Investigating and Supporting the Understanding and Application of Chemistry within the Pharmacy Degree Programme

Marianne Rial

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Abstract

Pharmacy education continues to evolve with the increasingly clinical role of the pharmacist in the UK healthcare system. The importance of chemistry within the pharmacy degree has been a long-debated topic. However, the subject's significance continues to be recognised within regulatory education standards in the UK and around the world. Chemistry holds a pivotal role in underpinning clinical knowledge for pharmacists. The understanding of chemical concepts allows them to make more informed decisions on the medication they are recommending or prescribing. Nonetheless, chemistry can be complex, and students may struggle to connect some of the abstract concepts within chemistry to real world application in pharmacy practice. There are few previously published studies that have investigated learning chemistry on a non-chemistry major degree, so this study aimed to fill this gap in the literature.

This study set out to gain a deeper understanding of any factors affecting the learning of chemistry on the pharmacy programme, staff and students perceptions of chemistry within the degree and the impact of curriculum approaches. Finally, it endeavoured to support pharmacy students in understanding and applying their chemistry knowledge in a pharmacy context.

A mixed methods approach was selected to utilise both qualitative and quantitative data collection and analysis. This methodology allowed the research questions to be addressed with a greater breadth and depth. A sequential model with three phases was used. The first phase analysed possible factors affecting engagement and attainment in a first-year chemistry module. It found that some demographic factors appeared to influence engagement with, but not attainment on, a piece of summative coursework. The second phase explored academic staff and pharmacy students' perceptions of chemistry in the pharmacy degree. It then explored students' perceptions of the curriculum structure. Students' understanding of thinking integratively, i.e. connecting their knowledge between chemistry and clinical teaching, was also discussed. Among the identified themes, the importance of relevance and the ability to integrate underpinning science with practice were highlighted. The findings from these two phases enabled a detailed identification of the issues and were subsequently used to inform the development of a teaching intervention. In the third phase, a series of patient focused case-based workshops were designed and delivered. These workshops encouraged group work and development of higher order thinking skills like clinical problem solving using their chemistry knowledge. This teaching

was evaluated by the students who considered what improvement in skills they perceived and what future support would be beneficial for them.

Having students as partners in some of the data collection was also a key component of this doctoral study. They specifically worked with the researcher during the student qualitative data collection. They provided thoughtful insights into the question development of the research tools, and their involvement enhanced the richness of the dataset and the authenticity of the approach.

The term ‘relevance’ was highlighted by both staff and students throughout the qualitative data analysis. However, although students wanted ‘relevant’ chemistry teaching, their specific perceptions on this varied between individuals depending on previous experiences and career aspirations. Students’ integrative thinking skills were not consistently demonstrated without guidance and scaffolding. Clear contextualisation of chemistry with relevance to practice helped students feel engaged and think in a more integrative way. Students appreciated a patient-focused approach to learning chemistry and engaged well with this method of teaching due to its clear link to their future role in clinical practice.

This thesis provided a deeper understanding of students’ perceptions on chemistry within the pharmacy degree. It identified pharmacy students’ specific needs, helping them to use chemistry in an applied and meaningful way. The findings suggest that students need to be introduced to integrative thinking from the beginning of the programme and chemistry needs to be more integrated into practice teaching to allow them to appreciate, understand and apply the underpinning science behind their clinical knowledge.

This research highlights the continuing importance of learning chemistry with understanding and application as part of students’ preparation to become a pharmacist. It can be used to inform the strategic and operational approach to this area of teaching on the MPharm degree, using chemistry conceptual understanding to develop critical thinking skills and justify clinical decisions. This understanding of the fundamental science supporting clinical practice is pharmacists’ unique selling point and an important contribution to the multidisciplinary team.

Glossary

ACPE	Accreditation Council for Pharmacy Education
BERA	British Educational Research Association
CCAPP	Canadian Council for the Accreditation of Pharmacy Programs
COVID 19	Corona virus identified in 2019 resulting subsequent restrictions in large gatherings and therefore affecting teaching during subsequent years
CPD	Continuing Professional Development
DAM	First-year module for pharmacy students called Drugs and Medicines- focusing on chemistry using a contextualised approach
DH	Department of Health
Foundation year	12 months training placement for UK pharmacy graduates focusing on application of knowledge and skills (previously called pre-registration year)
GCSE	General Certificate of Secondary Education
GPA	Grade point average -academic achievement score used in the US but increasingly recognised internationally.
GPhC	General Pharmaceutical Council - the regulatory body for pharmacists and pharmacy technicians initially formed in 2011
HE	Higher Education
HESA	Higher Education Statistics Agency
MCQ	Multiple choice question
MMR	Mixed methods research
MPharm	Master of Pharmacy degree (currently the required accredited undergraduate degree needed prior to embarking on foundation year.
NHSE	National Health Service England
NSAID	Non-steroidal anti-inflammatory Drugs
OfS	Office for Students
PharmD	Doctor of Pharmacy (more commonly a US qualification) but increasingly seen in UK for pharmacists as post graduate study
POGIL	Process- orientated guided inquiry learning
Pre-registration year	Previous name for Foundation year (Was sometimes abbreviated to ‘pre-reg’).
QAA	Quality Assurance Agency
RPS	Royal Pharmaceutical Society- the representative pharmacy body in the UK since 2010 (to be replaced by Royal College of Pharmacy in April 2026)
RPSGB	Previous UK regulatory and representative body for pharmacists (disbanded by 2010 following Shipman review – see GPhC and RPS for current pharmacy bodies)

SChemEs	Structured Chemistry Examinations (inspired by OSCEs see Kirton et al.; 2014)
TA	Thematic analysis
TEF	Teaching Excellence Framework
THE	First year module for pharmacy students called Transition to Higher Education - focusing on knowledge and skills need for a pharmacy qualification in Higher Education
WHAMM	A mnemonic commonly used in community pharmacy to gather information to help diagnose and treat a patient's complaint
WP	Widening participation - strategy to improve access and support for students from under-represented groups

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Chapter 1- Introduction

This chapter discusses the importance of learning and teaching of chemistry within pharmacy programmes before presenting the aims and research questions that this thesis addresses. There is discussion on the learning of chemistry, the relevant background to pharmacy education, and the role chemistry plays within that structure, with the perceived issues identified and outlined. The relevant pedagogy to this area is also initially outlined and will be explored in further depth in future chapters. The exploration and explanation of these issues allow the researcher to frame the importance of learning chemistry with understanding and application within this context.

Chemistry is found at the core of this thesis with an important role in pharmacy as both a scientific and healthcare profession (Taylor & Harding, 2016). Understanding the chemical principles of pharmaceutical products allows pharmacists to make more informed decisions about patient care and their strong underpinning chemistry background differentiates them from other members of the multidisciplinary healthcare team (Mobley et al., 2024). Although the understanding of chemistry is important to ensure safe and effective delivery of pharmaceutical care (Krol & Albon, 2025), students may struggle to connect some of the abstract concepts within chemistry to real world applications in practice (Gilbert, 2006; Johnstone, 1991). This disconnect can have an impact on attainment and thus on academic progression (Guile & Ahamed, 2011). Gaining a deeper understanding of student and staff perceptions in this area as well as exploring appropriate and relevant pedagogical approaches and teaching strategies will help design support that could potentially foster deeper learning with understanding and application. It is hoped that this research can contribute to the continued improvement and enhancement of pharmacy education and also improve the quality and skill set of these future pharmacists as appropriately scientifically grounded healthcare professionals.

Following exploration of the issues and further identification of any support needed with the learning and teaching of chemistry, this thesis aims to design, develop and implement an innovative supportive teaching intervention. This teaching intervention aims to be a specifically relevant foundation for students to understand the chemistry needed for pharmacy students.

1.1 Being a Pharmacist in the UK

Pharmacists are registered health care professionals regulated by the General Pharmaceutical Council (GPhC) in the United Kingdom (GPhC, 2024). Although the pharmacy profession has a traditional foundation in scientific principles, it’s identity now has an increasingly significant clinical component to meet the needs of patients and healthcare systems as well as estimated future workforce requirements (HEE, 2019). Pharmacists play a crucial role within the healthcare setting, providing expertise on a wide range of issues relating to medications with their knowledge on drugs underpinned by their understanding of chemistry (RPS, 2019).

Currently, successful completion of a four-year Master of Pharmacy (MPharm) degree as well as one year of foundation training and a pass in the national registration exam are required to register as a pharmacist in the UK (GPhC, 2023).

1.2 Learning chemistry

1.2.1 The chemistry triplet

Learning and understanding of certain areas in chemistry have been recognised as difficult for some learners. Johnstone's pivotal paper presents the model of the chemistry triplet as a possible explanation for students' difficulties in chemistry (see figure 1). This concept set out in Johnstone (1991) acknowledges that chemistry is a complex subject that can be challenging for learners. He explains that the subject can consist of three main aspects: macroscopic elements, sub-microscopic elements and further representation through chemical symbols. It can potentially be difficult for students to understand all three elements at the same time. The macroscopic element can often be seen or smelt and is a tangible element, for example when carrying out an experiment and witnessing a colour change from the chemical reaction taking place. The sub- microscopic nature of chemistry however is not visible, for example atoms and electrons, so can be very challenging to understand and put into context as a new concept. Finally, the symbolic level of the triplet can be the mathematical formula and chemical symbols for elements which is another component to remember. Johnstone chose the triangle shape to emphasise that no aspect was more important than the other.

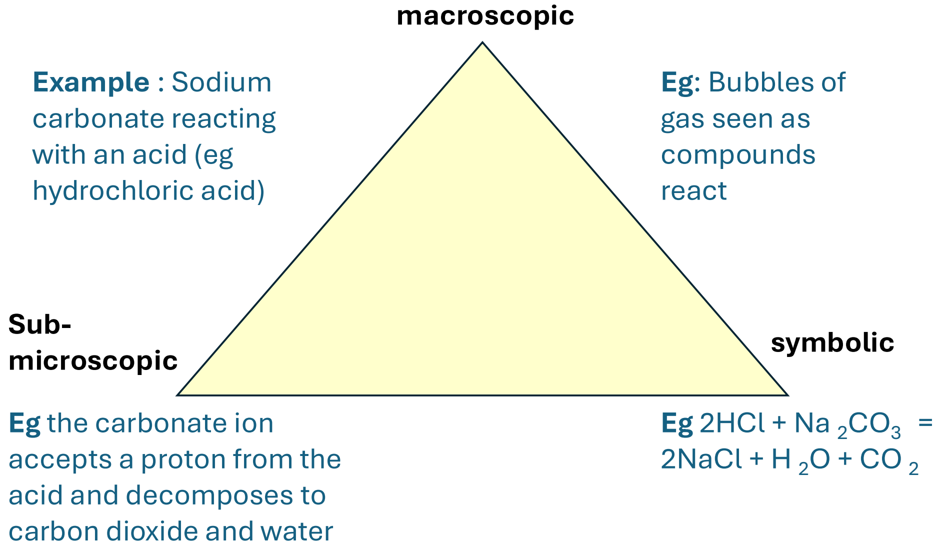

Figure 1 – The chemistry Triplet, adapted from Johnstone, (1991) with an added specific example to illustrate the three elements

1.2.2 Limits of memory capacity

Johnstone's earlier work within science education examined chemistry exam questions and the demand (i.e. the number of thought steps) they required to successfully answer them (Johnstone & El-Banna, 1986). Further work in this area hypothesised the success in correctly completing a question was related to the students working memory capacity. If the demand in the question exceeded their working memory, then the student's academic performance would fall (Johnstone & El-Banna, 1989). The working memory, rather than the long-term memory, is used for new and complex information that does not yet make sense to the learner. It has a limited capacity which clearly has an important impact on learning. Students can hold several pieces of information at the same time in the working memory, but it has a genetically defined capacity which is termed 'information load' (Baddeley et al., 2020). Chemistry often has topics with a high information load where students are required to hold many pieces of information at the same time in order to successfully understand the new learning. Johnstone and El-Banna's research (Johnstone & El-Banna, 1986, 1989) hypothesised that once students' working memory capacity was reached, their exam performance rapidly dropped.

Research into how the brain processes information and the subsequent hypotheses provides some further comprehension into understanding how learning can take place (see figure 2). With this knowledge and understanding of the processes involved when learning chemistry, how best to support students when studying a topic that is cognitively demanding and requires multiple thought steps can be considered. In this context, research into working memory and the brain's processing ability can provide some useful insights.

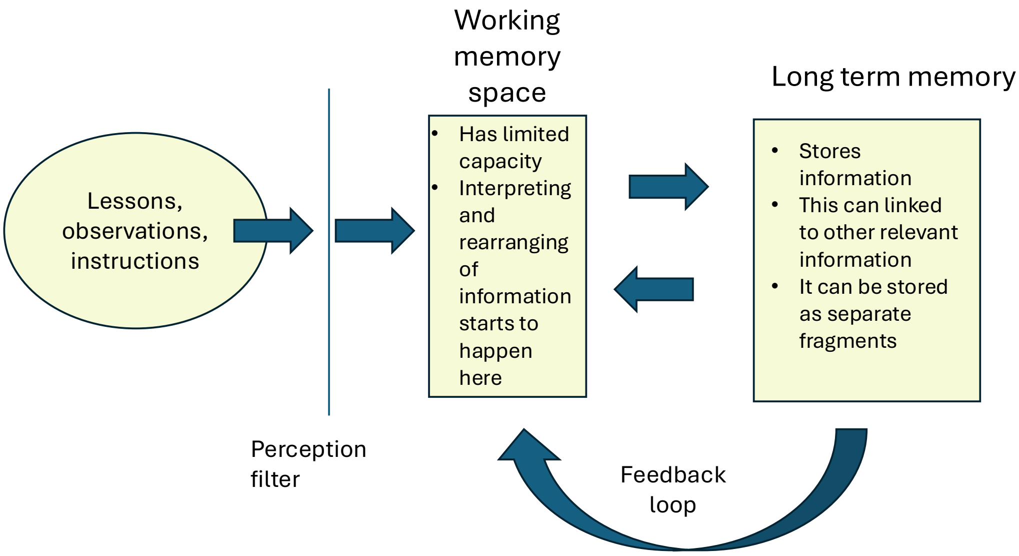

Figure 2 – An Information processing model (adapted from (Reid, 2008))

Reid (2008) highlighted the importance of adapting chemistry teaching to acknowledge the limited capacity of the working memory by summarising results of a range of experiments. Adaptions such as breaking down a complex task or topic into smaller chunks can make learning more manageable. He found that this adaptation improved student performance and acknowledged that this type of response was seen in previous studies. For example, having identified a drop in student performance when multiple steps were needed in a question, Johnstone & El-Banna, (1989) also explained that they noticed students could increase their performance again if they had a strategy to structure the questions into smaller chunks.

