmedia/6994cd5d-0155-4a7e-a8a7-32a9bbda81c3/Diagnostic-Radiography-Workforce-UK-Census-2022-report.pdf

St John-Matthews, J., Newton, P. M., Grant, A. J., & Robinson, L. (2020). Crowdsourcing in health professions education: What radiography educators can learn from other disciplines. *Radiography, 25*(2), 164–169. https://doi-org.hallam.idm.oclc.org/10.1016/j.radi.2018.11.006

Stark, L., & Hedgecoe, A. (2010). A practical guide to research ethics. In Bourgeault, I., Dingwall, R., & De Vries, R. (Ed.), *The SAGE handbook of qualitative methods in health research* (pp. 589–607). SAGE Publications Ltd.

Strauss, A. L., & Corbin, J. M. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory (2nd ed.). SAGE Publications.*

Strayhorn, T. L. (2018). *College students' sense of belonging: A key to educational success for all students.* (2nd ed.). Routledge.

Strudwick, R. (2015) Creating a professional culture. *Imaging & Therapy Practice*, 23–28. Retrieved from: https://www.proquest.com/docview/1718299630/fulltextPDF/B585179C893E4C6APQ/1?accountid=13827&sourcetype=Trade%20Journals

Tabak, I., & Eleni, A. (2018). Research on scaffolding in the learning sciences A methodological perspective. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman & P. Reimann (Eds.), *Book international handbook of the learning sciences*. Routledge.

The Nursing and Midwifery Council (NMC). (2024, October). *Simulated practice learning.* Retrieved Jan 31, 2025, from https://www.nmc.org.uk/standards/guidance/supporting-information-for-our-education-and-training-standards/simulated-practice-learning/

Thoirs, K., & Coffee, J. (2012). Developing the clinical psychomotor skills of musculoskeletal sonography using a multimedia DVD: A pilot study.

Thomas, M. (2014). Paradigms and philosophies. In A. McIntosh-Scott, T. Mason, E. Mason-Whitehead & D. Coyle (Eds.), *Key concepts in nursing and healthcare research* (pp. 18–23). SAGE Publications.

Thompson, M. J. (2017). *The Palgrave handbook of critical theory* (1st ed.). Palgrave Macmillan US. https://doi.org/10.1057/978-1-137-55801-5

Thomson, S. B. (2010). Sample size and grounded theory. *Journal of Administration and Governance, 5*(1), 45–52.

Thomson, & Paterson. (2014). Sonographer registration in the United Kingdom – A review of the current situation. *Ultrasound: Journal of the British Medical Ultrasound Society, 22*(1), 52–56. https://doi.org/10.1177/1742271X13517381

Tolsgaard, M. G., Rasmussen, B., Tappert, C., Sundler, M., Sorensen, J. L., Ottensen, B., Ringsted, C., & Tabor, A. (2014). Which factors are associated with trainees' confidence in performing obstetric and gynecological ultrasound examinations? *Ultrasound in Obstetrics & Gynecology, 43*(4), 444–451. https://doi.org/10.1002/uog.13342

Tolsgaard, M. G., Ringsted, C., Dreisler, E., Nørgaard, L. N., Petersen, J. H., Madsen, M. E., Freiesleben, N. L. C., Sørensen, J. L., & Tabor, A. (2015). Sustained effect of simulation-based ultrasound training on clinical performance: A randomized trial. *Ultrasound in Obstetrics and Gynecology, 46*(3), 312–318. https://doi.org/10.1002/uog.14780

Tolsgaard, M. G., Madsen, M. E., Ringsted, C., Oxlund, B. S., Oldenburg, A., Sorensen, J. L., Ottesen, B., & Tabor, A. (2015). The effect of dyad versus individual simulation-based ultrasound training on skills transfer. *Medical Education, 49*(3), 286–295. https://doi.org/10.1111/medu.12624

Toubassi, D., Schenker, C., Roberts, M., & Forte, M. (2023). Professional identity formation: Linking meaning to well-being. *Advances in Health Sciences Education*, *28*, 305–318. https://doi.org/10.1007/s10459-022-10146-2

UK National Screening Committee. (2020). *UK national screening programmes.* Retrieved Sep 3, 2020, from https://www.gov.uk/government/groups/uk-national-screening-committee-uk-nsc

UKRI. (2024). *Making your research data open.* Retrieved Dec 30, 2024, from https://www.ukri.org/manage-your-award/publishing-your-research-findings/making-your-research-data-open/

Urban, R. R., Ramzan, A. A., Doo, D. W., Galan, H. L., Harper, L., Omurtag, K., Muffly, T. M., Sheeder, J., & Guntupalli, S. R. (2019). Fellow perceptions of residency training in obstetrics and gynecology. *Journal of Surgical Education, 1*(76), 93–98. https://doi.org/10.1016/j.jsurg.2018.06.013

Urban, R. R., Ramzan, A. A., Doo, D. W., Galan, H. L., Harper, L., Omurtag, K., Muffly, T. M., Sheeder, J., & Guntupalli, S. R. (2019). Fellow perceptions of residency training in obstetrics and gynecology. *Journal of Surgical Education, 76*(1), 93–98. https://doi.org/10.1016/j.jsurg.2018.06.013

Urquhart, C. (2023). *Grounded theory for qualitative research* (2nd ed.). SAGE.

Urquhart, C. (2013). *Grounded theory for qualitative research a practical guide*. SAGE.

van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: A decade of research. *Educational Psychology Review, 33*(3), 271–296. https://doi.org/10.1007/S10648-010-9127-6

van Dongen, van der Wal, Rinkes, Schijven, & Broeders. (2008). Virtual reality training for endoscopic surgery: Voluntary or obligatory? *Surgical Endoscopy, 22*(3), 664–667. https://doi.org/10.1007/s00464-007-9456-9

van Soeren, M., Devlin-Cop, S., MacMillan, K., Baker, L., Egan-Lee, E., & Reeves, S. (2011). Simulated interprofessional education: An analysis of teaching and learning processes. *Journal of Interprofessional Care, 25*(6), 434–440. https://doi.org/10.3109/13561820.2011.592229

Victoria State Government. (2016). *Victorian allied health workforce research project: Sonography workforce report* https://www.health.vic.gov.au/sites/default/files/migrated/files/collections/research-and-reports/v/victorian-allied-health-workforce-project-2016/sonography-workforce-report.pdf

Vizeshfar, F., Zare, M., & Keshtkaran, Z. (2019). Role-play versus lecture methods in community health volunteers. *Nurse Education Today, 79*, 175–179. 1 https://doi.org/0.1016/j.nedt.2019.05.028

Wallace, C. (2023). An exploration of simulation-based education from other health professionals, to create an informed and effective simulation delivery in a new diagnostic radiography programme. *Radiography, 29*, 886–891. https://www.radiographyonline.com/action/showPdf?pii=S1078-8174%2823%2900130-X

Walsh, C., England, A., Young, R., Moore, N., Hutch, A., Dennan, S., Rainford, L., Albeshan, S., Alashban, Y., & McEntee, M. (2024). The prevalence of harassment of diagnostic radiography and radiation therapy students whilst on clinical placement in the Republic of Ireland. *Medical Teacher, 46*(8), 1077–1083. https://doi.org/10.1080/0142159X.2023.2290464

Ward, K., Hoare, K. J., & Gott, M. (2015). *Evolving from a positivist to constructionist epistemology while using grounded theory: Reflections of a novice researcher*. SAGE Publications. https://doi.org/10.1177/1744987115597731

Waring, L., Miller, P. K., Sloane, C., & Bolton, G. (2018). Charting the practical dimensions of understaffing from a managerial perspective: The everyday shape of the UK's sonographer shortage. *Ultrasound (Leeds, England), 26*(4), 206–213. https://doi.org/10.1177/1742271X18772606

Watts, P. I., McDermott, D. S., Alinier, G., Charnetski, M., Ludlow, J., Horsley, E., Meakim, C., & Nawathe, P. A. (2021a). Healthcare simulation standards of best Practice simulation design. *Clinical Simulation in Nursing, 58*, 14–21. https://doi.org/10.1016/j.ecns.2021.08.009

Watts, P. I., Rossler, K., Bowler, F., Miller, C., Charnetski, M., Decker, S., Molloy, M. A., Persico, L., McMahon, E., McDermott, D., & Hallmark, B. (2021b). Onward and upward: Introducing the healthcare simulation standards of best Practice. *Clinical Simulation in Nursing, 58*, 1–4. https://doi.org/10.1016/j.ecns.2021.08.006

Weller. (2015). *The potentials and pitfalls of using skype for qualitative (longitudinal) interviews*. UK: National Centre for Research Methods. https://eprints.ncrm.ac.uk/id/eprint/3757/

Weller, S. (2017). Using internet video calls in qualitative (longitudinal) interviews: Some implications for rapport. *International Journal of Social Research Methodology, 20*(6), 613–625. https://doi.org/10.1080/13645579.2016.1269505

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity.* Cambridge University Press.

Wertz, F. J., Charmaz, K., McMullen, L. M., Josselson, R., Anderson, R., & McSpadden, E. (2011). *Five ways of doing qualitative analysis: Phenomenological psychology, grounded theory, discourse analysis, narrative research, and intuitive inquiry.* The Guilford Press.

Williams, C. J., Edie, J. C., Flinton, D. M., & Harrison, G. (2013). Transvaginal ultrasound simulation and its effect on trainee confidence levels: A replacement for initial clinical training? *Ultrasound, 21*(2), 50–56. https://doi.org/10.1177/1742271X13481215

Williams, P., Wilford, B., & Cutler, S. (2014). Qualitative analysis. In A. Ramlaul (Ed.), *Medical imaging and radiotherapy research: Skills and strategies* (pp. 274–304). Churchill Livingstone.

Winstone, N., Balloo, K., Gravett, K., Jacobs, D., & Keen, H. (2022). Who stands to benefit? wellbeing, belonging and challenges to equity in engagement in extra-curricular activities at university. *Active Learning in Higher Education, 23*(2), 81–96. https://doi.org/10.1177/1469787420908209

Wise, S. P., & Willingham, D. T. (2009). Motor skill learning.

Wolcott, H. F. (1994). *Transforming qualitative data: Description, analysis and interpretation*. SAGE Publications.

Woo, J. (Undated, Undated). *A short history of the development of ultrasound in obstetrics and gynecology.* Retrieved 20/8/2019, from www.ob-ultrasound.net/history1.html.

World Health Organisation. (2011a). *Patient safety curriculum guide multi-professional edition*. https://iris.who.int/bitstream/handle/10665/44641/9789241501958_eng.pdf?sequence=1

World Health Organisation. (2011b). *Patient safety curriculum guide: Multi-professional edition*. Switzerland: WHO Press. https://iris.who.int/bitstream/handle/10665/44641/9789241501958_eng.pdf?sequence=1

World Health Organisation. (2013). *Transforming and scaling up health professionals' education and training*. https://iris.who.int/bitstream/handle/10665/93635/9789241506502_eng.pdf?sequence=1

World Medical Association. (2024). *WMA - the world medical association-WMA declaration of Helsinki – ethical principles for medical research involving human participants.* Retrieved from: https://www.wma.net/policies-post/wma-declaration-of-helsinki/

Yin, R. K. (2016). *Qualitative research from start to finish*. Guilford Press.

Younan, K., Walkley, D., Quinton, A. E., & Alphonse, J. (2022). *Burnout in the sonographic environment: The identification and exploration of the causes of sonographer burnout and strategies for prevention and control*. Wiley. https://doi.org/10.1002/sono.12333

Yuval-Davis, N. (2006). Belonging and the politics of belonging. *Patterns of Prejudice, 40*(3), 197–214. https://doi.org/10.1080/00313220600769331

Ziada, Ditmyer, & Abubakr. (2021). *Reflections of psychomotor skill development in preclinical simulation: A qualitative analysis*. Wiley. https://doi.org/10.1111/eje.12684

Zigmont, J. J., Kappus, L. J., & Sudikoff, S. N. (2011). The 3D model of debriefing: Defusing, discovering, and deepening. *Seminars in Perinatology, 35*(2), 52–58. https://doi.org/10.1053/j.semperi.2011.01.003

ZOOM. (2021). *White paper: August 2021: ZOOM security guide* https://explore.zoom.us/docs/doc/Zoom-Security-White-Paper.pdf

Appendices

Appendix 1: Ethical approvals

Sheffield Hallam University ethics committee reference number ER21930888.

Ethics review reference number	Title of research study	Approval date	Date of any post-approval amendments (if applicable)
ER21930888	The role of simulation in sonographer education.	15/06/2020	**Date of approval amendment 1**: 01/02/2022 **Date of approval amendment 2**: 26/09/2022

Appendix 2: Data visualisation and NVIVO 12

This research used NVIVO12 software to manage, analyse, and visualize the large volume of qualitative data systematically. NVIVO visualisation tools eased the process of finding relationships between data sets, which was crucial in the analysis of the large volume of data generated during the research process. Data visualisation in health research, particularly in quantitative research is well established. For example, data visualisation on health and populations using sunburst charts was used by Florence Nightingale to show that avoidable diseases were causing significant war mortalities (Graham, 2017).

Slone (2009) reported a lack of qualitative tools for effective visualisation and analysis of qualitative data, but more recently, developments in software provide powerful qualitative analysis and visualization tools (Lumivero, n.d.)), which offer opportunities to explore large volumes of qualitative data. NVIVO Tools enabled the researcher to explore large volumes of complex data systematically, aided by a variety of data visualisation tools including wordclouds (figure A2.1), and mindmaps (Figure A2.7), which would not have been possible through simple review of text-based transcripts (Kennedy & Allen, 2017).

Coding frequency analysis for each transcript allowed the researcher to gain an overall view of the main areas discussed during each interview, and reassured the researcher that participants were not being “led” to similar discussions by the interviewer (See examples in Figure A2.2 and A2.3).

Figure A2.1: M Word frequency cloud (Complete data set)

Figure A.2.2: Coding density Educator Interview 1 – focus on the future

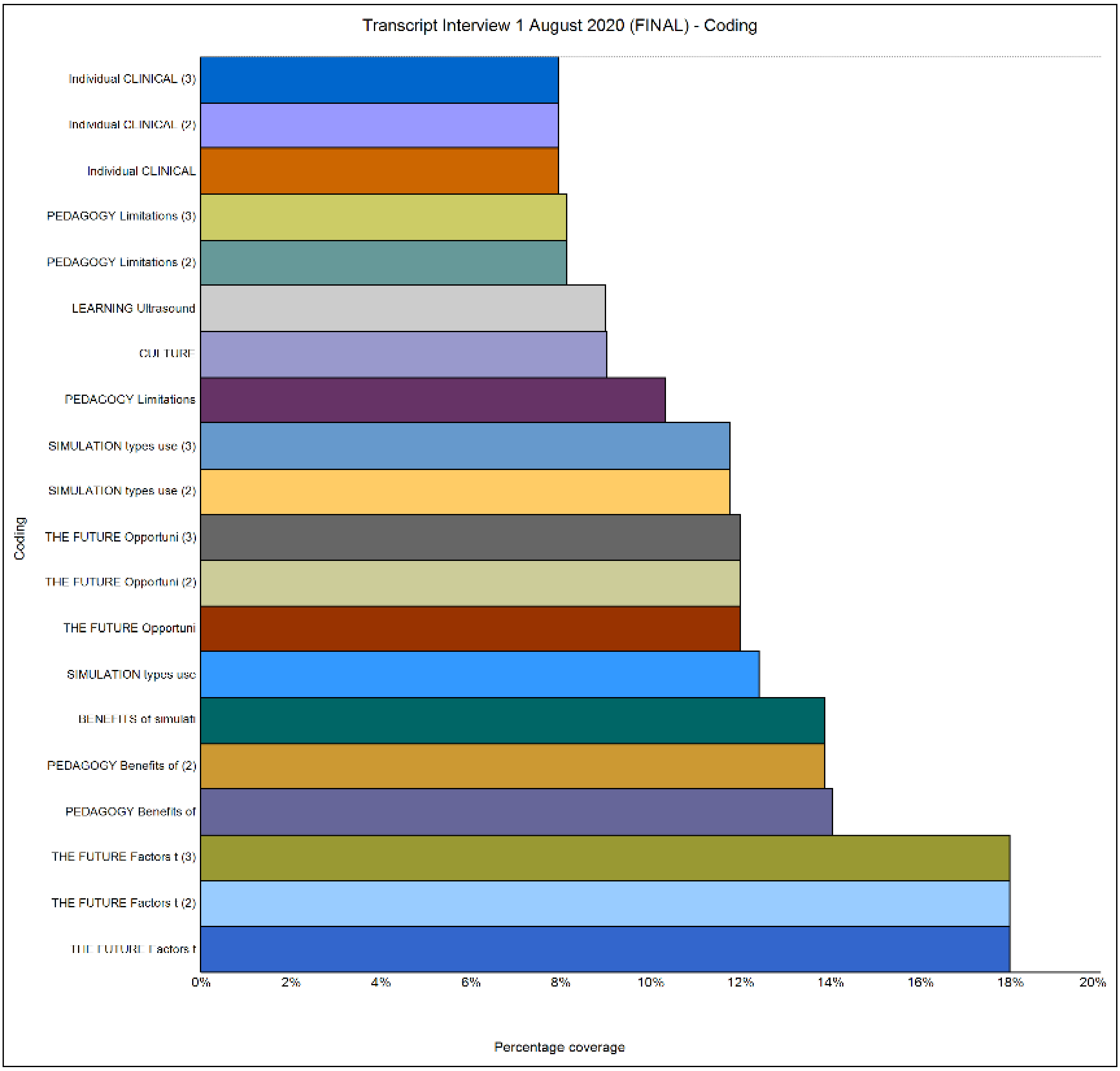
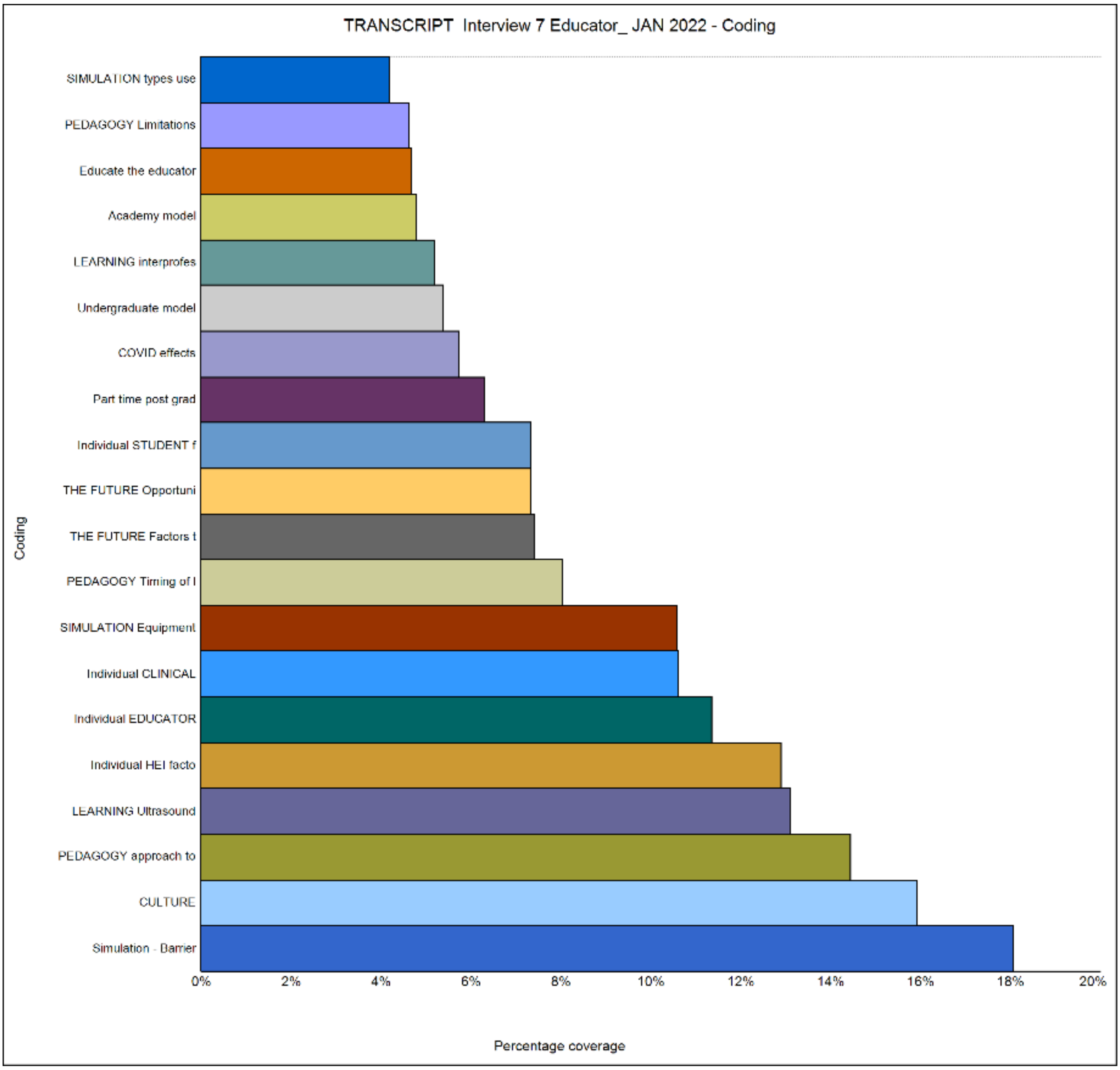