An additional strategy to reduce the load on the working memory mentioned by Reid, (2008) was the concept of pre-learning. With some information within the long-term memory, there is less 'new' information so less to be stored in the limited capacity working memory.

The relevance of this limitation and its impact on students' learning influences the research within this thesis so is discussed further in section 5.1.3 when considering curricular overload.

1.2.3 Beyond the chemistry triplet

Whilst the complexity of chemistry illustrated by the chemistry triplet (Johnstone, 1991) provides some insight into learning chemistry, further research following its initial publication highlights the limitations of this model and other factors that influence the learning of chemistry.

Differences in how students and educators can interact and understand a concept when using the triplet has been recognised. Research considering how an expert may learn and understand a concept when compared to a novice to the subject has been investigated. Kozma & Russell (1997) found distinct differences between the two groups. This can be related to the deep understanding of concepts already held by experts as opposed to the novices who will need to acquire, process and understand all aspects of the subject. Understanding the language of chemistry was also shown to have an impact on the novice's ability to learn. It is essential that these highlighted differences are acknowledged when academics, as experts, are planning teaching sessions for novice students.

Continuing on this theme, other researchers have stressed the need for adaption of teaching methods when considering the chemistry triplet. It was specifically designed so no one component of the triplet was considered more important but this is potentially too simplistic and does not acknowledge the diversity of some student populations. Rees et al., (2018) discovered students with English as an additional language largely benefited from supplementary teaching solely on chemistry language in combination with the standard chemistry module teaching.

Other researchers have critically discussed the overarching use of this pedagogical model. Talanquer, (2011) acknowledged the benefits of the triplet but also provided a critical perspective. He argued that for some complex concepts, the triplet is not able to fully capture this complexity and distinctions between each component of the triplet is not always clear. He provides a much more complex model which aimed to encompass many dimensions of chemistry. These criticisms do have an impact on teaching chemistry and whilst he suggested the triplet should continue to be used, it should not be a singular approach, and educators need to go beyond this to help students with their understanding of concepts.

Taber, (2013) revisited the triplet and argued that if students are struggling with the complexity, opportunities can be given to re-enforce the ideas through contextualisation but the depth in which the topic is being explored can also be reduced.

1.2.4 Contextualisation

Whilst the chemistry triplet can encourage students to apply knowledge and demonstrate understanding by describing a concept through all three components of the triangle, contextualisation goes one step further. Contextualisation can support students if they are struggling with complexity for several reasons (King et al., 2008). By putting the chemistry concept into a context, it allows students to link abstract concepts to everyday life, this potentially reduces perceived complexity. This context can allow the student to link to their prior knowledge and by building on previous knowledge, it can reduce the load on the working memory. Several researchers have also noticed that students seem more motivated by this method of context-based learning (Bennett & Holman, 2003; Gilbert, 2006; Vaino et al., 2012).

The pivotal paper by Gilbert (2006) outlined criteria for successfully contextualising chemistry teaching, providing four different models and he argued this method of teaching helps students focus on how facts are connected, keeping them engaged and improving understanding rather than attempting to learn facts in isolation. The concept of contextualisation has influenced the design and development of teaching interventions to encourage understanding and application when learning chemistry within pharmacy (Fergus et al., 2015, 2019). Within the wider chemistry setting, it has been used within secondary education both internationally (Parchmann et al., 2006) and in the United Kingdom (Bennett & Lubben, 2006).

Although it has an imperative science focus, pharmacy is a vocational degree. The concept of contextualisation can be applied as a way of bridging the gap between theoretical chemical principles and their real-world pharmaceutical application (Fergus & Kostrzewski, 2011). This helps demonstrate how relevant the topic is to the student.

In addition to the chemistry triplet education model, the published research on learning chemistry often also links to the way teaching material is delivered and experienced by students and how these impact on their learning. The pedagogical concepts discussed in this section will be revisited and will be explored in greater depth throughout the thesis, specifically in relation to each of the research questions and the corresponding research projects conducted.

1.3 The current structure of pharmacy education within the Higher Education setting in the UK

The GPhC, as the profession's regulator, is also responsible for regulating and maintaining the standards of pharmacy degrees and subsequent training.

The structure of undergraduate pharmacy education has undergone multiple changes over the last twenty years, adapting due to the changes in patient populations and the required healthcare provision and subsequent changes in legislation (NHS England, 2019, 2023; Smith & Darracott, 2011). These structural changes have impacted on the chemistry and science content and the emphasis of it within the degree. An understanding of the history and circumstances surrounding these changes helps to explain the position of chemistry within today's pharmacy curriculum.

Prior to 1997, the pharmacy degree was designed and developed as a 3-year Bachelor of Science course to ensure that an appropriate curriculum of science and clinical material could be taught (Taylor & Harding, 2016). However, the role of the pharmacist began to evolve beyond one of extemporaneous preparation and dispensing. The increasing number and complexity of medications being used meant that a more clinical role was called for (Sosabowski & Gard, 2008). In line with the Bologna declaration to ensure more parity with pharmacy degree courses across the European Union (European Education Area, 2022) the degree increased from a three year to a four-year course (Smith & Darracott, 2011) (Sosabowski & Gard, 2008).

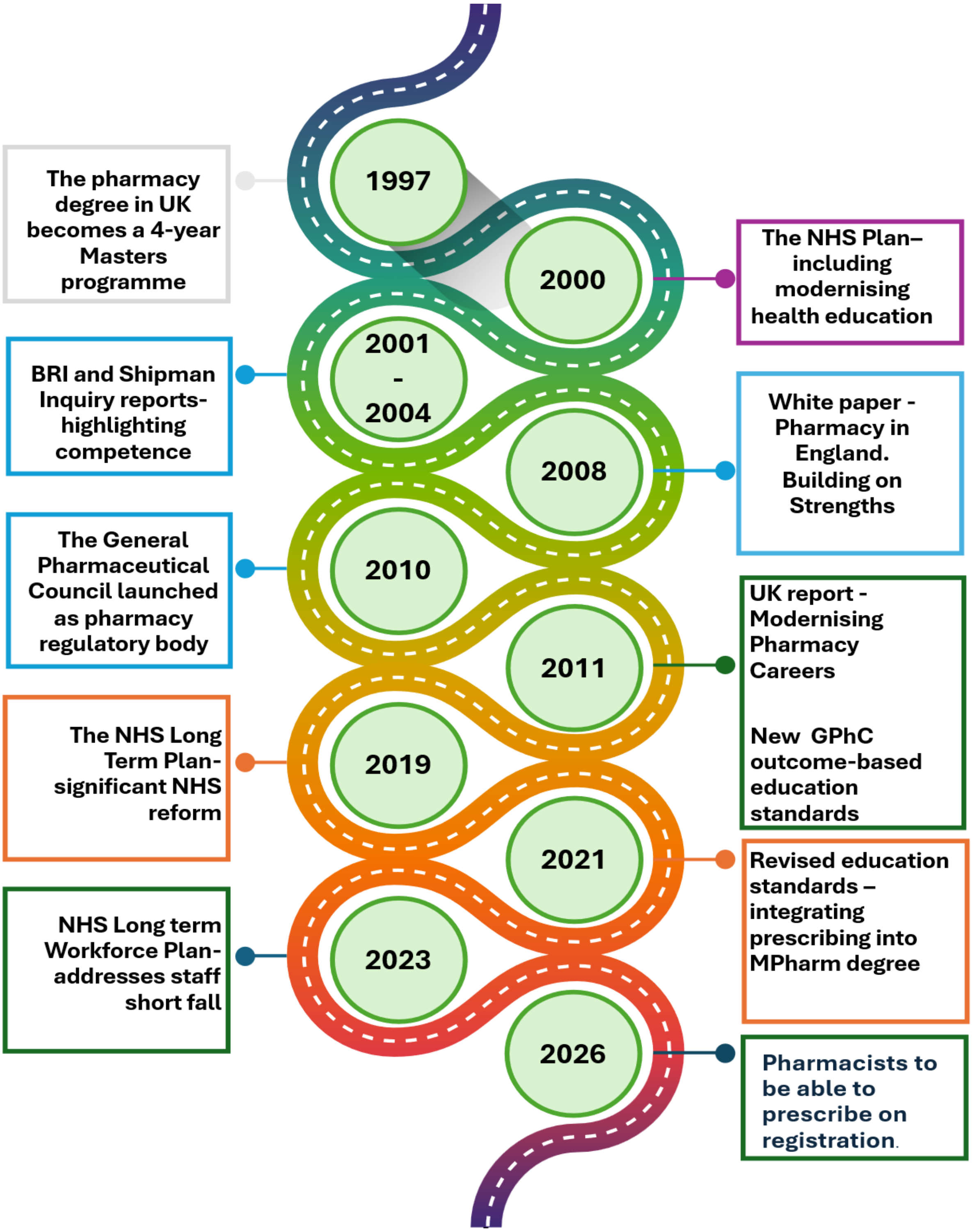

Figure 3 – Summarised timeline of relevant history from the introduction of the four-year degree programme to the present day

The NHS Plan (NHS, 2000), a policy document setting out the government's plan for reform and investment, emphasised the diverse and valuable role of many healthcare professionals and specifically stated that pharmacists would continue to move away from a dispensing role to medicines management roles.

To help guide decisions on the UK pharmacy education changes needed to meet these new roles, several projects were commissioned by the Pharmacy Practice Research Trust to help shape future education using the best possible evidence (Willis et al., 2006; Willis & Hassell, 2007; Wilson et al., 2006, 2005; Wright et al., 2006). The research project by Wright et al., (2006) compared pharmacy education and training in the UK with other developed countries namely Australia, New Zealand, the USA and Canada. It found that, in these other countries, the design and assessment of their degree courses differed significantly from the UK. The methods of assessment were more competency based in other countries with a "wide digest of different assessment methods" (Wright et al., 2006, page 44) when compared to pharmacy education in the UK.

The increasingly clinical role of pharmacists continued to evolve and was supported on a national political stage; a government white paper 'Pharmacy in England: building on strengths- delivering the future' (Department of Health, 2008) confirmed the expansion of the pharmacists' role and also specifically mentioned a more appropriately clinical approach to pharmacy education.

The General Pharmaceutical Council was formed in 2010 following a requirement to separate regulatory and representative body functions (The Pharmacy Order, 2010). A review of the education structure in the UK, Modernising Pharmacy Careers (Smith & Darracott, 2011) saw the importance of a more integrated approach to the degree programme and the pre-registration year highlighted. The proposal also discussed the need for development of and assessment of stronger clinical skills. Following a detailed review of the education standards, the GPhC published an education framework as a distinct change from the previous curriculum syllabus (GPhC, 2011). This significant change to the structure of the undergraduate degree was made to better align with the increasingly clinical role of the pharmacist, requiring the degree course to evolve to meet these needs (Department of Health, 2008). To meet these new standards, a fundamental change to teaching and assessment was needed; students were now required to show competence and meet specific learning outcomes rather than theoretical knowledge which had been a criticism of the previous degree structure due to a lack of this type of authentic assessment which was directly relevant to practice (Wilson et al., 2005). There was no longer a set curriculum but a set of outcomes that needed to be taught and assessed, with assurance that students met each of these outcomes by the end of their study period (GPhC, 2011).

Previously there had been an outline of subject knowledge to be taught and assessed on the MPharm degree, including the chemistry content as a benchmark standard. This Quality Assurance Agency (QAA) benchmark statement for MPharm degree (QAA, 2002) emphasised the knowledge, abilities and skills that are essential for a pharmacy graduate. However, this statement has not been updated since 2002 so is no longer valid and has been removed from publication. Although the QAA stated this benchmark statement will be updated, there is not yet a planned publish date for this.

A significant challenge with the previous 3 year degree structure was the lack of assurance of competence. The introduction of learning outcomes for both the degree and the pre-registration year sought to resolve this. Previously, with theory assessments passed, there was no requirement to demonstrate application of knowledge and skills (Sosabowski & Gard, 2008). In a modern healthcare setting with an understandable focus on patient safety and clinical governance (NHS, 2023), a lack of this reasonable assurance cannot be a viable option.

Following the most recent national review to ensure the NHS was 'Fit for the Future' (NHS England, 2019), it was proposed pharmacists could become independent prescribers without the additional post-graduation prescribing qualification (HEE, 2019). This review reflected the increasing challenge and pressure on the NHS workforce and proposed a long-term sustainable plan for safe and effective healthcare provision. In 2021, the GPhC updated its Standards for Initial Education and Training of Pharmacists (GPhC, 2021). These standards incorporated teaching and assessment on independent prescribing as well as an increased requirement for practice placements. This meant that those joining the GPhC pharmacist register from 2026 will be independent prescribers at the point of their initial registration as a pharmacist (HEE, 2025). The GPhC 2021 educational standards are the current standards that all Master of Pharmacy programmes in the UK must be accredited to at the current time.

1.4 The role of chemistry in the UK pharmacy degree

Although the changes to the UK pharmacy educational standards have placed increasing emphasis on direct patient clinical care and subsequently independent prescribing, it would be wrong to assume that science is deemed as no longer important, this is inappropriate because of the impact of a drug's chemical structure on its mode of action, absorption and side effect profile. Its significance is still embedded despite substantial changes to the required programme standards and learning outcomes (GPhC, 2011, 2021). For example, in the 2011 education standards (GPhC, 2011), chemistry and science had a prominent place, with science highlighted multiple times throughout the document including within standards (requiring students to have "an integrated experience of relevant science and pharmacy practice" (GPhC, 2011, p19)). The most recent standards (GPhC, 2021) also continue to emphasise this significance with an expectation that students will "apply the science behind pharmacy throughout all learning" (GPhC, 2021. p9) as a mandatory learning outcome.

Integration between science and practice is a pivotal part of curriculum design and is a theme throughout both recent GPhC pharmacy educational standards, this is discussed further in section 1.5 and section 2.1.4.