Figure A.2.3: Coding density: Educator Interview 7 – Focus on barriers and culture



NVIVO supported line-by-line coding, theme development and identification of patterns in the data. NVivo also provided a platform to develop a framework matrix to support theory development (See examples from different stages of the analysis Figure A2.4, A2.5, A2.6), and this allowed easier visualisation of relationships between coded data through mind maps, concept maps, and project maps (Dhakal, 2022; Few, 2013). These data visualisation tools provided essential information which informed decision making during analysis.

Figure A2.4: Initial codes, early stages of analysis

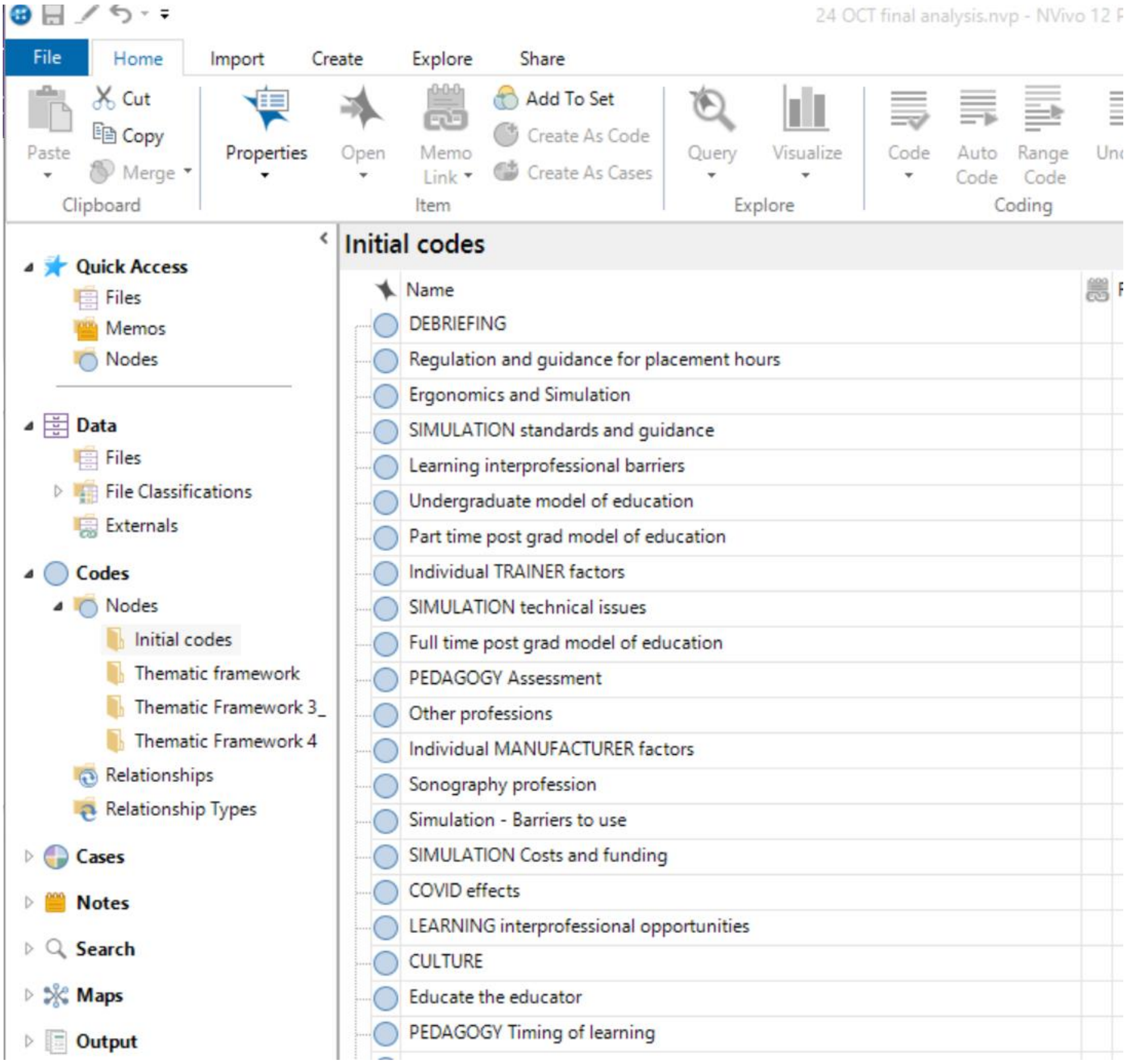


Figure A2.5 Mid stage of theory development Mind Map: Categories and subcategories after coding and analysis