The response to this societal role change for pharmacists and the educational standards review re-ignited a debate about the position of science within the degree programme which has yet to be resolved. There are a range of opinions and beliefs involved in this debate discussed below, which seem influenced by academic background, current roles as well as one's own experience of pharmacy undergraduate training. A conference presentation by Scotland's Chief Pharmacist at that time which suggested a move away from science in the degree (Chapman, 2014) was met with strong opposition from a range of established academics in the Pharmaceutical Journal (Furman, 2014; Martini et al., 2014; Perrie, 2014).

Stating that chemistry should (or should not) be included in the pharmacy degree is not a sufficient level of detail for this debate without the consideration of context and the type of teaching and assessments that can be used. A more sensible discussion considers the teaching methods used to convey this information. These previously may have focused on didactic delivery of large volumes of complex theory to meet the specified curriculum content (Guile & Ahamed, 2011; Sosabowski & Gard, 2008). A more appropriate approach reflects on how this information needs to be used by pharmacists, so its authentic application is considered. Consideration of the integration of practice and science teaching with an emphasis on application of knowledge and relevance to future practice is discussed in detail in Husband et al., (2014), a much cited and respected paper. An integrated curriculum can be defined as one where the summation of different academic disciplines forms a coherent whole and, importantly, where the relationships between the different disciplines have been carefully and strategically considered when forming the composite. With pharmacy curriculum integration, it is important to produce graduates who have the capacity to apply their knowledge to a range of complex problems where available information is often incomplete. This paper discusses the development of an integrated curriculum in which students are presented with an organised, logical sequence of material, but still challenged to make their own integrations and develop as integrative thinkers. An evidence-based model upon which an interdisciplinary undergraduate pharmacy curriculum can be built is presented and has been used by many pharmacy programmes across the UK.

To consider a balanced picture, some of the reasons given against the inclusion of chemistry are summarised here and will be discussed in further detail during the thesis. There is no doubt that with the increasing clinical role, more clinical teaching as well as clinical skills development needed to be added to the programme curriculum. As new content and skills are required, there is an inherent challenge to fit everything into limited time. This has led to the argument of what could be removed and replaced to accommodate emerging newer elements (Chapman, 2014; Guile & Ahamed, 2011). Whilst important, the consideration of the content alone is not acknowledging the science of learning. Some of the resistance to the inclusion of chemistry or the calls for its removal may be linked to its perceived lack of relevance to clinical knowledge and skills. With the ever-increasing complexity of drugs and healthcare provision, it is progressively difficult and now impossible to teach all medications and diseases (Angelo et al., 2022). A focus on developing skills like integrated critical thinking which foster a deep understanding of concepts and underpinning science does consider the skills needed for a qualified pharmacist (Pearson & Hubball, 2012). Healthcare professionals including pharmacists are expected to engage with lifelong learning (Rouse, 2004), acknowledging the fact that the healthcare setting is consistently evolving so further learning is needed to ensure currency of knowledge and skills. This recognition of lifelong learning acknowledges that not everything can be taught at undergraduate level.

Some skills taught during the traditional pharmacy degree programme are science related, for example laboratory manipulation skills. These skills may be different to clinical skills but there are elements related to both. For example, manual dexterity is needed in both physical examination of patients and using equipment in the laboratory, so the skills developed in the laboratory setting are transferable to the clinic setting. Risk assessment and record keeping are also important in both practical chemistry and pharmacy settings. Traditionally, the science content has often been embedded earlier on in the programme; students need to pass these modules before continuing to develop their clinical skills (Guile & Ahamed, 2011). The more clinical role and subsequent introduction of clinical skills to the programme can be seen as progression of the profession, but the consequence of losing the underpinning science needs to be considered.

Some of the skills that learning science foster are also transferable and relevant to clinical skill development. Research in medical education has often highlighted the benefits from their underpinning science teaching. Critical thinking and problem solving are developed (Ribeiro et al., 2015) which can be used when dealing with patient queries and practising evidence-based medicine. Education experts argue this science background is needed to gain a full understanding of evidence based practice (Greenhalgh, 2003). Students are often required to work in groups when completing laboratory work and communicate findings clearly and concisely which builds their collaboration and communication skills (Mc Goldrick et al., 2013). Developing students' learning of science at university can build on their prior knowledge from secondary education so it is often easy to embed this teaching and further skill development from the beginning of a programme. Additional clinical skill development is still required but there is clear evidence that the skills developed in science teaching are relevant and transferable.

Pharmacy as a profession is founded on science (Skau, 2007), although the profession has moved from a niche focus on extemporaneous dispensing, it still has a unique contribution to make in the healthcare setting. A clinical role is not a reason to exclude science altogether, it is a reason to review and restructure considering the most appropriate learning, teaching and assessment methods. This review may inevitably mean a reduction in total chemistry content after some of these changes. Some argue this is a dumbing down of the curriculum (Florence, 2011) but the perspective of meeting learning outcomes to produce competent practitioners should be the focus (Faruk Khan et al., 2011). The 'Modernising Pharmacy Careers' UK review (Smith & Darracott, 2011) highlighted the need for a pharmacist to be a health care professional who has multiple skills within science and the clinical setting. The undergraduate Master of Pharmacy degree remains a vocational degree that allows progression into any branch of pharmacy including industry, hospital, community and primary care. Therefore, the degree must be suitable for all branches of the profession, even if a specific branch appears to be increasing in popularity. Career choices of pharmacy students have been shown to change over time due to a variety of factors and differing opportunities being available as the profession and needs of the population changes (Hanna et al., 2016; Savage et al., 2009; Willis et al., 2006).

The current body of evidence suggests that this unique position of pharmacy is not necessarily reflected in pharmacists' own perceptions of their identity. Multiple identities (e.g. the scientist, the clinical practitioner, the social carer, the business person) were acknowledged during qualitative research involving individual and group interviews (Elvey et al., 2013) although this may be related to the multiple sectors and therefore roles pharmacists may have. A recent review of multiple studies across several countries found that pharmacists do not consistently consider themselves clinicians (Kellar et al., 2021). However, some of these studies are historical and attitudes and perceptions may change once careers are established for those who have completed pharmacy programmes under the new educational standards.

Researchers have focused on how to successfully achieve relevant learning outcomes (Alsharif et al., 1999; Faruk Khan et al., 2011) to support the argument for continued inclusion of chemistry within the pharmacy degree. The discussion focuses beyond just the inclusion of an extensive subject area but on ensuring the right depth and breadth of this area. It also considers how it is taught, what skills are developed and how these are demonstrated and assessed. There is a recognition that there is a skill gap between learning theory and then being able to apply this knowledge to relevant situations (Bandiera et al., 2013) which can be narrowed by teaching and assessment that encourages application of knowledge. (The foundation-clinical gap is discussed further in chapter 7). The structure and design of the curriculum is important here with the need for integrated materials and the recognition that these knowledge and skills are linked to more than just academic ability (Toklu & Hussain, 2013). To demonstrate their competence, pharmacy students need to demonstrate their ability to apply knowledge as a specific skill (Persky et al., 2019) and communicate this application to other healthcare professionals, patients and carers (Luiz Adrian et al., 2015).

1.5 The structure of pharmacy education within the Higher Education setting across the world

This debate regarding the science content within pharmacy education is not restricted to the UK but has also been seen in other countries where the role of the pharmacist was evolving to become increasingly complex and clinical (Wilson et al., 2005; Wright et al., 2006). The changes seen in the UK in recent years have also been happening globally with the USA, Canada and Australia also continuing to progress clinical pharmacist roles within their healthcare settings.

Although historically, chemistry has been at the core of pharmacy undergraduate education globally, the curriculum has become more patient focused whilst aiming to maintain the underpinning fundamental chemistry and science (Skau, 2007). In the USA, the Accreditation Council of Pharmacy education standards (2016) (ACPE, 2016) continued to highlight the need for the development of science skills as its first standard. The recently updated standards (ACPE, 2025) which were implemented from July 2025, have science embedded through the revised curriculum standard 2. Similarly, the Canadian Council of Accreditation of pharmacy programs (2020) (CCAPP, 2020) acknowledges the constant importance of science, stating that the foundational science “should be in sufficient depth to provide [a] foundation for pharmacy practice responsibilities as well as emerging roles”(CCAPP, 2020, p 11).

This recognition that science and practice content is a global discussion is important when it comes to reviewing the current literature base. As these countries also face the challenges of balancing science and clinical content in their programmes, their publications on teaching interventions are relevant and educational for the UK. Developing countries are also increasing their clinical expertise which is having an impact on their status within the interprofessional healthcare setting (Toklu & Hussain, 2013). There are multiple pharmacy programmes now established internationally which have been directly validated by UK universities and significantly influenced by the UK pharmacist roles and also UK standards

(UCL, 2025; UH-GAF, 2025; UNM, 2025). Through experience of recruiting students for the Overseas Pharmacists Assessment Programme (OSPAP), a variety of topic content as well as assessment types can be seen in qualifying pharmacy programmes across the Globe. A recent review by the GPhC acknowledged the differences seen when compared to the UK and are planning a further review of the overseas qualification route (GPhC, 2025a).

The next chapter (specifically section 2.4.3) will review literature on relevant chemistry teaching in detail with a focus on identifying gaps relevant to the pharmacy education setting.

1.6 Curriculum design and meeting education standards – consideration of teaching, learning and assessment

Due to the significant change in pharmacy programme requirements in the UK, consideration was given to relevant pedagogic elements which could support the delivery of these new updated standards. These were highlighted and used as principles to help meet these educational standards (GPhC, 2011).

Embedded in these standards was the need to ensure that science would underpin the learning of pharmacy practice. Integration was essentially mandatory and a well-documented method of achieving this was through consideration of Harden's ladder of integration (Harden, 2000) which was already utilised and respected in medical education.

Integration is discussed throughout literature, but it is acknowledged that an agreed definition should be used so it is clear what this thesis is referring to. This will be discussed and defined in chapter 2 as part of the literature review for the purposes of this thesis.

1.6.1 The integration ladder

Using Harden's key paper (Harden, 2000), progression along this ladder shows an increase in integration on each of its 11 steps. 'Isolation' on the bottom rung represents separate disciplines teaching in complete isolation without acknowledging the rest of the curriculum. Only the top three rungs of the ladder were considered appropriately integrated by the GPhC. A multi-disciplinary curriculum implies that teaching is focused on cases and contexts where students apply their skills and knowledge to solve the problem. A trans-disciplinary approach at the highest rung of the ladder has students learning in a practice setting bringing together material from a range of subjects. Several schools have adapted well to this approach; Husband et al., (2014) provide an example of an inter-disciplinary model of integration within their curriculum. Their design at the University of Durham showed an organ and system-based design to modules rather than discipline focused. Curriculum design and the implementation of an integrated structure impacts interpretation of the curriculum by students so may help to positively influence students' understanding of the importance of this integration (Kulasegaram et al., 2013).

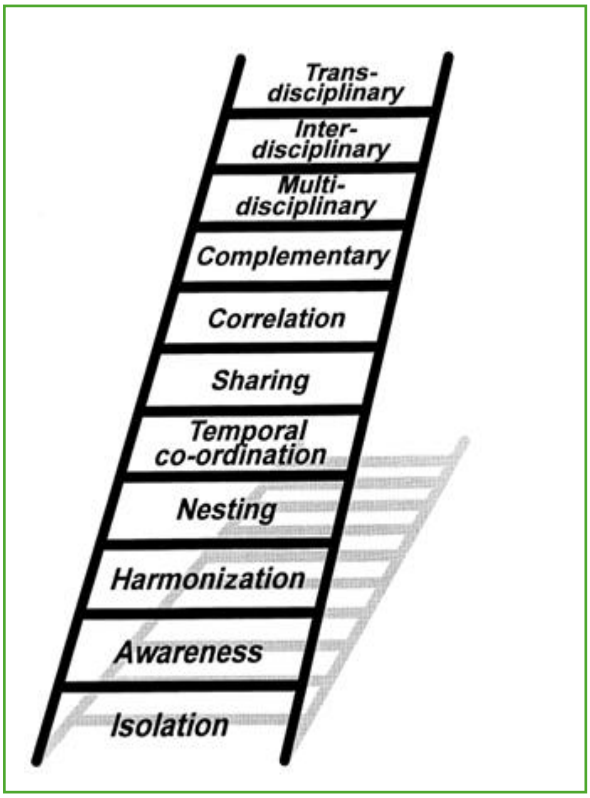

Figure 4 – The integration ladder; diagram taken from (Harden, 2000)

Whilst examples of integration have been developed, implemented and described for pharmacy programmes in the literature (Alsharif, 2007; Alsharif & Galt, 2008; Faruk Khan et al., 2011; Karimi et al., 2010; Kearney & Larrañeta, 2021), there is, as yet, no clear overarching evidence that demonstrates what type of integrative curriculum is most effective with few studies directly comparing traditional and integrated models (Kerr et al., 2020). One of the challenges is that integration is not explicitly defined and without an official definition, it is difficult to compare studies and review truly integrated approaches (Nazar et al., 2019; Sun et al., 2023). The significant increased staff workload and time involved in this change to curriculum has been cited as one of the common barriers to an integrative curriculum (Aref et al., 2021).

1.6.2 Spiral curriculum

It was proposed that the new Master of Pharmacy structure should be planned with the spiral curriculum model in mind, acknowledging the increased complexity of subjects taught throughout each year, with the final year being significantly more complex than the first year.

This model was first developed by Jerome Bruner (Rockich-Winston, 2017). Bruner was a psychologist who thought that intellectual ability built up in stages so a subject should be taught in its basic form and re-visited frequently and built upon in complexity to ensure the student develops a deep understanding. This model was adapted by the General Medical Council as an approach to medical education in the early nineties and continues to be used (Harden, 1999). Returning to topics during the degree can be deemed a successful method of ensuring the curricula is up to date with the increasing advances seen in licensed medication (Rockich-Winston, 2017).

1.6.3 Miller's Pyramid

How students can be assessed was also considered following the implementation of the new educational standards, acknowledging that solely using written assessments would not be fit for purpose (Wilson et al., 2005; Wright et al., 2006). Miller's pyramid (Miller, 1990) was highlighted as a model for the assessment of clinical competency. This model emphasises how the students' development of competencies should increase over the degree course and during the pre-registration year. Notably, it does not remove exams or knowledge-based tests, recognising that knowledge should be secure before as it acknowledges that a demonstration of being secure its application is assessed.

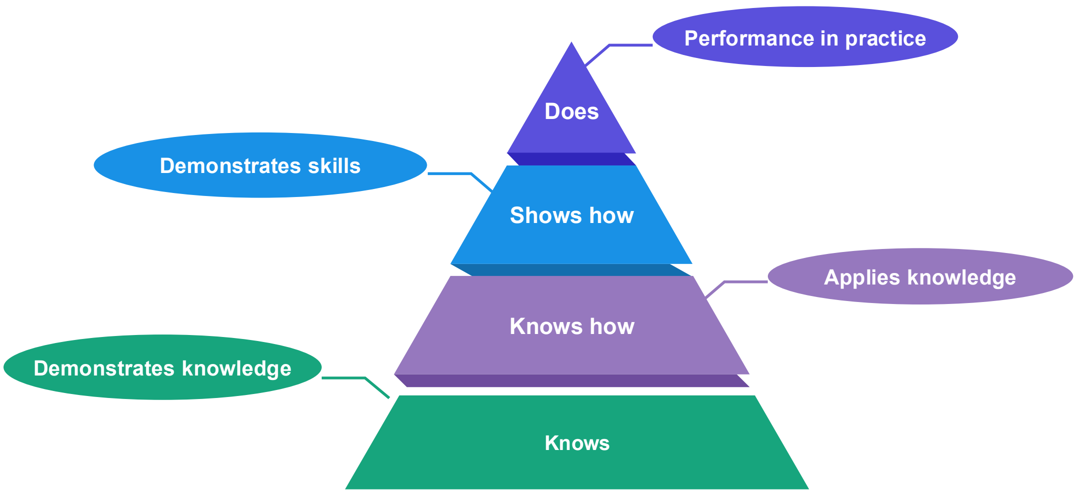

Figure 5 – Miller's Pyramid (adapted from (Miller, 1990))

The implementation of a variety of assessment techniques that allow students to demonstrate skills and competencies rather than knowledge alone can be categorised as authentic assessment. Authentic assessment requires students to show an "active demonstration" of their knowledge (Biggs, 2003). In addition, clinical simulation and

Objective Structured Clinical Examinations (OSCE's) are beneficial learning experiences in their own right and can ensure that students develop, practise and become competent in skills necessary for practice (Corbo et al., 2006; Kirton et al., 2014; Wright et al., 2006). Students tend to engage well with this type of assessment (Oyler et al., 2016) which also allows them to synthesise information and problem solve in a real-life context. This authentic teaching and assessment, encourages meaningful rather than rote learning (Husband et al., 2014). The importance of meaningful learning as opposed to rote learning has been frequently discussed and defined (Bretz, 2001; Mayer, 2002) with it being described as supporting learners to make sense and develop deep understanding of the learning material. The significance of meaningful learning is explored further in section 2.1.7.

Consideration of an integration structure model (Harden, 2000) and an assessment framework (Miller, 1990) does help in curriculum development however it does not consider any of the specific challenges faced when learning different subjects such as chemistry. This needs to be considered because even with an integrated approach, these challenges will still be faced. These issues will be explored further within the thesis.

1.7 Other relevant key learning concepts

Although not specifically referred to in the GPhC educational standards, there are other pedagogical elements which are drawn upon in curriculum design and delivery at a higher education level.

Demonstrating synthesis of information when critically thinking rather than solely remembering knowledge links to Bloom's taxonomy. The educational psychologist, Benjamin Bloom explored the spectrum of cognitive processes involved in thinking and learning. His team categorised the cognitive domain of learning which relates to gaining knowledge and acquiring intellectual skills (Anderson et al, 2001). He and his colleagues argued that the lowest level of learning was basic fact recall and to develop academically, this should be built upon to more complex tasks like being able to analyse or evaluate the information rather than just recall it which may not demonstrate clear understanding. A deeper level of understanding and greater cognitive processing is needed to successfully master the higher order skills like critical thinking and problem solving (Anderson et al, 2001).

Bloom’s pedagogical concept consists of three domains with the cognitive domain (Bloom et al., 1956) and affective domain (Bloom et al., 1973) being most relevant to this doctoral study. Being able to demonstrate the application of knowledge rather than solely remembering knowledge is thought to show a deeper level of understanding and greater cognitive processing. In terms of the affective domain, students’ perceptions and attitudes also affects their interaction with the subject. Teaching and assessment interventions have had understanding and application of knowledge at their heart rather than basic knowledge recall. These domains will be explored in further when discussing meaningful learning in section 3.9 and assessment design in section 4.1.6

1.8 Chemistry positioning within an example MPharm modular structure

Having knowledge of chemistry's position within an example pharmacy degree structure may help understand the students' experience so is explained more explicitly here. It should be noted that the General Pharmaceutical Council does not specify a pre-determined modular structure, so each School of Pharmacy is different. (Although all programmes must be accredited so the GPhC are satisfied that they meet the standards for education (GPhC, 2011, 2021)).

The programme at the University of Hertfordshire has been designed with input from all relevant disciplines with the curriculum lead having a pharmacy practice background. Knowledge and skills in chemistry are taught from first year onwards with more foundational concepts being the focus in the earlier years. The focus becomes more disease focused from second year onwards with teaching around disease states, building in complexity each year.

Although the content is planned in an integrated way, it is noted there are current no chemistry academics who are also registered pharmacists. There are some co-taught sessions with both pharmacy practice and chemistry staff present but it can be challenging to organise with large teaching workloads across multiple programmes. Generally, practice staff teach the clinical material and chemistry staff teach the science material even though the modules have integrated contents and assessment. Practice staff do not routinely support laboratory practical classes.

Further details on the modular content of the programme can be found in appendix 1.

1.9 The importance of this research

This research aims to explore several areas which may impact the learning and teaching of chemistry within the Master of Pharmacy programme whilst considering the application and understanding of this knowledge. Staff and student perceptions will be investigated as well as teaching tools which may influence this learning. There is little research regarding comparison of student and staff perceptions around the learning and teaching of chemistry, specifically on pharmacy degrees. Although there have been previous studies on students' perceptions towards chemistry learning in pharmacy (Jesson et al., 2006; Mawdsley & Willis, 2019; Prescott et al., 2014; Smith et al., 2017), currently there is little research specifically regarding chemistry academic staff perceptions on important factors affecting teaching (and learning) of chemistry and any differences between students and academics. This research aims to add to the existing literature in this area, acknowledging that the changes to the programme and the expanding pharmacy clinical and prescribing role may influence these viewpoints. This study also aims to expand the evidence base of using a patient centred approach when studying chemistry, considering the new clinical and prescribing responsibilities which were beyond the scope of the pharmacist's role when many of these previous studies were conducted.

It is important that the continued importance of science within the pharmacy programme curriculum is acknowledged despite the increasingly complex clinical requirements. The aim is to ensure students finish their degree scientifically literate, with an understanding of key concepts and an ability to apply this knowledge to clinical problems (Husband et al., 2014).

At the core of this research's originality is its inclusion of students during the research development and collection phase. Participatory research (Seale, 2010) is an approach that is considered as more collaborative than previous historical approaches where academics had sole involvement on the research design with possibly no or very different lived experiences to the directly affected participants. In participatory research, individuals (the students in this case) are acknowledged as being directly affected by and part of the issues being investigated. Becoming actively involved in the research allows a more authentic approach with the potential for more in-depth findings as the student voice is being clearly heard and acknowledged. The student involvement has allowed the researcher to develop a deeper reflection and understanding of the findings. It also highlighted the need to consider language and explanations when discussing pedagogy, when an academic's understanding is commonplace, but students may not be familiar with integration, contextualisation, and spiral curriculum. This distinct perspective is a novel approach to this area so offers an original research perspective as well as expanding and updating the literature base in this area.

Several terms relevant to this research have been researched and defined as part of the literature review process in chapter 2.

1.10 The objectives and research questions of this project

An initial review of literature on this area allowed the researcher to develop further understanding of the problem and formulate research objectives. The research questions were then developed.

The general objectives of the overall project are:

1. Identify and analyse in detail factors affecting chemistry learning in the context of a non – chemistry major degree programme from a staff and student perspective
2. Identify understanding of contextualisation, its importance, relevance and implications within the MPharm student population at University of Hertfordshire
3. Develop and implement an approach to effectively contextualise chemistry within a pharmacy context and evaluate its impact on learning.

1.11 Consideration of the research questions

Table 1 - The research questions

The research question	How and where will this be answered?
What influences students' understanding and application of knowledge of chemistry within the MPharm degree? (linked to objective 1 and 2)	Literature review (chapter 2) Primary data collection from PeerWise study allowed exploration of whether demographics have an impact (Phase 1- chapter 4). Phase 2 where interviews and focus groups explore perceptions on this.
What are MPharm students' attitudes towards the relevance of chemistry within the MPharm degree as well their motivation and most effective ways to learn and understand chemistry? (linked to objective 1 and 2)	Literature review (chapter 2). Primary data collection from interviews and focus groups in phase 2 (chapters 5 and 6) address perceptions and identify and analyse themes.
What do University of Hertfordshire staff understand to be the student perceptions regarding chemistry on the MPharm programme? (linked to objective 2)	Phase 2 of project with primary data collection and analysis from interviews with academic staff (chapter 5)
What strategies can support students' application of chemistry and integration with practice learning within the MPharm degree? (linked to objective 3)	Phase 3 of project (chapter 7) designs, develops and delivers a teaching strategy to support. This design of this strategy is influenced from data analysis of phase 1 (chapter 4) and phase 2 of the project (chapters 5 and 6).

1.12 Overview of the thesis chapters

Figure 6 presents a summary of the eight chapters that make up this thesis. A brief overview of each chapter is also provided below.

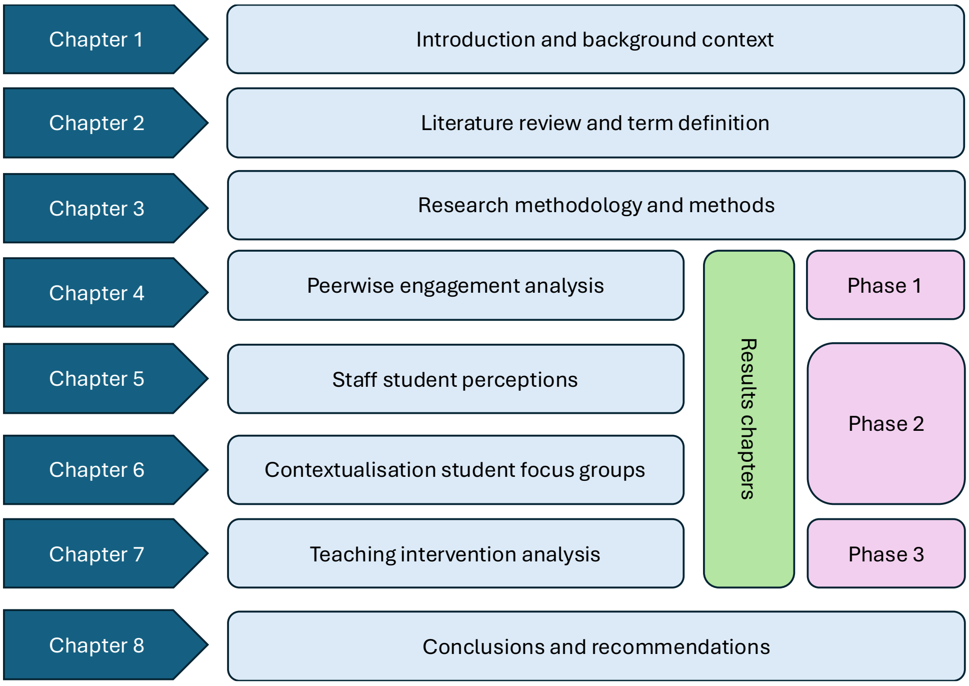

Figure 6 – Diagrammatical representative of the thesis structure

Chapter 1 introduces the study providing a summary of the background and context to the subject area. It identifies the aims and objectives of this thesis as well as how the research questions will be addressed. The importance of this research and its contribution to the field are discussed.

Chapter 2 presents a narrative literature review to outline the key themes that are considered in this thesis and considers prior studies that link to this research area.

Chapter 3 is where the worldview and methodology for this thesis are explained and justified. The philosophical assumptions made for this thesis, the specific types of primary data collected, and the tools selected to analyse the data and ethical considerations are provided.

Chapter 4 is the first of the results chapters and discusses the findings from phase one of the study. Following engagement with an online educational support tool (PeerWise), the student demographics and PeerWise data are analysed. The quantitative data analysis investigates the attainment of students in a summative assessment and their contribution to the support tool which required involvement with peers. This chapter investigates the impact of a range of demographic factors seen within students. It considers their bearing on the attainment and engagement with the peer support tool.

Chapters 5 and 6 present the data and findings for phase 2 of the project. In chapter 5, student and staff perceptions of chemistry within non-chemistry major degrees are investigated through individual semi structured interviews. Following on from the research into general perceptions of chemistry in non-chemistry degrees; student specific perceptions of their understanding of contextualisation and integration within the curriculum and how well they are able to engage with integrative thinking are then investigated with the findings presented.

Chapter 7 presents the findings of phase 3, the final phase of the project. Following analysis of the phase 2 data, a teaching intervention to directly support and scaffold integrative learning is designed and developed in the form of contextualisation workshops. This series of compulsory workshops for first year MPharm students focuses on a pharmacy practice approach, linking back to the relevant chemical structures and properties of the drugs discussed. The design and development of these workshops with student involvement in the process is discussed as well as the analysis of the student questionnaires completed after attendance at this teaching intervention.

Chapter 8 is the conclusion chapter where each of the research questions are reviewed and answered in turn. Recommendations are provided as well as a discussion of future research. Limitations of the overall project are considered with discussion of their potential impact on the research.

1.13 Overarching argument of the thesis

This thesis argues that teaching chemistry on the pharmacy degree programme impacts and can potentially enhance students' ability to problem solve as a health care professional. Teaching chemistry through clinically relevant and application-focused approaches can promote meaningful understanding. It can improve the pharmacy students' ability to use their scientific knowledge during clinical problem solving in practice.

Multiple phases were designed in order to investigate this argument thoroughly. Within phase one, association between demographic factors and engagement with a chemistry formative task (and corresponding assessment) were investigated. This analysis sought to establish if engagement and achievement in this area could be specifically attributed to demographic factors. To gain a better understanding of lived experience, qualitative analysis was the primary mode of research in the next phase. So, in phase two, qualitative analysis was used to explore students and staff perceptions on their experience of pharmacy education within their degree and perceived learning and understanding. Finally in phase three, a novel educational approach was designed, developed and delivered to pharmacy cohorts which was informed by their shared insights generated during the earlier phases of the study. These insights guided both the content and structural design of the intervention. This new approach was evaluated with both qualitative and quantitative data collection.