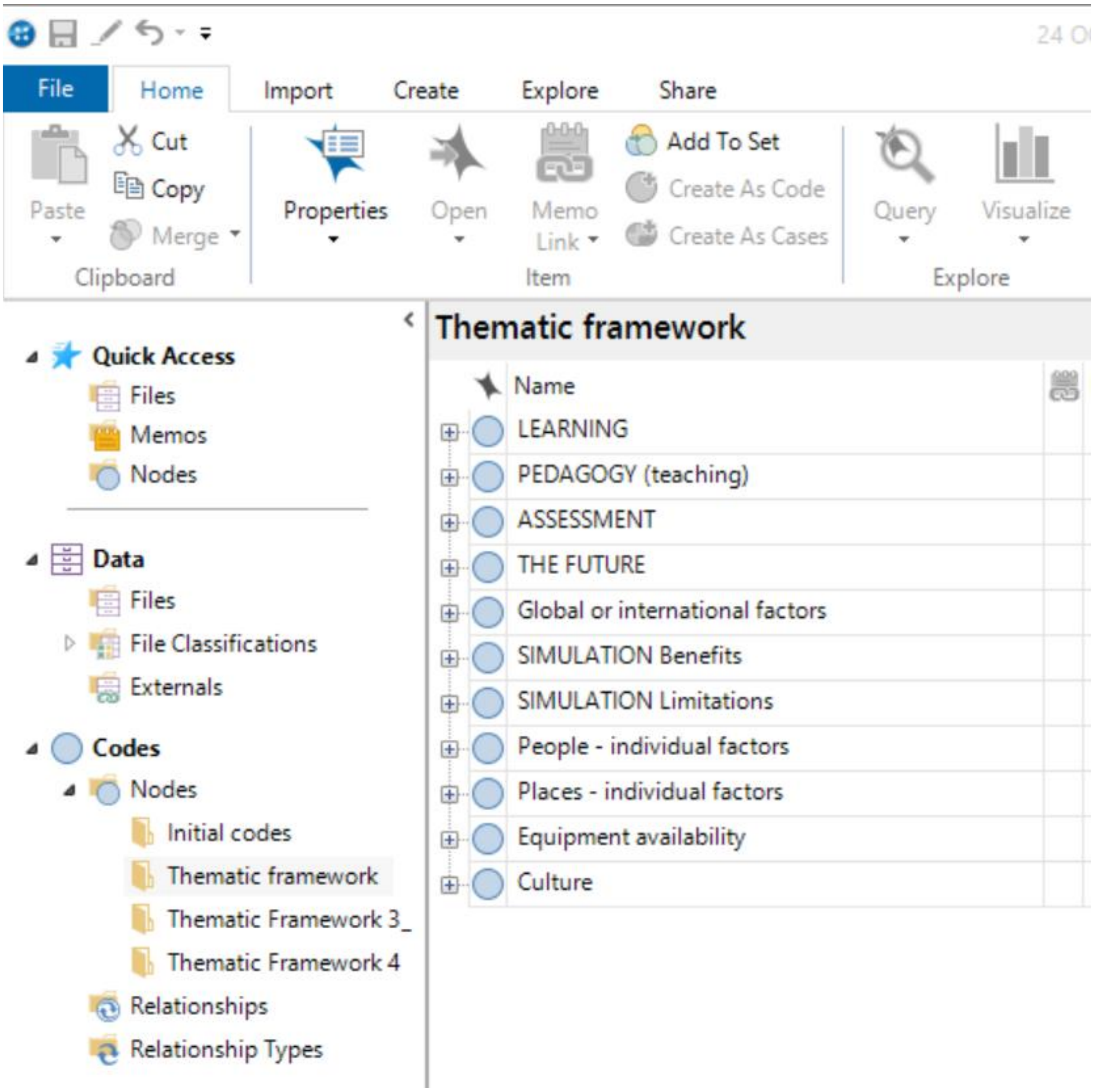
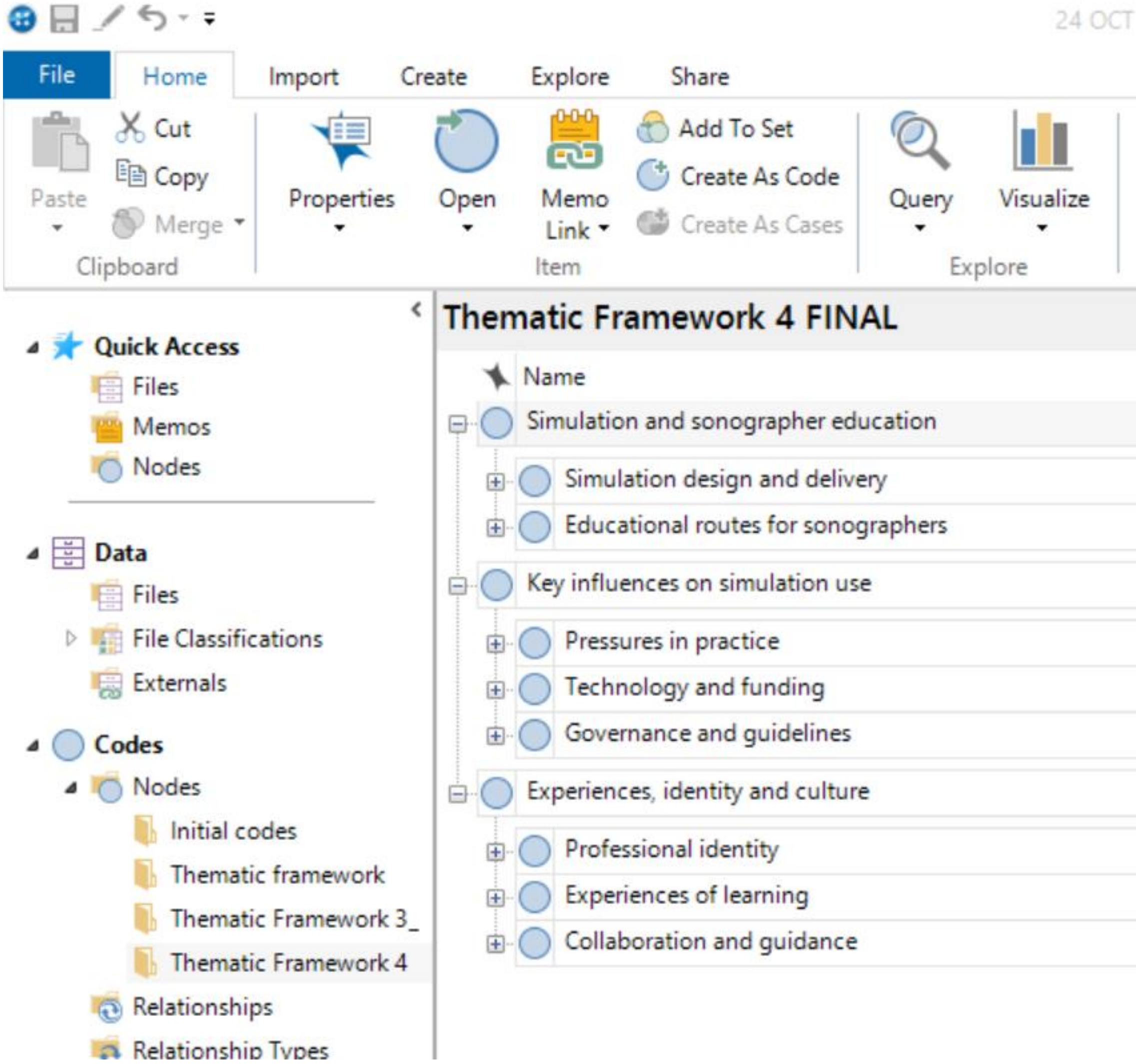


Figure A.2.6: Final stages of category development



Hierarchy charts provided a useful overall view of the data and distribution of subcategories (Figure A2.7). When the hierarchy chart was sorted, three core categories emerged which included consideration of the entire data set:

1. Simulation and sonographer education
2. Key influences on simulation use
3. Experiences, identity and culture

Figure A2.7: Mind map to organise subcategories and core categories

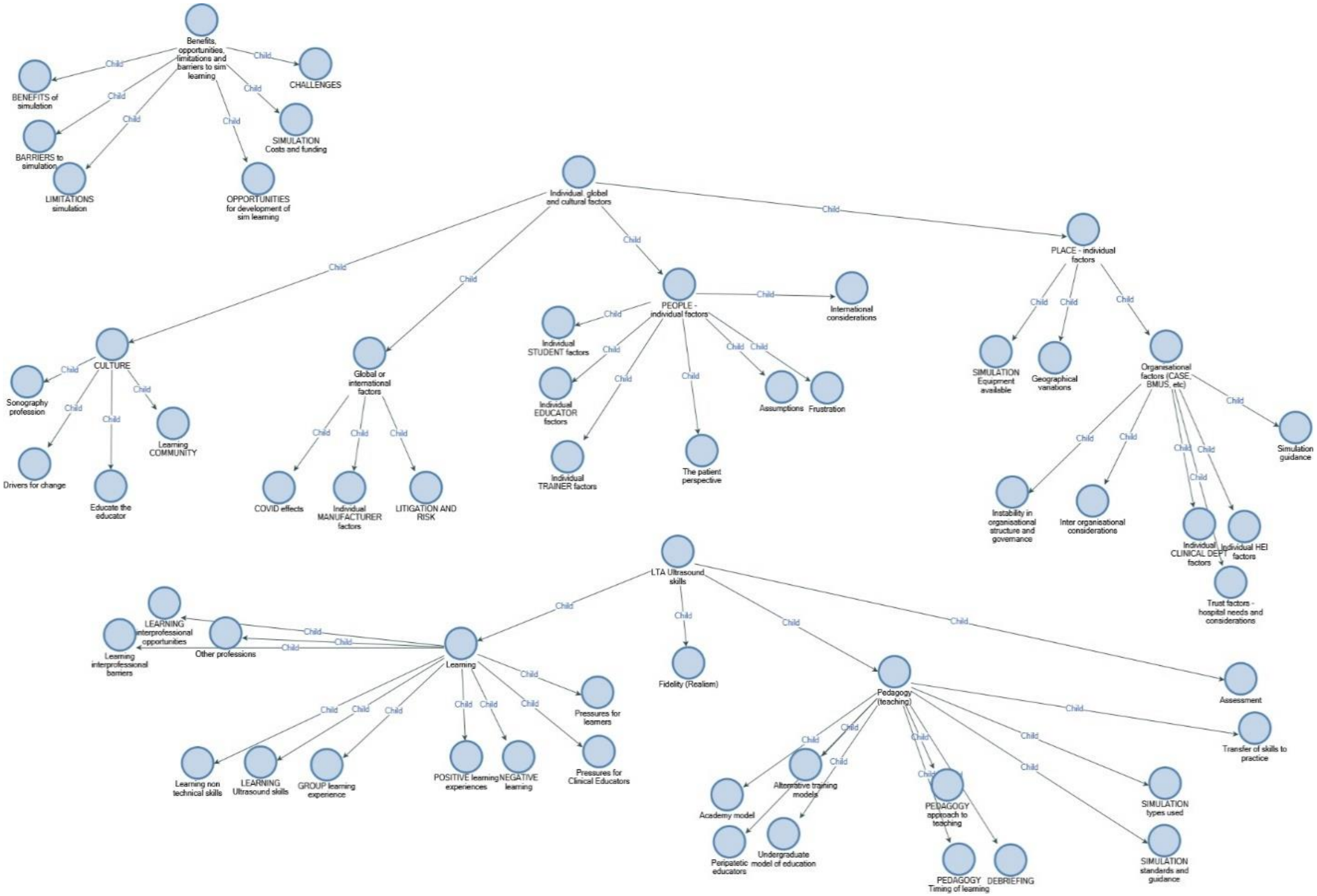


Figure A.2.8: Hierarchy Chart (Complete data set)

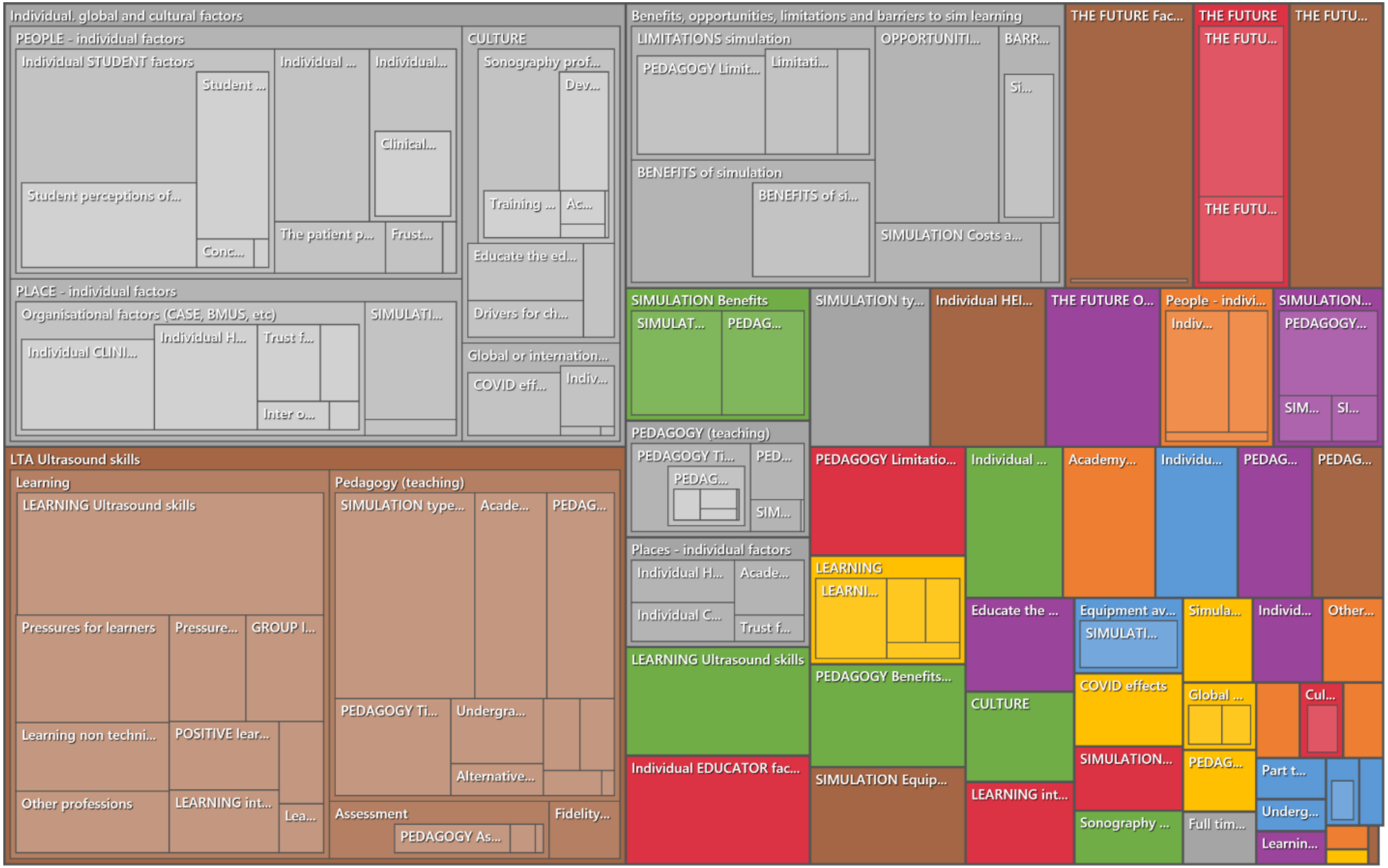
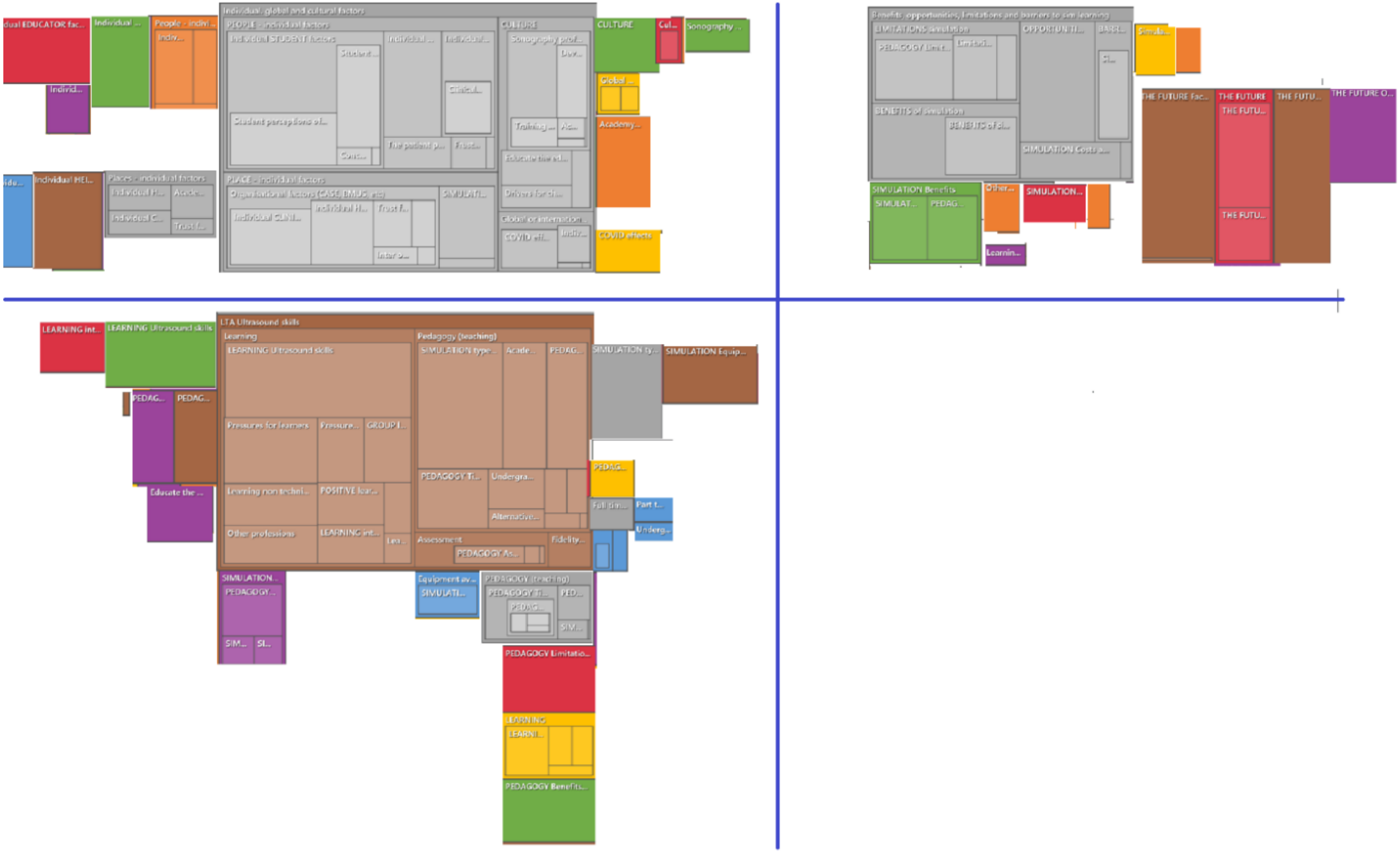


Figure A.2.9: Sorting of complete data set by final core categories



Appendix 3: Research dissemination

Conference presentations related to this thesis:

Hynes, C. (2022, July). Educator perspectives of simulation in sonographer education: constructivist grounded theory study [Oral presentation]. UKIO Congress, Liverpool, UK

Hynes, C., Nightingale, J. & Collins, M. (2022, September). A constructivist grounded theory study of the use simulation for Sonographer Education: Exploring educator experiences [Poster presentation]. NET 2022, Advance HE: Networking for Education in Healthcare Conference, Lancaster University, UK.

Hynes, C. (2022, December). The role of simulation in sonographer education. [Oral presentation: Invited speaker]. BMUS 2022, 53rd Annual Scientific Meeting of the British Medical Ultrasound Society. Cardiff, UK.

Hynes, C.M., Nightingale, J.M, & Collins, M. (2024, March). Simulation – the future of ultrasound education? [Poster presentation]. European Congress of Radiology (ECR) 2024, Vienna, Austria.

Hynes, C.M. (2024, June). The role of simulation in sonographer education: a constructivist grounded theory study [Poster presentation]. Doctoral School Postgraduate Research Showcase Event, Sheffield Hallam University, UK.

Hynes, C.M., (2024, November). Simulation in sonographer education: Student perspectives [Oral presentation]. Society and College of Radiographers Achieving Excellence in Radiography Education Conference 2024. Birmingham, UK.