It is important that pharmacy students are educated to become integrative practitioners with understanding of both science and practice concepts. Investigations within each phase aimed to contribute answers to the research questions outlined in section 1.10.

Chapter 2 – Literature review and term definitions

This thesis explores student learning and understanding of chemistry within a programme which requires deep understanding of chemical concepts, but where chemistry is not the main focus i.e. a non-chemistry major degree. The type of literature review to conduct was considered with the merits of two main approaches, systematic and narrative reflected upon (Gregory & Denniss, 2018). Although systematic reviews are considered rigorous, they can also be narrow and rigid which would not be suitable for this area. This is because the thesis research questions are broad and therefore the background literature search criteria to be included needs to be wide as there are several themes relevant to each of the research questions. This is both intentional and beneficial as it allowed the researcher to develop a thorough and deep understanding of the area. Conversely, it was also noted that because of the specificity of non-chemistry major programmes considered in this research, i.e. the pharmacy degree, there may be very few papers that were directly applicable and so many may be deemed irrelevant if using the very strict criteria required in a systematic review.

Narrative reviews can appropriately critique the evidence base, deepen the understanding of a specified area and can be carried out and presented in a logical and organised manner (Greenhalgh et al., 2018; Gregory & Denniss, 2018). Thus, a narrative literature review was selected as the most appropriate method and conducted rather than a systematic review. It aimed to provide a broad and comprehensive overview of the current literature. The review of literature will be presented in relation to the relevant themes associated with the research. These themes include student and staff perceptions in relation to learning chemistry, teaching interventions to improve learning, understanding and application of chemistry. The themes are defined in detail in section 2.3.

In addition to the literature review of the identified themes, there are several relevant terminologies that are referred to throughout the thesis. These terms do not have universally recognised definitions, so these have been specifically researched and defined for the purpose of this thesis.

In terms of timeframes for the inclusion of documents for the literature search, it was deemed that it would not be appropriate to have set dates for all searches as some pivotal articles and pedagogical theories are older (e.g Bloom et al., 1956; Flexner, 1910) and need to be acknowledged even though more recent discussion on these concepts in published articles is available and hence will also be reviewed and critiqued.

2.1 Key definitions for common terminology used

The first strand of work in reviewing the literature was concerned with defining key terminology used throughout the thesis. Several key terms are used regularly, and it is important that they are clearly defined to ensure consistency and clarity in their usage. These terms were initially divided into two categories: student terms and teaching terms. Each term within the categories was considered and an agreed definition justified.

Whilst there is a wide range of terminology used within the thesis, the seven terms considered below were chosen for further analysis and discussion because of the lack of consensus in academia of a respected recognised definition. During the project, it was agreed that if a published article had put forward an appropriate evidence-based definition for a term, this term could be used. Where this was not the case, the researcher has proposed a definition following comprehensively researching the topic. These definitions are explored below and summarised in table 2.

2.1.1 Student terms - Student Engagement

The importance of student engagement is often discussed within the Higher Education setting, being considered a factor in determining institution rankings within university league tables and as a proxy indicator of quality for curriculum and assessment design from a pedagogical perspective (Buckley, 2014). A single definition of student engagement however continues to be elusive despite its agreed importance amongst educators (Headland, 2024).

Research on student engagement starts in the earlier years within the school setting, with published literature explaining engagement as having three elements, behavioural, emotional and cognitive mirroring the structure of Bloom's taxonomy (Armstrong, 2010). Each of these elements can look very different but all can be considered as engagement. The first; behavioural engagement is related to following the rules within the classroom and not participating in or creating disturbance. The second; emotional engagement is exemplified when there is clear interest shown and a feeling of belonging. Finally, cognitive engagement is linked to a student's specific learning and their enjoyment of studying and further academic challenge (Fredricks et al., 2004).

There is a wide variation when it comes to defining student engagement amongst well cited authors with a different emphasis depending on their role and speciality. Coates, (2005) discusses the link between quality assurance and student engagement, highlighting that as well as considering the teaching, how specifically involved students are at university should be factored in when determining the quality of an institution. The QAA continued this theme (QAA, 2018) and discusses student engagement as a strategic goal providing an assurance of the quality of the provision and their student experience. The Office for Students three-year strategy for 2025-28 (OfS, 2025) has student engagement at its centre but has divided it into three strands which link to their strategic regulatory work rather than individual student engagement as described in Fredricks et al., (2004). The acknowledged benefits of student engagement vary in the literature, with learning specifically emphasised in some cases (Chi & Wylie, 2014) whilst in others, it can be considered via general retention of students on a course at a university (Thomas et al., 2021). The wide range of discussions relating to different interpretations of student engagement makes it harder to have a recognised definition.

A large study (Kuh et al., 2008) looking at a sample of approximately 6000 students across 18 colleges and universities in the USA found that academic achievement and persistence to continue their studies was better in students with higher levels of (self-reported) engagement. Within the article, they considered the time students spent studying, the time they spent on co-curricular activities and finally their responses to a national student survey (NSSE, 2021) as a defined representation of student engagement. Krause, (2005) argues there is evidence that engagement can be encouraged and fostered in individual students through teaching, learning communities and institutional policies. She highlights that the term student engagement can encompass many behaviours, but it is a concept that needs to acknowledge the different circumstances and commitments that students may have. Although a student's situation and background have been found to have an impact on engagement, it can be improved upon and is not pre-determined (Hu & Kuh, 2002; Krause, 2005).

Whilst trying to determine a definition for student engagement, it was noted that although there is a plethora of literature where student engagement is written about, there is a noticeable lack of direct student involvement in the published research (Trowler, 2010). This absence of the authentic student voice will be taken into consideration and discussed further when planning the methodology to answer the research questions in this thesis.

There is an acknowledged variety of definitions and focal points for student engagement within the literature. However, as this thesis is specifically concerned with engagement in teaching and learning, for the purpose of this study, student engagement will be defined within the narrower terms specifically linked to the cognitive dimension of engagement and so is considered as:

- A student's direct engagement with their academic study to improve their learning, understanding and application.

The context of this definition highlights a student's individual influence on their own learning. It correlates well with the philosophy of constructivism. The philosophical worldview of this thesis is discussed in more detail in chapter 3 (section 3.2).

2.1.2 Student terms - Student Motivation

Motivation and the theories behind what drives this feeling have been researched over many years (see e.g. Ames & Archer, 1988) with evidence highlighting that motivation can develop and vary depending on the learning environment (Schunk et al., 2014). A definition of motivation is offered as "the process whereby goal- directed activities are instigated and sustained" (Schunk et al., 2014 page 5).

Motivation can be complex with multiple factors involved, it can be discussed as extrinsic or intrinsic (Ryan & Deci, 2000) whereby intrinsic motivation involves a personal satisfaction and enjoyment from being involved and engaged in an activity and extrinsic motivation is linked to more external rather than internal personal factors, for example, payment associated with the activity or improved social status. There are five main theories regarding human motivation with some overlapping themes between them (Cook & Artino, 2016) and is a prevalent area of study across multiple branches of psychology. However, in the context of this thesis, student motivation is considered as:

- The drive students have to participate in learning and strive for academic success which may encompass both intrinsic and extrinsic components which can be different for different students.

2.1.3 Student terms - Student Attainment

Attainment in higher education is part of the highly monitored success stage of the student journey and considers the academic outcomes achieved by students (OfS, 2024). This term is linked to a national scale of final degree outcomes. Any gaps that may be present as a consequence of different student characteristics or demographics and any possible modifiable reasons behind that, are considered at a national level as part of the Office for Students work. Historically, grading students was a way of communicating the level of their submitted work with a relevantly standardised system which is recognised and comparable both within an institution as externally across a country (Schneider & Hutt, 2014). With globalisation, an internationally recognised system becomes more attractive at the higher education level with the Grade Point Average (GPA) system giving a clearer picture across the student's whole degree and acknowledged as a prudent option within the UK's Teaching Excellence Framework (Department for Business, Innovation and Skills, 2016).

Research into attainment has highlighted that multiple factors can impact on it. A meta-analysis looking specifically at tertiary education (Richardson et al., 2012) highlighted that cognitive factors like prior attainment as well as non-intellectual factors like student motivation and learning strategies influenced students' final GPA.

York et al., (2015) conducted a literature review to investigate the wider term of academic success (rather than student attainment) and found that it encompassed more than just reported academic achievement but also the acquisition of skills, persistence with their programme of study and satisfaction of the overall experience. These were also considered important and relevant to what was deemed academic success. Further discussions of how overarching "success" is defined are present in the literature, with academic marks being only part of the story highlighted again. Non- academic evidence is perceived by students, future employers and the public as having value. Recent research from a qualitative study involving three focus groups of undergraduate psychology students at a UK university highlighted that attainment should be considered as more than just academic grades. Cachia et al., (2018) found that students want to continue their success following university with employability skills and work experience being seen as just as important as the knowledge and grades gained at university. Some of this group's more recent research, (Lynam et al., 2024) continued to focus on the student voice rather than the educators' thoughts in this area. They found that students explained coping well with the workload, meeting their own personal goals and financial stability were important in their overarching view of academic success.

In the context of this study, it is acknowledged that the relevance of final overarching degree attainment is less relevant. As a consequence of the focus on chemistry being within a non-major degree, results of individual tests will be more relevant in this context than overarching degree classification (or possibly subject specific i.e. chemistry prior qualification). As a result, for the purpose of this thesis, attainment is defined as:

- The graded outcome for a recognised formative or summative assessment at the relevant level of study.

2.1.3.1 Links between engagement, motivation and attainment

With regard to the terms, motivation and engagement, they are both important when it comes to student learning. Whilst they have been researched separately with different theories and models linked to them, each tends not to exist without the other as they are closely related concepts. Martin et al., (2017) argued that motivation can be considered a student's internal drive to study whereas engagement can be considered the behaviours that a student displays in the classroom setting.

Attainment, engagement and motivation can be considered closely related to one another and although they do influence each other, they are not synonymous. Engagement can be observed within a teaching setting when a student is actively participating in the class. A student's motivation, depending on personality, may not be so obvious. Being engaged and motivated does not guarantee high attainment. Steinmayr & Spinath, (2009) looked at 342 high school students and investigated factors influencing achievement. They did identify motivation as a potential predictor of how academically successful a student can be, but underlying cognitive ability was a stronger predictor of this.

John Hattie, a researcher who has investigated what both positively and negatively influences student achievement found many influential factors (Hattie, 2009). These included the skill of the teachers, specific teaching methods which promote a deep understanding of the subject as well as student self-efficacy and reflection all had a significant impact on improving achievement.

Although there is evidence that engagement and motivation can positively shape students' success, attainment is such a multi-factorial construct (OfS, 2022), it is incorrect to assume that being motivated and engaged will automatically result in high attainment in a subject. As stated, the way a subject is taught and presented to students has an impact on their interaction with it and leads onto the importance of the additional concepts discussed below.

2.1.4 Integration

The term integration is used in the higher education context to demonstrate the co-ordination and connectedness of various aspects that influence learning and attainment. These include the provision of support services, timetable and transport planning as well as the specific learning and teaching elements (Tinto, 2012), with the general aim to promote and improve retention.

In terms of teaching and learning, considering integration within a curriculum is most relevant for this thesis. There are many articles describing methods of integration being used within a curriculum but there is no universally accepted definition. Kerr et al., (2020) conducted a review looking at published studies discussing integrated curricula across a range of health care professional programmes. These studies employed a range of innovative learning approaches to achieve integration, however there was limited evidence of their effectiveness. Whilst most reported positive outcomes, there was a lack of substantive evidence showing consistent improvements in knowledge or skills acquisition which may be influenced by a relative lack of comparative or longitudinal studies.

In the context of this thesis, the definition of integration given by Kerr following her extensive scoping review will be used (Kerr et al., 2020).

- It is a “multi-faceted term describing a curriculum design which may be defined by model (horizontal, vertical, spiral), theme (systems-based, stages of life, topic, cross-cutting theme) and integrative teaching and learning approach (problem-based, case-based, experiential, enquiry-based, team-based learning, inter-professional education) and level of integration” (Kerr et al., 2020 page 13).

Whilst the above definition does encompass a wide range of elements, this thesis is focused on the skills that integration aims to develop. By teaching a combination of topics together, students can be encouraged to identify connections between them. This may promote synthesis of new ideas and deeper understanding (Sun et al., 2023).

It is noted that most of the literature does not discuss any impact the teacher has on student development. A recent publication (Micallef, 2025) highlights the importance of the lecturer’s approach rather than topic combinations alone which can build these skills (Micallef, 2025). This thesis will consider whether a curriculum design centred on integration promotes the development of consistently thinking in an integrative manner in addition to a novel teaching approach.

Whilst Kerr’s statement provides an excellent strategic definition, it is also important to consider how integration can be described at an operational level when thinking about teaching interventions and how to explain to students that ‘thinking integratively’ is important. Mawdsley & Willis, (2019) conducted a series of focus groups with pharmacy students at the University of Manchester which explored their thoughts on how they experienced the curriculum and a definition was provided to ensure students fully understood what was being discussed. This definition of integration will be adhered to in this thesis when considering integration at an operational level: “integration is when connections are made across different modules or subject areas of the pharmacy course” (Mawdsley & Willis, 2019 page 452).

Levels of integration in relation to curriculum design are also important to consider. As this is a UK based study, it is deemed appropriate to adhere to the GPhC’s integration guidance that corresponds to Harden’s ladder (Harden, 2000) which is described in more detail in Chapter 1 (figure 4 and section 1.6.1).

2.1.5 Contextualisation

Chemistry is the science which underpins many of the important principles relevant to pharmacy. It has been discussed in an earlier chapter that some students can find some aspects of chemistry challenging to learn. Teaching methods and theories take into consideration what may be done to support students with their learning with contextualisation being a recognised area of research with a supported evidence-based rationale towards its use. Gilbert's seminal paper (Gilbert, 2006) addresses this potential learning challenge and explores how 'context' as a concept can have a positive impact on learning. He presents four models to be used within teaching which are illustrated in figure 7 below with suggested examples to provide further understanding of each model.