Hynes, C.M. (2024, December). The role of simulation technology in teaching and learning. [Oral Presentation: Invited speaker]. BMUS 2024, 55th Annual Scientific Meeting of the British Medical Ultrasound Society. Coventry, UK.

A3.1 UKIO 2022 – Proffered Paper (presentation)

Hynes, C. (2022, July). Educator perspectives of simulation in sonographer education: a constructivist grounded theory study [Oral presentation]. UKIO Congress, Liverpool, UK

Abstract:

Title:

Educator perspectives of simulation in sonographer education: a constructivist grounded theory study.

Background

Simulation encompasses a wide variety of teaching methods, and it is increasingly used in healthcare education. The development of high-fidelity ultrasound simulators has increased the potential of this educational tool, but there is limited evidence on how simulation can effectively support sonographer education.

Method

This study formed part of a programme of research for a PhD award, with ethical approval obtained from Sheffield Hallam University. A constructivist grounded theory approach using qualitative interviews explored the views and experiences of 12 ultrasound educators using simulation for sonographer education. Individual interviews were conducted using online video conferencing. Interviews were recorded, transcribed and analysed using an inductive, constant comparative approach.

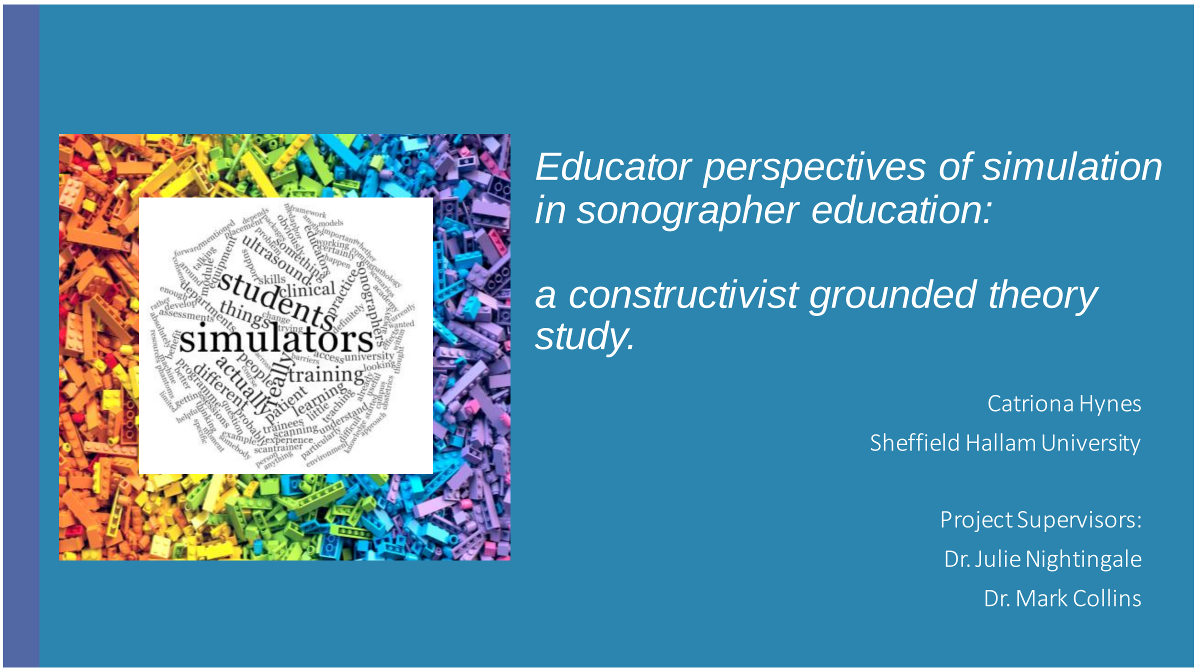
Results

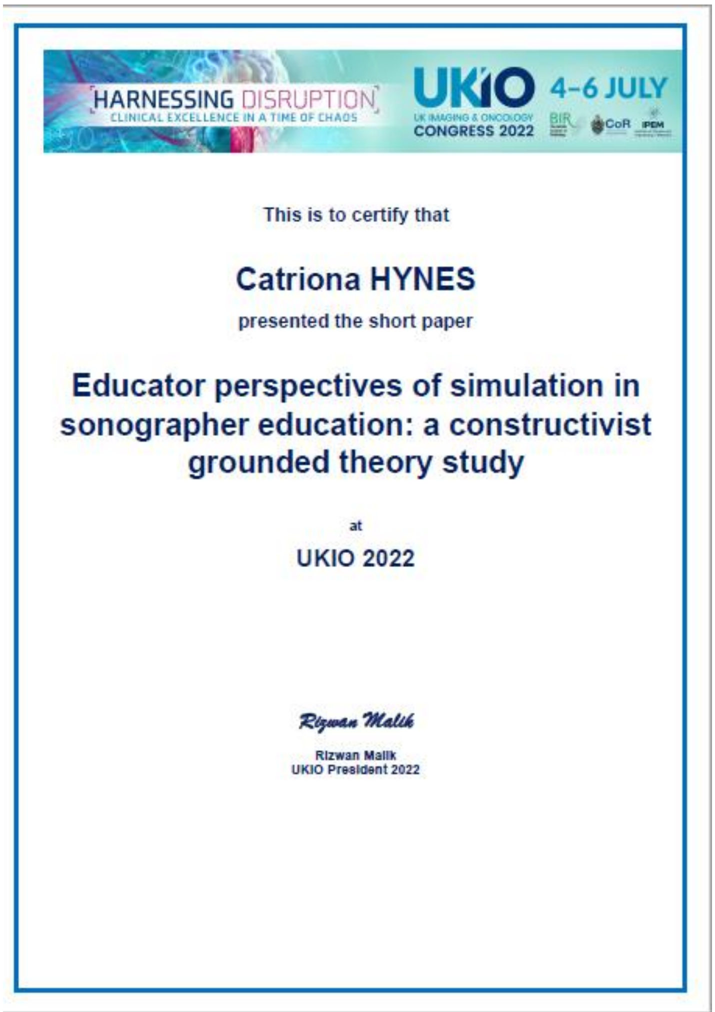
The study confirmed that simulation is regularly used in sonographer education, mainly using high fidelity task-trainers for self-directed student learning. The use of simulation learning is currently limited by availability of space and equipment, costs, time, and limited educator training in simulation as a pedagogical tool. Sonography educators showed enthusiasm for simulation learning, but simulation was not always embedded throughout the curriculum, and there is potential to use a wider variety of simulated learning more consistently in sonographer education.

Conclusion

There is huge potential to include a wide variety of well-designed simulations in sonographer education to enhance student learning, and to relieve some pressures on clinical trainers in busy and understaffed ultrasound departments. To facilitate this, time for design and planning, educator training and capital investment are required to allow simulation to be used to its' full potential for sonographer education.

A3.3.1 UKIO 2022: Proffered paper





This is to certify that

Catriona HYNES

presented the short paper

Educator perspectives of simulation in sonographer education: a constructivist grounded theory study

at

UKIO 2022

Rizwan Malik

Rizwan Malik
UKIO President 2022

A3.2 NET Conference 2022: Poster Presentation

Hynes, C., Nightingale, J. & Collins, M. (2022, September). A constructivist grounded theory study of the use simulation for Sonographer Education: Exploring educator experiences [Poster presentation]. NET2022, Advance HE: Networking for Education in Healthcare Conference, Lancaster University, UK.

Abstract: P3vii, 14:15 - 14:45, 7 September 2022

Poster presentation: A constructivist grounded theory study of the use simulation for Sonographer Education: Exploring educator experiences

Authors: Catriona Hynes, Professor Julie Nightingale & Dr Mark Collins, Sheffield Hallam University

Promotional abstract: The development of high-fidelity ultrasound simulators has increased the potential of this educational tool, but there is limited evidence on how simulation can effectively support clinical skills development in Sonographer training programmes. This study found that although there is huge potential to include a wide variety of well-designed simulations in Sonographer Education to enhance student learning, simulation strategies are not always implemented effectively or consistently in Sonographer Education. There is a need for educator training, time for design and planning, and capital investment to allow simulation to be used to its' full potential for Sonographer Education.

Main focus/category of, or issues addressed by, the poster: Simulation encompasses a wide variety of teaching methods, and it is increasingly used in Healthcare Education. The development of high-fidelity ultrasound simulators has increased the potential of this educational tool, but there is limited evidence on how simulation can effectively support clinical skills development in ultrasound training programmes. This study explored educator experiences in the use of simulation for Sonographer Education, including key challenges in using simulation for development of clinical skills in ultrasound practice.

Research approaches and underlying evaluation: This study formed part of a programme of research for a PhD award, with ethical approval obtained from Sheffield Hallam University. A constructivist grounded theory approach using qualitative interviews explored the views and experiences of eight ultrasound educators using simulation for Sonographer Education. Individual interviews were conducted using online video conferencing. Interviews were recorded, transcribed and analysed using an inductive, constant comparative approach.

Implications for healthcare education: The study confirmed that simulation is regularly used in ultrasound education, mainly using high fidelity task-trainers for self-directed student learning. The effective use of simulation for clinical skill development is currently limited by availability of space and equipment, high costs, time, and limited educator training in the use of simulation as a pedagogical tool. Educators showed enthusiasm for simulation learning, but simulation was not always embedded throughout the curriculum. There is huge potential to include more simulated learning in Sonographer Education, but to allow simulation to reach its full potential in ultrasound clinical skill development educators need training, time for design and planning, and capital investment.