Gilbert acknowledges that the meaning of context within teaching can be interpreted and delivered in different ways so critically discusses his four described generic models. Each model builds on the level and diversity of context. Model 4 was considered the preferred model as it combines both a relevant physical setting or situation with relevant context which impacts the students and the communities around them. It is noted however that this paper did not provide any evidence of comparing these models in a teaching setting and that the effectiveness of each model had not been directly evaluated. Since its publication, contextualised teaching approaches have been designed and delivered at a higher education level, with their impact being evaluated and published. Published literature which is relevant to the contextualised delivery of chemistry on pharmacy programmes will be discussed later in this chapter (section 2.4.3).

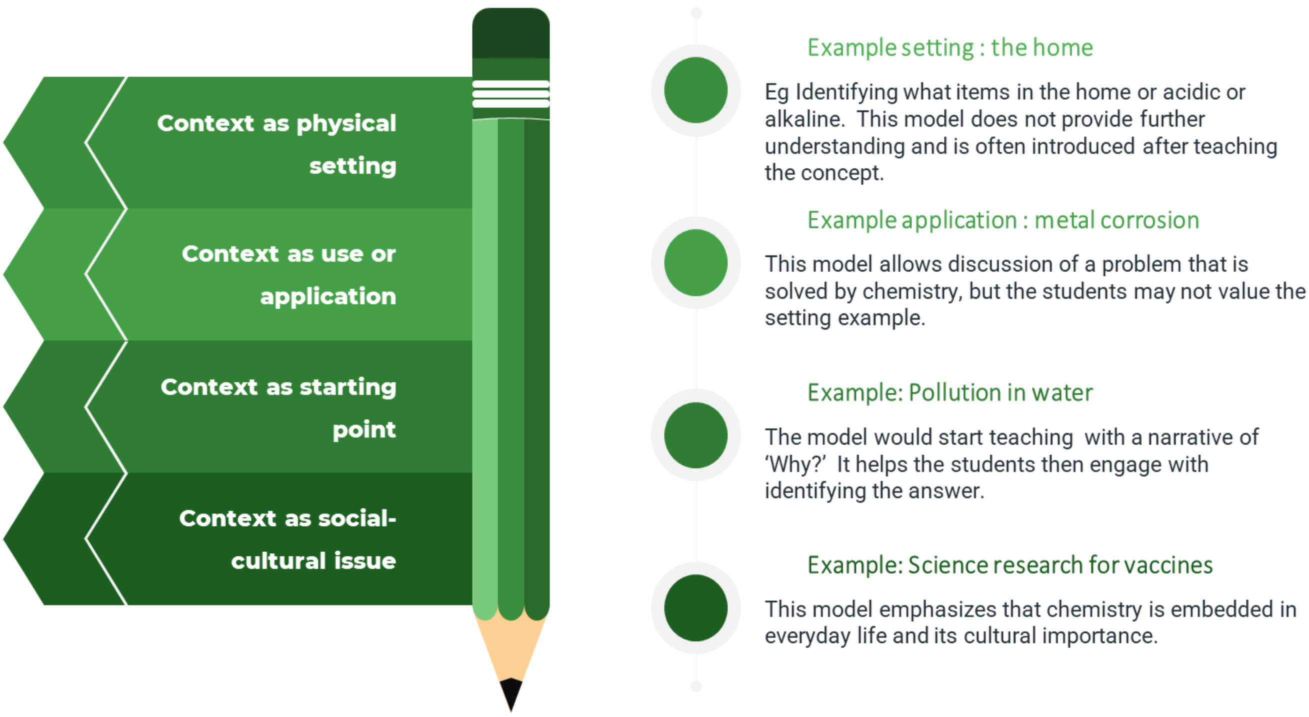

Figure 7- Diagram to illustrate Gilbert's four models on the concept of context in chemistry teaching (Gilbert, 2006)

It is acknowledged that Gilbert's article does not link explicitly to healthcare. Within pharmacy teaching, providing context through real life examples is insufficient as clear connections to health-related issues matters should be incorporated. Specifically in healthcare education, contextualisation is a way of addressing any gap between science and clinical knowledge. The combination of science and practice contents was established in medical education following the Flexner report (Flexner, 1910) initially highlighting the importance of standardising curricula and incorporating science and medicine topics. However, it did not convey clearly the need for contextualisation (Finnerty et al., 2010) meaning the role and value of underpinning science to clinical teaching needed to be realigned and clearly articulated since its implementation. Medical educators in both the US and Asia have highlighted their concerns with the presentation of science in the curriculum. Gwee et al., (2010) reported students have poor retention of knowledge and understanding of concepts when context is not clearly provided, recommending that the role of science should be made clearer and specifically how it links to diagnostic and therapeutic decisions. Incorporating science teaching with a clear context can help students work towards independently being able to make justifiable clinical decisions (Pangaro, 2010).

Within this thesis, contextualisation is defined as:

- The use of 'real-life' and relevant health- related examples within teaching to establish clear connections to chemical concepts.

This allows students to understand the reasons why a concept is important to them and their learning.

2.1.6 The links between integration, contextualisation and relevance

Both integration and contextualisation are important terms but are considered distinct. Integration refers to specifically combining both science and practice in learning and teaching activities whereas contextualisation supports the learner by describing the concept using a real-life example intended to resonate with them. This may or may not be related to clinical or pharmacy practice. This is especially relevant to the science (in this case chemistry) taught within a health care programme as using health-related examples will be most relevant for students in this area. Integration and contextualisation are recognised as valued approaches to teaching chemistry in a way that helps them learn and understand a topic or concept. Students can directly appreciate why it is important and relevant to the tasks they may encounter in their future career (Fergus & Kostrzewski, 2011; Hall & Allman, 2020). These approaches can encourage the development of application of new knowledge, either in relation to a real world context or by connecting concepts.

Relevance is also an important key concept within this thesis as it informs the conceptual framework. These three concepts interconnect to allow students to problem solve complex clinical issues. How students construct their knowledge and understanding is influenced by experiences and prior knowledge (Hodson & Hodson, 1998). There is not an objective reality (Bodner, 1986). Whilst integration combines topics from different subject areas, contextualisation helps to place this information within a meaningful real world setting. Both these concepts need to consider relevance, in terms of the setting but also when distinguishing which is most important. Recognising and utilising these concepts when planning teaching helps to facilitate the development of higher order thinking skills. Students can learn to connect and interpret information, and it may enhance their development of problem solving skills (Bretz, 2001). These concepts highlight that knowledge is being actively constructed by the students rather than passively acquired. This learning is individual and is linked to a student's other experiences and earlier learning (Hodson & Hodson, 1998).

The principles discussed in relation to contextualisation and integration have been utilised in several teaching interventions with examples available in published literature. Examples of relevant teaching interventions where these principles are incorporated and discussed are presented in section 2.4.3.

2.1.7 Active learning

Now a commonly used term in teaching, the principles behind active learning are underpinned by some key education theories presented by psychologists from across the globe.

Lev Vygotsky, a Russian psychologist who carried out his research in the 1920's and 1930's (Kozulin, 2003) argued that social interaction is crucial for learning and for the development of thinking and problem-solving skills. He developed the concept of the zone of proximal development (ZPD) which represents the gap between what a learner may understand and achieve on their own, compared to the higher, more complex tasks they would be able to achieve with support from a more knowledgeable person (Eun, 2019). This concept highlights the emphasis that Vygotsky placed on active learning with and from peers and teachers as part of human cognitive development (Vygotsky, 1978).

Jean Piaget, a biologist and psychologist, researched child development and how thinking and understanding emerges (Huitt & Hummel, 2003). The overarching philosophy presented was that children need to learn through experimentation within their own natural environments, interacting with other children and with teachers facilitating this rather than solely providing new information (Huitt & Hummel, 2003).

These theories have the same underlying principles, where students need to be active participants rather than passive empty vessels listening to new information. In addition, these concepts, where social interactions are required for learning as well as the need for active construction of this new knowledge, are grounded in the philosophy of constructivism (Bodner, 1986). Constructivism is discussed further in terms of a theoretical framework for the thesis in chapter 3.

Using Piaget's and Vygotsky's ideas as his starting point, Bruner investigated cognitive psychology further (Bruner, 1960), discussing the processing models of the brain and focusing on constructing new knowledge through student centred approaches. He supported Piaget's philosophy of learning by experience and Vysotsky's philosophy on the social nature of learning as well as the requirement for a student's active involvement. (Information processing models as well as Bruner's spiral curriculum have previously been discussed in chapter 1, section 1.2.2 and 1.6.2)

Bonwell & Eison, (1991), a US report, explained that actively engaging students may help them to learn. It encouraged the use of active learning within the classroom, advocating that change was needed to move away from the traditional didactic lecture to a more interactive teaching environment. They conclude with the benefits and potential better outcomes associated with active learning, calling for further research in this area of learning and teaching to provide greater evidence.

Active learning continues to be discussed by academics with studies highlighting the positive effects on the students learning, however there is no standard definition for this concept. A systematic literature review has been conducted to specifically identify a definition for 'active learning' as a term (Doolittle et al., 2023). Based on their research and analysis, the authors suggest the following definition:

"active learning is a student centred approach to the construction of knowledge focused on activities and strategies that foster higher-order thinking" (Doolittle et al., 2023 page 1).

This will be considered the correct definition in this thesis.

Like some of the terms already discussed, the simplicity of the description can be a barrier. Without an internationally recognised definition for specific teaching approaches, more detail is required in published studies. In order to be meaningful, information is specifically required in terms of which methods were used for active learning by teachers in an educational setting and if these methods lead to a significant and measurable benefit for students when compared to the more traditional teaching methods. This will allow these methods to be reproduced and evaluated to provide further relevant evidence.

2.1.8 Meaningful learning

The importance of understanding as an element of the learning process is a significant part of this thesis. Thus, meaningful learning as an approach, as opposed to rote learning with memorisation, needs to be defined.

The educational psychologist, Ausubel used the phrase "meaningful learning" in the 1960's to describe a constructive and effective way to learn (Bryce & Blown, 2024). He proposed that new learning material needs to be clearly presented and organised as well as linking to the student's own prior knowledge which will help anchor the new information. The student needs to be actively involved and seek to link this new knowledge to their own existing knowledge to fully understand the context, thus making it meaningful. More recently, work done by the educator Joesph Novak (Novak, 2002) supported Ausubel's theory of how knowledge is assimilated, highlighting the differences from rote learning. He explained the importance of relevance for this new information and the need for it to relate to existing knowledge and importantly the need for the student to choose to actively engage with this new learning. Ausubel's initial work laid foundations for the philosophy of constructivism, with Novak's explicitly linking to it. Both highlighted that learners are processing new information by actively constructing and organising it with their own individual previous knowledge and experiences.

The principles of the educational philosophy of Piaget and Vygotsky also continue to be relevant here as participation and active positive engagement from students can result in meaningful learning (Huitt & Hummel, 2003; Kozulin, 2003).

The concept of meaningful learning was much respected once published, with educators welcoming the term, including the distinguished US chemistry education Professor Bretz. (Bretz, 2001) explained the key components of Novak's theory and encouraged further chemistry education research using this theory driven framework as a fundamental part of the design.

For the purposes of this thesis, meaningful learning can be defined using extracts from one of Novak's books. Although he does not provide a specific definition, he describes it in detail in one of its chapters. Using this as the basis, the definition is:

"Meaningful learning results when the learner chooses to relate new information to ideas the learner already knows. It requires (i) well organised and relevant concepts and propositions held by the learner, (ii) materials that are rich in concepts and meanings (iii) a learner's desire to integrate new knowledge with prior knowledge (Novak, 2010 p 43 and 44)."

Through his continuing research, Novak investigated tools which may assist students with meaningful learning, publishing pioneering work on concept maps and how these can be constructed to support meaningful learning (Novak & Cañas, 2006). He also considered learning theory and the use of concept mapping in the context of teaching chemistry (Novak, 1984). As the concept of meaningful learning involves the construction of knowledge, it is underpinned by the theoretical framework of constructivism which is discussed further in chapter 3.

2.1.9 Summary of term definitions

Following the discussion and defining of terms, a summary is provided in table 2 for ease and clarity for the reader.

Table 2 – Summary of defined terms

Term	Confirmed definition for this thesis
Student Engagement	A student's commitment to their academic study in order to improve their learning, understanding and application.
Student Motivation	This is considered the drive students have to participate in learning and strive for academic success
Student Attainment	This is the academic result for a recognised formative or summative assessment at the relevant level of study.
Integration (strategic definition)	This is a "multi-faceted term describing a curriculum design which may be defined by model (horizontal, vertical, spiral), theme (systems-based, stages of life, topic, cross-cutting theme) and integrative teaching and learning approach (problem-based, case-based, experiential, enquiry-based, team-based learning, inter-professional education) and level of integration" (Kerr et al., 2020 page 13)
Integration (operational definition)	"integration is when connections are made across different modules or subject areas of the pharmacy course" (Mawdsley & Willis, 2019 page 452).
Contextualisation	The use of 'real-life' and relevant health- related examples within teaching to establish clear connections to chemical concepts.
Active learning	"Active learning is a student centred approach to the construction of knowledge focused on activities and strategies that foster higher-order thinking"(Doolittle et al., 2023 page 1).
Meaningful learning	Meaningful learning results when the learner chooses to relate new information to ideas the learner already knows. It requires (i) well organised and relevant concepts and propositions held by the learner, (ii) materials that are rich in concepts and meanings (iii) a learner's desire to integrate new knowledge with prior knowledge (Novak, 2010 p 43 and 44)

2.2 Literature search for relevant published articles

The second strand of this chapter is a narrative literature review investigating the relevant themes linked to the thesis research questions. Published studies within the higher education settings were sought, reviewed and critiqued for presentation in this chapter. Three databases were selected to inform the literature review (Education Research Complete, Scopus and ERIC). This combination was selected due to the extensive range of literature and resources they could provide, the wide scope of both education focused material as well as material linked to multiple disciplines like science and pharmacy. In addition to searching electronic databases, a second strategy of citation searching of articles read was also carried out to find further literature. Both these tasks helped to ensure a thorough and comprehensive literature review.