References:

Burden, C., Preshaw, J., White, P., Draycott, T.J., Grant, S. & Fox, R. (2013) 'Usability of virtual-reality simulation training in obstetric ultrasonography: A prospective cohort study'. Ultrasound in Obstetrics and Gynaecology, 42(2), 213-217.

Charmaz, K. (2014) Constructing Grounded Theory, 2nd ed, London: SAGE Publications.
Gibbs, V. (2015) 'The role of ultrasound simulators in education: an investigation into sonography student experiences and clinical mentor perceptions.', Ultrasound, 23, 204-211.

McGaghie, W.C., Issenberg, S.B., Petrusa, E.R. & Scalese, R.J. (2010) 'A critical review of simulation-based medical education research: 2003–2009.' Medical Education, 44(1), 50-63.

Nestel, D., Kelly, M., Jolly, B. & Watson, M. (2018) Healthcare Simulation Education, Chichester, West Sussex: Wiley Blackwell.

Parsh, B. (2010) 'Characteristics of Effective Simulated Clinical Experience Instructors: Interviews with Undergraduate Nursing Students.' The Journal of Nursing Education, 49(10), 569-572.

Tolsgaard, M.G., Ringsted, C., Driesler, E., Norgaard, L.N., Petersen, J.H., Madsen, M.E., Freiesleben, N.L.C., Sorenson, J.L. & Tabor, A. (2015) 'Sustained Effect of Simulation Based and Gynaecology, 46(3), 312-318.

Keywords: Simulation. Ultrasound. Sonographer.

A constructivist grounded theory study of the use of simulation for Sonographer Education: Exploring educator experiences

Catriona Hynes, Sheffield Hallam University

Professor Julie Nightingale, Sheffield Hallam University

Dr Mark Collins, Sheffield Hallam University

BACKGROUND

Simulation encompasses a wide variety of teaching methods, and it is increasingly used in healthcare education. Long term workforce shortages of sonographers, and ongoing lack of clinical training capacity is restricting opportunities to develop newly proposed training frameworks to support the sonography career structure (Harrison & Beardmore, 2020). In order to expand the number of trainees, alternative approaches to clinical education are required (HEE, 2020). The development of high-fidelity ultrasound simulators has potential to increase sonographer training capacity, but there is limited evidence on how simulation can be most effectively used to support clinical skill development in ultrasound training programmes. This research aimed to investigate the role of simulation and develop recommendations to facilitate optimal learning when using simulation for sonographer education.

METHODOLOGY

This study formed part of a programme of research for a PhD award, with ethical approval obtained from Sheffield Hallam University. A constructivist grounded theory methodology (Charmaz, 2014) using qualitative interviews explored the views and experiences of eight ultrasound educators who had experience in using simulation for sonographer education. Individual interviews were conducted using online video conferencing. Interviews were recorded, transcribed and analysed using NVIVO12 software, with an inductive, constant comparative approach (Figure 1). Four key themes were identified, which are presented in Figure 2.

Figure 1: Methodology summary

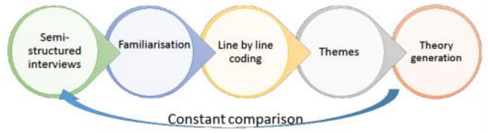


Figure 2: Key themes

Themes			
Individual, cultural and global factors	Benefits, limitations and barriers	Learning, teaching and assessment	The future

RESULTS

There is widespread use of high-fidelity task trainers for self-directed learning of specific practical skills for sonography trainees, with some tutor-led learning using simulators, phantoms and volunteers. Simulation learning largely focused on psychomotor skills development and recognition of ultrasound image appearances.

Individual, cultural and global factors

- Educators feel pressured in their roles, and **lack the time** required to effectively embed simulation learning in the curriculum. Working in isolation and feelings of frustration with processes, meant that educators feel **powerless to change**.

"we run out of time and have to prioritize getting the lectures............the simulation hub comes almost last in our thoughts"

- **Student engagement varied**, and **educators feel overwhelmed** by the volume and complexity of information on simulators.

"you could have loads of really good ideas, but it's actually very variable whether the students then engage"

Benefits, limitations and barriers

- Simulation seen as useful for confidence building, **psychomotor skill development** and recognition of image appearances to support theoretical teaching
- Use of live models is not suitable for all areas of practice, and there are various important **ethical considerations.**
- Educators feel the **equipment and space** currently available do not mimic clinical environments enough to enable high fidelity simulations.
- **Accessibility** of equipment, and high **costs** are limiting factors.

"There is only so much money you want to spend it, because there is a limit to how much the University has to spend on equipment, and the ultrasound courses aren't generally the most profitable, because they are relatively small programs."

Learning, teaching and assessment

- Overall educators had a **trial and error approach** to using simulation and were not well informed on existing national guidance and frameworks for simulation and TEL learning.
- There is little use of well structured lesson plans or **debrief,** and little use of simulation in summative assessments due to perceived limitations.
- Lack of regulatory framework for sonography, and feelings of professional protectionism meant that educators were disengaged from (or unaware of) institutional and national **simulation strategies**.

"Accrediting body does not recognize simulation placement hours" and "We have no regulatory framework (or adequate) oversight."

The future

- Although educators showed interest and willingness to learn, there is a **lack of ownership**, with educators wanting "someone" to develop sonography specific guidance.

"I think one of us needs to take the role in leading it........ somebody needs to take ownership of it and drive it forward and force us all into it."

- Development of new educational routes, demand for ultrasound training for other professionals, and development of training academies will increase use of simulation learning.

"I feel ultrasound has to be taken seriously and good quality training is the way forward to address the (workforce) shortages. I don't see how we're going to achieve addressing the workforce shortage if we don't do something differently."

CONCLUSION

The study confirmed that simulation is regularly used in sonographer education, mainly using high fidelity task-trainers for self-directed student learning. Currently there is a **disconnect between the vision and reality** in design and implementation of simulation in sonographer education, due to a lack of time, training and educator confidence to effectively use simulation throughout their curricula. Sonography educators showed enthusiasm for simulation learning, but simulation was not always embedded throughout the curriculum, and there is potential to use a wider variety of simulated learning more consistently in sonographer education. There is a **need for change** if use of simulation is to be optimized in sonographer education.

There is **huge potential** for use of simulation learning for sonographer education, but this should include a wider variety of well-designed simulations to enhance student learning. To facilitate this, **investment** in staffing and facilities, training, and time for design and planning are required to allow simulation to be used to its' full potential for sonographer education. The effective use of simulation for clinical skills development is currently limited by availability of space and equipment, costs, time, and limited educator training in the use of simulation as a pedagogical tool.

REFERENCES:

Charmaz, K. (2014). *Constructing grounded theory* (2nd ed.). SAGE Publications.

Harrison, G., & Beardmore, C. (2020). Ultrasound clinical teaching capacity in England: A scoping exercise. *Radiography, 26*(1), 3-8. 10.1016/j.radi.2019.09.005

Health Education England. (2018). *Sonography.* Health Education England. https://www.hee.nhs.uk/our-work/so

Contact details

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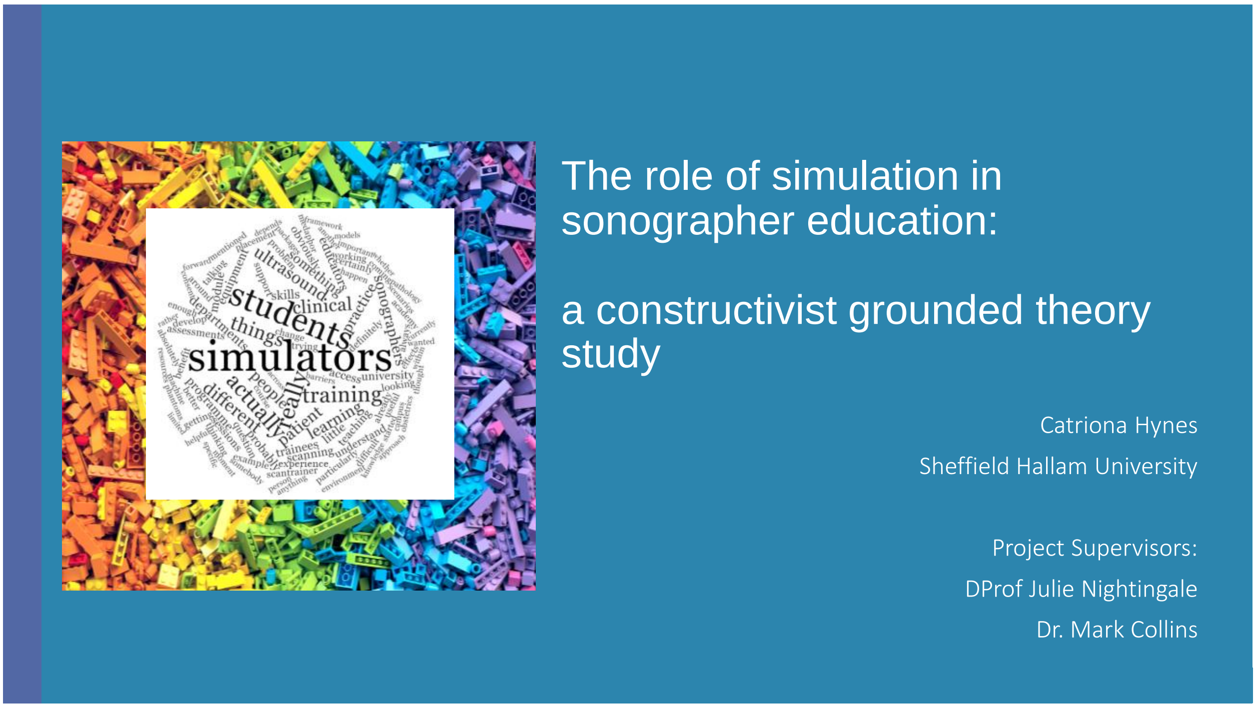
Download this poster:

A3.3 Invited Speaker: 52nd Annual Scientific Meeting of the British Medical Ultrasound Society (BMUS) 2022:

Hynes, C. (2022, December). The role of simulation in sonographer education. [Oral presentation: Invited speaker]. BMUS2022, 53rd Annual Scientific Meeting of the British Medical Ultrasound Society. Cardiff, UK.

Title: The Role of simulation in sonographer education



BMUS

CPD Certificate

I certify that

Catriona Hynes

Attended

Ultrasound 2022

On

6th December 2022

As an Invited Speaker / Faculty Member

Ultrasound 2022
6th - 8th December 2022
at
Cardiff City Hall

Mrs Pamela Parker
BMUS President

This course has been approved by
BMUS for 7 category 1 CPD points

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A3.4 ECR 2024 – E-Poster

Hynes, C.M., Nightingale, J.M, & Collins, M. (2024, March). Simulation – the future of ultrasound education? [Poster presentation]. European Congress of Radiology (ESR) 2024, Vienna, Austria. DOI: 10.26044/ecr2024/C-12568

DOI-Link: https://dx.doi.org/10.26044/ecr2024/C-12568

Abstract: ECR Abstract #12568

Title: Simulation – the future of ultrasound education? A constructivist grounded theory study.

Presenting Author: Catriona Hynes

Author block: C. M. Hynes, J. M. Nightingale, M. Collins; Sheffield/UK

Topic: Ultrasound

Presentation Format: Poster presentation

Purpose or Learning Objective:

Growing demand for ultrasound services and workforce shortages negatively affect sonographer training. Simulation has potential to support student learning and support transition to practice. This study aimed to investigate the role and scope of simulation in sonographer training, and to develop recommendations to facilitate optimal learning.

Methods:

Following ethical approval, qualitative online interviews explored the views and experiences of 21 participants involved in UK ultrasound education. Participant groups included national stakeholders, academic staff and sonography students. Interviews were recorded, transcribed and analysed using a constructivist grounded theory approach.

Results or Findings:

The study confirmed that simulation is regularly used in UK sonographer education, mainly for technical skill development. Most participants showed enthusiasm for simulation learning, but simulation was not consistently embedded in curricula; there is potential to use a greater variety of simulated learning to develop a broader range of skills.

The effective use of simulation is currently limited by availability of space and equipment, costs, time, and limited educator training in the use of simulation as a pedagogical tool. Educators need to be well informed and engaged to ensure learners get most benefit from simulation learning, yet there is a lack of specific guidance for effective implementation of simulation in sonographer education.

Conclusion:

Simulation for ultrasound education is in its infancy, and there is huge potential to develop a wide variety of well-designed simulations in sonographer education. This in-depth exploration of experiences of using simulation is the first step in informing the effective design and delivery of ultrasound education. This study provides recommendations for good practice in the effective use of simulation in sonographer education.

Limitations:

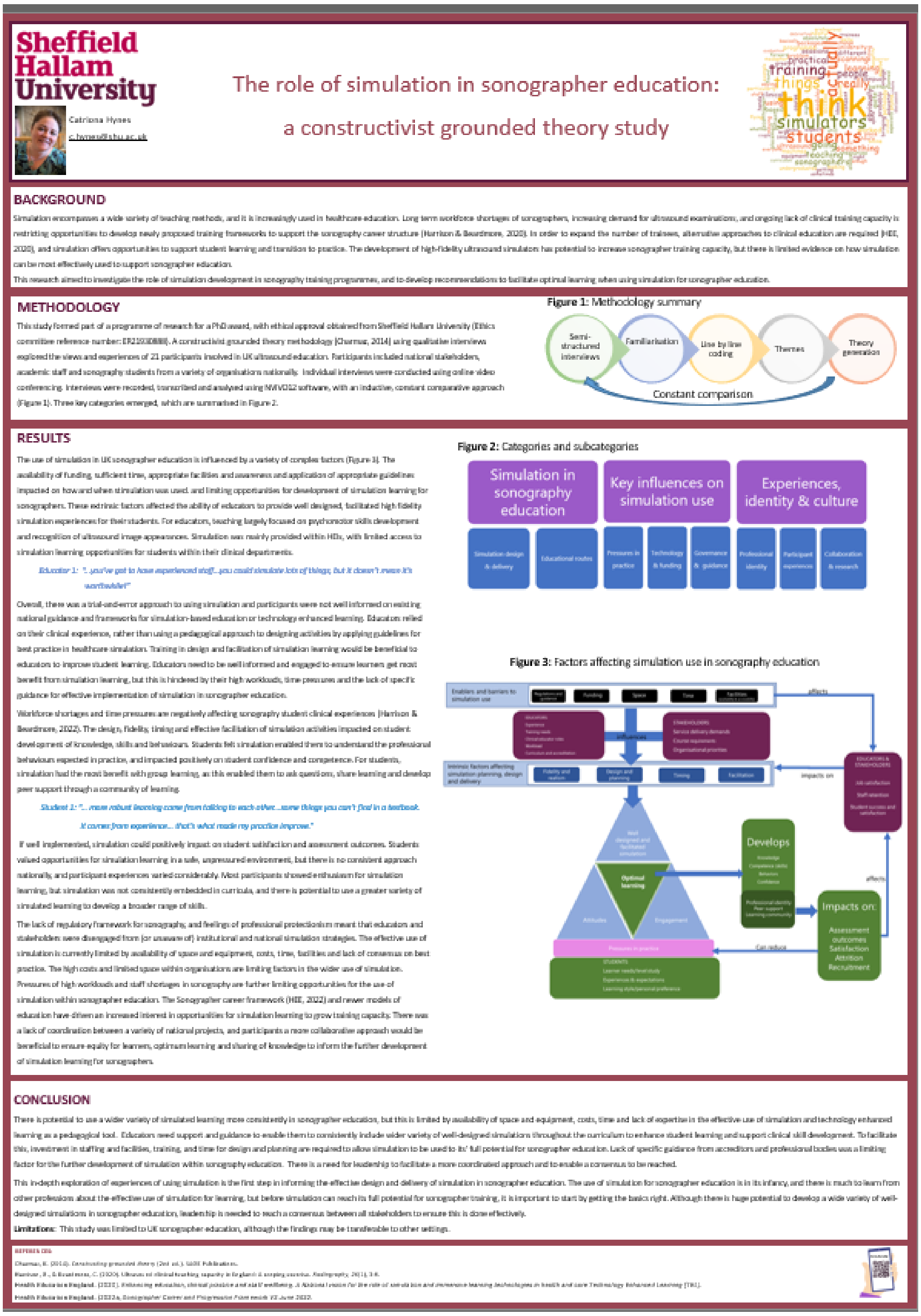
The study was limited to UK sonographer education, although the findings may be transferable to other settings.

Funding for this study: No funding provided.

Has your study been approved by an ethics committee? Yes

A3.5 Sheffield Hallam University Postgraduate Research Showcase 2024

Hynes, C. (2024, June). The role of simulation in sonographer education: a constructivist grounded theory study [Poster presentation]. Doctoral School Postgraduate Research Showcase Event, Sheffield Hallam University, UK.



A3.6. Achieving Excellence in Radiography Education & Research Conference 2024

Hynes, C.M., (2024, November). Simulation in sonographer education: Student perspectives [Oral presentation]. Society and College of Radiographers Achieving Excellence in Radiography Education Conference 2024. Birmingham, UK.

Abstract:

Title: Simulation in sonographer education: Student perspectives

Themes: Simulation, Research-informed education

Introduction

Demand for ultrasound services is growing, but chronic workforce shortages negatively impact sonographer training. The aim of the study was to investigate the role of simulation and develop recommendations to facilitate optimal learning when using simulation for sonographer education.

Methods

This study was completed with ethical approval obtained from Sheffield Hallam University. Qualitative interviews explored the views and experiences of 7 sonography students across UK HEIs were completed as one phase of a larger PhD study. Individual online video interviews were conducted, recorded, transcribed and analysed using a constructivist grounded theory approach.

Results

Most participants showed enthusiasm for simulation learning. Although simulation was regularly used in UK sonographer education, this was mainly for technical skill development, and simulation was not consistently embedded in curricula. Students valued simulation learning which provided opportunities to support their development of a new professional identity, learning opportunities which ensured their psychological safety, and opportunities to build a community of peer support.

Conclusion

There is potential to use a greater variety of simulated learning for a broader range of skill development in sonographer education. Educators must be well informed ensure learners get most benefit from the potential of simulation learning. Simulation for ultrasound education is in its infancy, and there is huge potential to develop a wide variety of well-designed simulations in sonographer education. This in-depth exploration of experiences of using simulation for sonographer education is of considerable interest in ensuring student perspectives inform the effective design and delivery of ultrasound education.

A3.7 Invited speaker: 54th Annual Scientific Meeting of the British Medical Ultrasound Society (BMUS) 2024

Hynes, C.M. (2024, December). The role of simulation technology in teaching and learning. [Oral Presentation: Invited speaker]. BMUS2024, 55th Annual Scientific Meeting of the British Medical Ultrasound Society. Coventry, UK.