The searches were refined so that only articles published in English were reviewed as well as experiences only pertaining to higher education settings. It also specifically looked at research carried out within pharmacy degree programmes as a non-chemistry major degree. In terms of relevant countries, the variety of roles that pharmacists play across the globe were considered. The clinical expertise and role as part of the multi-disciplinary team are considered similar in the US, Canada and Australia when compared to the UK. Because of this and the previous review of national educational standards, the aim of undergraduate programmes can be considered similar and so the reviewed studies were restricted to these countries. (The educational standards for these countries have already been discussed in chapter 1, section 1.5)

2.3 Themes of the literature review

The review of the literature was focused on three main themes which were explored in detail to gain a deeper insight into the subject area. These were:

1) the perceptions of students on learning within their degree, namely chemistry within non chemistry major (pharmacy) degrees

2) the perceptions of academic staff teaching chemistry within non chemistry major (pharmacy) degrees

3) teaching intervention examples supporting pharmacy students to learn chemistry with understanding and application for the professional healthcare environments they will work in as pharmacists.

A range of synonyms were used when searching databases as it was recognised that multiple words could be used to cover this topic. For example: when looking for articles related to theme 1 and 2, academics, professors, educators, students, staff, lecturers, faculty were used; perceptions, thoughts, perspectives, views and opinions were also used. When looking for relevant articles linked to theme 3, active learning, meaningful learning, integrated learning, problem based, case based, context based, collaborative, discovery, team-based and application-based learning in both chemistry and pharmacy were used as search terms.

2.4 Summary and critical review of the literature discussed under each theme

Relevant articles for each of the three identified themes will be discussed under each subheading.

2.4.1 Student perceptions

A range of articles were identified which explored pharmacy students' perceptions in the relevant area. Some papers explored students' opinions of chemistry and science within the pharmacy degree in general, whilst others sought their opinion on a newly implemented teaching session or approach. To adhere to the identified theme and the overarching intention of this doctoral study, only papers that specifically referred to the chemistry content in the teaching and learning of pharmacy are reviewed and critiqued here.

During the expansion and clarification of pharmacists' role in the UK in the early 2000's, several studies were conducted during the transition period. The student focused research that was conducted explored student perceptions and opinions on curriculum content and delivery. A report published by Wilson et al.,(2005) looked at the differences in curriculum, teaching styles and assessments at 16 schools of pharmacy in the academic year 2003 to 2004. As part of the project, students across the 16 schools were invited to take part via questionnaire. In total, 741 final year MPharm students across these schools participated and answered questions on several issues including the science content of the degree. Over one third of the students felt that there was too much science in the course. On the subject of practicals, just under 30% felt that practicals in pharmaceutics, pharmacology and medicinal chemistry were the 'least useful' whereas 92% felt that clinical and dispensing classes were useful.

A further study by this UK research group, (Jesson et al., 2006), used focus group interviews with 44 students participating from over nine Schools of Pharmacy, to explore how students felt about the balance between science and practice within their degrees. They found that students perceived the emphasis on science, specifically in the earlier years, to be high. Students often appreciated the need for this underpinning science in their later years but did not initially recognise this. The authors concluded that paying particular attention to the sequencing of teaching and integration of science and practice elements may enhance students' understanding of materials as well as overall engagement.

It is noted that this research was published prior to implementation and development of the new educational standards and associated MPharm programme (GPhC, 2011, 2021) so reflects the earlier, more traditional pharmacy curriculum. The research helped to inform the development and implementation of the newer standards and a more integrated approach to pharmacy teaching nationally.

Following the implementation of the GPhC 2011 educational standards (GPhC, 2011), Prescott et al., (2014) investigated pharmacy students' perceptions on the relevance of certain subjects taught in their degree, towards their future career. A total of 254 students participated in questionnaire completion at a single UK institution. The authors found that, although students stated that chemistry (and biology) were important, those in the later year groups thought chemistry less relevant than those in earlier year groups. They suggested those students who did not recognise the relevance of a subject tended to be less engaged with it and continued to highlight the importance of integration of science and practice early on in the curriculum.

A study at a different UK institution, (Smith et al., 2017), looked at students' perspectives of the chemistry content in their pharmacy degree, how relevant they felt it was for their future professional role (as well as teaching support provided through the university's virtual learning environment (VLE)). A total of 122 responses were received following distribution of the online questionnaire. The majority of students recognised the importance of chemistry but rated both chemistry and biology modules as less enjoyable than pharmacy practice modules. It was also found that prior attainment and experience in chemistry at secondary school level did not appear to influence students' perception of chemistry at a university level. The study concluded that the further support materials provided by the VLE with a contextualised approach would be welcomed by the students.

Several articles were identified that discussed the approaches taken to teaching chemistry within the degree programme as opposed to only considering the subject areas and explored students' thoughts on these approaches.

A three-year longitudinal study at one US institution (Alsharif & Qi, 2014) investigated how the attitude, enthusiasm and teaching style of the medicinal chemistry lecturers influenced pharmacy students' perceptions. They found that this positively impacted on the motivation and vitality of students (with a total of 472 students participating in the study). Whilst providing interesting data, this study did not specifically continue the link to any changes to a students' ability to apply this underpinning knowledge to clinical problem solving. However a later study by the same research group, (Alsharif et al., 2016), looked further into clinical skills development from the underpinning medicinal chemistry teaching. Following completion of a pharmacy skills laboratory, a total of 121 students reflected on their performance and completed a questionnaire which showed self-efficacy scores improved after the medicinal chemistry teaching. However, it is acknowledged that this may not equate to overall improvement in academic performance.

Islam & Schweiger, (2015) developed and delivered an integrated course with the PharmD programme at one US institution, specifically integrating medicinal chemistry, pharmacology and pharmacotherapeutics. They aligned the teaching with organ systems and associated diseases. Following its implementation, they evaluated their students' perceptions of this integrated approach. A total of 169 students responded with the majority of the students responding positively to this integrated approach, but with the more senior year group having a statistically significant higher positive response rate when compared to the lower year group. This suggests that students appreciate the clinical links to practice more as they progress through the programme and develop a deeper understanding.

Austin et al., (2020) acknowledged that although an integrated approach brings the opportunity to understand and apply this knowledge to practice, students can also find this challenging. They developed a range of enrichment activities at their US institution to support students' integrated learning and help them make connections between the disciplines. The survey of participating students, (116 in total), showed that they felt their confidence had improved as well as metacognition skills. However, it is noted that participation in these enrichment sessions was voluntary so these may have already been high attaining students.

Most studies exploring perceptions that were reviewed did not look at achievement, although a study by Gupta et al., (2021) explored both the students' perceptions of the use of active learning methods in medicinal chemistry as well as academic performance in US national pharmacy assessments. The study found that students who were performing well in the active learning tasks went on to perform well in the national pharmacy assessments. Students agreed that the active learning methods used were useful for their learning. However, it is noted that other possible confounding factors were not controlled or considered, for example prior attainment or motivation within the group. Although there is clear correlation between active learning and academic performance here, it does not necessarily mean there is causation.

Integrated curricula are regularly discussed in the pharmacy literature, but it had not been clear how students experience it until Mawdsley & Willis, (2019) investigated this at a UK institution. A total of 51 students participated (in eight focus groups) to explain their lived experiences of studying on an integrated programme. They understood that teaching was horizontally integrated and appreciated when integration was made explicit by their lecturers. They still found integrated assessments challenging and the authors concluded there needs to be further work to ensure teaching fully aligns with assessments that can test higher order integrated thinking.

Finally, there were a range of papers reviewed that explained innovative and novel methods used to teach chemistry during the pharmacy degree and students' perceptions were sought following their implementation.

These examples included the development of a virtual escape room (Barrickman et al., 2023) to teach cardiology knowledge and skills, a 3D modelling workshop to help students understand drugs and receptor interactions (S. Hall et al., 2017), a series of team based multidisciplinary workshops (Kolluru et al., 2012) and integrated case-based teaching of medicinal chemistry (Das et al., 2018). Analysis of students' perceptions in these examples found that students generally enjoyed these sessions, were more engaged and thought they were effective in supporting them learn the concepts. It is not unexpected that students would enjoy new and possibly more interesting methods of teaching when compared to standard lectures and workshops. It is unclear whether their implementation has an impact on future application of knowledge and a deeper understanding as the evaluation considered student perceptions rather than learning gains, however the teaching approaches do align with active and meaningful learning principles discussed in section 2.1.

It is acknowledged that these studies have not provided any insight into whether there is an improvement in abilities or attainment, but these were outside the scope of this theme. One aim of underpinning chemistry knowledge is to deepen students' understanding, using this to build on their problem solving and decision-making skills. It is unclear whether students fully appreciate this is what the pharmacy degree programme is trying to achieve and is an area that should be explored in more detail. The articles that have discussed student perceptions here have taken a variety of data collection approaches with either questionnaires, focus groups or interviews being utilised. Whilst the benefits of questionnaires need to be acknowledged in terms of number of respondents, the ability to retrieve rich qualitative information when using in depth focus groups and interviews need to be considered (Denscombe, 2017). The benefits and drawbacks of these data collection methods will be reflected on in chapter 3 when planning the research in this doctoral study.

2.4.2 Staff perceptions

Following the literature search, there were few published articles identified that directly related to educators' opinions on teaching chemistry within non-chemistry major degrees. It was also found that articles in this theme were primarily investigating other aspects, for example, students' perspectives, and inclusion of staff opinions involved in delivery or preparation of the teaching was included to provide some further insight. It should be noted that studies which focused solely on staff perspectives of aspects such as student professionalism or types of teaching in general were excluded if they did not specifically relate to the teaching of chemistry with the pharmacy degree.

Roche et al., (2000) explored the chemistry content of pharmacy programmes in the US via a survey which received responses from 33 schools of pharmacy. Part of this survey also explored academic staff attitudes towards the chemistry in their pharmacy programmes. In terms of themes identified, respondents discussed chemistry as a strong foundation for therapeutic decision making and they felt it also helped teach skills like problem solving and critical thinking. They acknowledged the importance of how chemistry should be taught; in terms of relevance as well as active learning approaches like case-based learning. It is noted that this survey took place in 1997 to 1998 and pharmacy programmes, as well as the role of pharmacists have changed significantly since then.

A further study by Henriksen & Roche, (2012) included clinical colleagues in the design and delivery of medicinal chemistry modules at their US institution to provide a more integrated approach. In terms of opinions on this teaching, the article primarily focused on the students' experience of the learning, but staff opinions were also sought. Three teaching staff who had a clinical background and were involved in supporting the interdisciplinary approach of these modules provided their opinion via a survey. There was not a full consensus on how beneficial these teaching reforms were, with 2 staff members agreeing that clinical relevance of medicinal chemistry was reinforced by their involvement, and one stating they were unsure of this. Whilst these survey results may provide some interesting insights from the staff, the very small number and lack of detail provided in this small section of their research means that there is still further evidence required.

In a similar way to Henriksen & Roche (2012), Das et al., (2018) explored the introduction of medicinal chemistry case-based learning within the PharmD programme at a US institution. Whilst the majority of the research was analysis from a survey on students' perceptions, they did also seek the opinions of three post qualified pharmacists, one of whom was an academic. The responses were positive, specifically highlighting the real-world application of the cases and the support they could provide in learning how to make and justify therapeutic decisions. Whilst this provides some interesting insights, the very small number of participants and lack of a clear and robust methodology for this small section of their research suggests that this is an area that is worthy of further exploration given the identified gap in the literature.

Due to the paucity of relevant articles on staff perspectives, a paper outside the specified geographical area was reviewed and included. Although it is based on pharmacy academic staff in South Africa, the paper by Singh et al., (2020) is pertinent to this thesis as it considered staff perceptions on the knowledge, skills and overarching qualities gained by pharmacy students during their studies. Six academic staff members of the pharmacy team were interviewed, one of whom worked within the discipline of pharmaceutical chemistry. All staff stated that they thought the ability to apply knowledge from across the disciplines to practical situations once qualified was an important graduate attribute. When compared to the qualification of pharmacy in the UK, South Africa requires completion of a bachelor's degree of pharmacy followed by a one-year internship. The degree is regulated nationally and has educational standards to adhere to which require students to have a strong knowledge base in science (Council of Higher Education, 2022) in addition to developing clinical skills. However, the clinical role of pharmacists in South Africa is not yet as developed as the profession in the UK (Crafford et al., 2023).

An article which specifically discussed educators' thoughts on the structure of a pharmacy curriculum was reviewed and included as it considered how science (including chemistry) and practice material is presented and taught to pharmacy students. The impact and the interpretation of an integrated curriculum and how this was perceived by educators was explored by Mawdsley & Willis, (2018) at a specific UK institution. Whilst there are many published articles about taking an integrated approach, this was the only article found which specifically discussed the approach directly with the members of staff who would be delivering the curriculum. Eight staff members were interviewed from a range of disciplines in a UK school of pharmacy. It stressed the range of understanding shown by staff and highlighted the risk that having no recognised definition of 'integration' brings. It also emphasised some of the tensions felt from an integrated approach by some of the science staff; "some of my colleagues [are] very against integration. They think it is downgrading the science" (Mawdsley & Willis, (2018) p377). It called for a clearer alignment of the design ensuring the implementation of fully integrated assessments to allow students to demonstrate the higher order thinking skills they have developed through the integrated approach.

From this literature search, it is clear that gathering academic staff opinions is an insufficiently explored area of research. Learning from their lived experience can add a further valuable dimension to pedagogical research.

It is acknowledged that in order to gain rich qualitative data when exploring attitudes, data collection methods like focus groups and interviews are well respected. Although questionnaires can allow for a higher number of participants when there are time constraints, the depth of the qualitative data when compared to interviews is considerably less. Given the small numbers of relevant academic staff (when compared to the number of undergraduate students), the use of interviews seems the most suitable research method to use to fully explore perceptions in this area. Although the use of surveys can be time efficient (and has been used in some of the papers discussed), interviewing individual staff is possible as part of this doctoral study and is considered more suitable for this type of data (Smith, 2010). Suitable methods for data collection will be discussed further and justified in chapter 3.

2.4.3 Teaching interventions

During the literature searches, several examples of teaching approaches to engage the students with chemistry teaching in higher education which clearly embed concept understanding were found, but the narrower scope of this theme was adhered to, with papers referring explicitly to chemistry teaching with the context of pharmacy programmes only being reviewed. In line with the theme, teaching interventions which specifically looked at application of knowledge within a pharmacy context utilising this underpinning science are discussed and critiqued in this section. Subheadings have been used to separate and categorise the types of intervention reviewed.

2.4.3.1 Teaching Interventions specifically starting in the first year of study

It has been argued that an integrated curriculum approach for pharmacy programmes is beneficial from the start of the programme rather than front loading a science foundation (Winch & Clarke, 2003). When the concept of integration is introduced later, there is a risk that students do not appreciate the relevance of the teaching and so do not engage with it as well as hoped (Prescott et al., 2014; Smith et al., 2017). Several authors were found to have addressed the challenge of relevant teaching from year one and designed teaching approaches to overcome this issue. Brown et al., (2009) recognised this concern and had noticed their students struggled to make the connections between their foundational science teaching and clinical pharmacy. Working together with both practice and science academics, they set up volunteer patient cases and students were required research aspects of their disease and treatments in an integrated way. Students then presented this work at the end of the year. The authors found this helped to foster integrated thinking skills and encouraged them to make connections and appreciate the relevance of all their subjects. However, it is not clear if overall competence in the subject was improved.

A strong foundation in the early years is imperative but there are examples of teaching which demonstrate a clear link between science and practice as well as embedding concepts. (Trippier, 2018) used a “molecule of the month” initiative to help his students link the concepts taught in organic chemistry to drug molecules and their mode of action. This allowed students to deepen their understanding and provided relevant clinical context at an early stage of their degree. Those who participated in this voluntary activity scored higher on the final module assessment when compared to those who did not.

2.4.3.2 Teaching interventions with medicinal chemistry as their starting point

A well-established research group based at Crieghton University in the USA have researched medicinal chemistry within pharmacy and PharmD programmes for many years, introducing Structurally- Based Therapeutic Evaluation of drugs as early as the 1990's (Alsharif et al., 1997, 1999) to encourage students to include their medicinal chemistry knowledge when making clinical decisions. This research work consistently strives to deepen students' understanding and use their medicinal chemistry knowledge to support their understanding of drug design, activity and also therapeutic decision making. The researchers have used a variety of methods to achieve this, Roche & Alsharif, (2002) used structured preparation before class with quizzes to support this learning. It meant that the on-campus teaching sessions were used for application of knowledge and engaging with others. These factors are known to have an impact on learning, with Bruner (Bruner, 1960) emphasising that revisiting earlier learnt material helps build more complex knowledge and understanding. Vygotsky (Kozulin, 2003) and Ausubel (Bryce & Blown, 2024) both advocated that active participation and peer interaction was a way of gaining higher level knowledge and achieving meaningful learning.

Integrated case study approaches have included teaching on specific common drug groups including ACE inhibitors (Alsharif, 2007) beta antagonists (Alsharif et al., 2006), proton pump inhibitors (Roche, 2006) and NSAIDs (Roche, 2009). The overarching design model for these sessions follows Bloom's cognitive and affective taxonomy (Alsharif & Galt, 2008) with application of knowledge as well as responding and organising learning material to new scenarios and working effectively in their teams (Bloom et al., 1956, 1973).

As the clinical role of the pharmacist has continued to expand, Alsharif & Faulkner, (2020) practised clinical decision making in workshops. Medicinal chemistry was at the core of this teaching which also introduced a thought process framework for care planning, using Alzheimer's disease and possible treatments as the example to be applied to the framework.

2.4.3.3 Teaching interventions using novel teaching approaches

Gamification is a well referenced method of engaging students in healthcare education (Van Gaalen et al., 2021). Roche et al., (2004) used this approach to help reinforce the relevance of medicinal chemistry, planning an innovative game taking inspiration from a popular TV game show. Students worked through increasingly difficult questions in teams and the feedback suggested that it helped them to link their medicinal chemistry and practice knowledge. Whilst a fun and innovative example, it would not be possible for wider use across a programme without a large amount of extra teaching and administration support.

A university in the UK has developed an enquiry-based learning approach (Sattenstall & Freeman, 2009) for first year students studying pharmaceutical chemistry. It aimed to promote integration between all subjects from an early stage in their pharmacy degree and summative assessments required students to apply their integrated knowledge to a specific therapeutic area. Although the paper is linked to previous educational standards, this university has developed and updated this approach following the GPhC 2021 standards (GPhC, 2021) (UoM, 2025).

Karimi et al., (2010) designed an approach that integrated the didactic teaching of pharmaceutical chemistry with the experiential components of their curriculum. Assignments were created (known as 'learning bridges') to be completed during placement days. These assignments required critical thinking and application of both practice and science. It helped students appreciate the relevance of the chemistry they were taught and using placement experience to help with this was a novel approach that had not been documented before.

Fergus et al., (2019) appreciated the need for a way of linking the scientific underpinning teaching with pharmacy practice learning. An integrated case study was designed for third year pharmacy students with student feedback showing that 100% of students felt it successfully integrated science and practice learning. In addition, a model framework was developed to help design future case studies to ensure they were appropriately contextualised and integrated.

2.4.3.4 Teaching interventions based in the pharmaceutical industry setting

Many examples of teaching interventions show how this integrated knowledge can be used in case studies from primary or secondary care settings, however an interesting example was found in relation to industry. Strohfeldt, (2019) describes how a practical class was adapted to simulate an industry setting. The students were set into teams as individual pharmaceutical companies. A virtual client was introduced to the practical and gave students tasks to complete. This allowed students to see the important patient safety aspect of maintaining and assuring the quality of pharmaceutical products. It is important to remember that the pharmacy programme is a standardised qualification for all sectors so students should be taught with industry specific examples as well as clinically focused ones.

2.4.3.5 Teaching interventions using the disease as a starting point

Miller & Mercer, (2017) delivered a module for pharmacy students on the topic of addiction and possible drugs of abuse. Rather than teaching the topics in isolation, they integrated the material with science and clinical-based academics involved in the design and delivery of the module. It aimed to demonstrate the integrated critical thinking used by a pharmacist working in this area with students agreeing the active learning methods helped their knowledge and understanding and they also saw the benefit of inter-faculty teaching.

2.4.3.6 Teaching interventions using the patient as a starting point

Marriott et al., (2012) from Monash University describe how a resource platform of a fictional community was developed. It contains characters with a range of ethnicities, ages and health-profiles. These characters then formed the basis of integrated teaching to allow the students to value both the science and practice aspects whilst relating to the fictional character. It is noted that this kind of project requires a significant time commitment and engagement from all staff and the integrated teaching materials still need to be developed following the design and conception of the community characters. An additional challenge is the monitoring of these characters and their illnesses that is needed to maintain consistency across the year groups.

Kearney & Larrañeta, (2021) wanted to develop teaching material that integrated both medicinal and analytical chemistry. They designed patient centred workshops with case studies featuring beta antagonists as the main therapy. Students interpreted analytical data and considered structure- related pharmacology to explain aspects of the case. These voluntary workshops were well attended and well received with 97% of survey respondents agreeing the teaching helped them apply and integrate their knowledge.

2.4.3.7 Teaching interventions adapted for the COVID 19 pandemic

With the advent of the COVID-19 pandemic and the prolonged need for social distancing, there was a need to move teaching online. Because of this, there was a real concern that peer interaction and active learning approaches that were pivotal for learning and understanding (Vygotsky, 1978) would be compromised. Examples were identified in the literature that successfully adapted chemistry teaching during this time. Singhal, (2020) designed and delivery a medicinal chemistry programme where students were required to use their integrated knowledge on endocrinology cases, using their knowledge of drug structures to decide treatments. This utilised the POGIL (process-orientated guided-inquiry learning) approach (Simonson, 2023) which is a student centred approach, allowing them to construct their own knowledge and understanding through peer interactions and problem solving activities. Whilst online, Singhal used virtual break out rooms via Zoom with facilitators supporting students in these rooms and this approach was received positively by the students. The assignment remained unchanged and the average scores when teaching virtually showed no significant difference to online teaching from the previous years.

Barrickman et al., (2023) used the novel approach of escape rooms as a teaching method and was able to successfully adapt this to a virtual online environment. The puzzles centred on cardiology and integrated material from chemistry, pharmacokinetics as well as having the clinical details to form a simulated case. Students' scores in a pre and post-test were compared, and statistically significant improvements were seen.

2.5 Identified gaps in the literature

Following consideration of the published literature, any identified gaps are set out under the three identified literature themes

2.5.1 Student perspectives

Despite the clear focus on educational excellence with the incorporation of integrated teaching approaches in many pharmacy degree programmes; directly exploring pharmacy students' thoughts and perceptions regarding their understanding of the teaching and the aims behind integration have seldom been addressed.

Some of the detailed qualitative research from pharmacy students can be considered out of date acknowledging the significant changes to the degree and the health care provision that have taken place, both in the United Kingdom and across the world. It is appropriate for students' thoughts and perspectives to be investigated further following the increasingly clinical and pivotal role for pharmacists and the changes in GPhC educational standards.

2.5.2 Staff perspectives

There has been found to be very little research into educators' perspectives, especially in relation to chemistry teaching and more specifically this teaching within a healthcare profession course.

This doctoral study would like to allow the educators' voice to be heard in terms of their lived experience within the classroom setting. Recognising their experience and expertise could contribute a distinct and more diverse perspective to the research.

2.5.3 Chemistry Teaching interventions within the Master of Pharmacy student population

There is a wealth of well documented interventions that have been used and trialled in pharmacy students then followed up with a range of evaluations. The majority of the teaching interventions that are documented have often been taught from a science perspective and written to incorporate a clinical scenario. There are fewer that consider integration from a practice point of view first with the underpinning science being needed to fully understand the concepts. There could be a greater emphasis on how pharmacists can justify the decision-making process when choosing the right drug for either independent prescribing or recommending it directly to a prescriber. In addition, there is little evidence that the need to communicate complex information to a lay patient is practised by applying the students' deep understanding of their underpinning chemistry.

There are also few examples of student involvement in the development and delivery of these integrated approaches. As students are known to value and often rely on the explicit highlighting of integration within their learning (Mawdsley & Willis, 2019), this may be a worthwhile area for further investigation as their direct insight may be valuable. DellaVecchia et al., (2017) reported on a pharmacy student employed as a teaching assistant as part of an undergraduate medicinal chemistry module. Post module evaluation showed that their involvement complemented peer to peer learning, deepening students' knowledge and understanding (Eun, 2019) and the students reported an increased level of confidence as well as helping bridge the gap between science and practice.

There is little evidence of comparing these innovative methods with 'standard' teaching practice. However, it is acknowledged that it would be challenging to separate out a cohort into a new approach and standard teaching practice from an ethical point of view. It could potentially be done on a voluntary basis, but students who proactively volunteer for active learning may be already more engaged so could introduce a factor of bias.

2.6 Planned contribution to the literature

It is noted that the range of universities that offer a Master of Pharmacy programme in the UK has increased in recent years, many with a prominent widening participation agenda when compared to the more traditional older universities. The programme structure has also changed significantly since the majority of research on pharmacy students' perspectives has been completed. Exploring both students and staff perspectives in this institution with a widening participation agenda will meaningfully add to the body of literature in this area. There can be further exploration into students' understanding of thinking integratively and how effectively the teaching highlights the need for this and any explicit links in the modular structure of their degree. Staff can explain what impact and effect they intend to achieve with the teaching methods they use and any perceived barriers and challenges they may face.

The incorporation of the student voice also will be considered further in the development of teaching materials as this could be beneficial (Nelson, 2015). Their perspectives are often gathered after the interventions from the literature examples found, but there is little evidence of their direct involvement in initial design. Whilst it is acknowledged that students do not have the expertise for teaching design and delivery, their scaffolded input may be beneficial and their lived experience at this point prior to roll out to the whole cohort should be considered as a new approach to provide a different perspective and therefore novel research.

In terms of teaching interventions, cases will be structured with the patient at the centre, reflecting how a pharmacist would approach patient care in practice rather than from the perspective of individual subject disciplines. It also links to standard 1 of the GPhC standards for pharmacy professionals (GPhC, 2017). Providing teaching where students work towards a rationale for making therapeutic decisions and allowing them to justify their decisions with their underpinning science knowledge would be beneficial. This links to the core of evidence-based medicines and decision making. Whilst students are taught the importance of clinical guidelines, just adhering to guidelines is not enough as could be considered rote learning rather than demonstrating higher order thinking.

2.7 The thesis conceptual framework and consideration of philosophical world view

Having critically reviewed the literature and defined key terms, these insights can be used to propose a conceptual framework for the thesis. The central concepts of this thesis are contextualisation, integration and relevance with higher order thinking being a key cognitive process that it is hoped students achieve.

These identified key concepts interconnect to influence a student's development of higher order thinking. Chemistry teaching material which has relevant content for pharmacists can allow students to appreciate how it can be applicable to future practice (Fergus & Kostrzewski, 2011). Teaching can also be contextualised within relevant settings to support the learner in connecting the science knowledge with practice examples, supporting understanding and meaningful learning (Alsharif et al., 2006; Kearney & Larrañeta, 2021). Embedding the relevant chemistry linked to practice topics when teaching (so using an integrated approach) can also help the student to connect knowledge by facilitating deep understanding, rather than rote learning (Roche & Alsharif, 2002).

Adhering to this conceptual framework when exploring learning and teaching and designing teaching interventions can potentially influence the cognitive process of higher order thinking (Mawdsley & Willis, 2019). Actively integrating knowledge across a range of topics within a suitably relevant context may promote higher order thinking and problem-solving (Husband et al., 2014). Learning may be enhanced in these situations as it fosters and encourages deeper understanding and application of this newly acquired knowledge (Overton, 2016).

The philosophical worldview of constructivism can provide an explanation of why these concepts work together to promote and encourage higher order thinking skills (Bretz, 2001). This is discussed further in chapter 3 (section 3.2).

Chapter 3 -Theoretical framework, methodology and research design

This chapter will discuss and justify the philosophical assumptions and worldview that informed this doctoral study. It will also further outline and justify the aims and research questions of the thesis. The selected methodology and overarching research designs will be described and finally, the research methods for each phase of the study and an outline of their subsequent analysis will be discussed and explained.

3.1 Summary of the rationale for exploring this research area

The science of chemistry, how it is taught and therefore learnt was the starting point of this doctoral study. Chemistry is an integral part of the pharmacy programme and underpins clinical knowledge in this field (GPhC, 2020). Although it may be possible to rote learn clinical information without the input of science, there is a finite limit to the amount of novel information that can be stored in a brain due to working memory capacity (Reid, 2009). Also, without the underpinning chemistry concept knowledge, it is not possible to demonstrate understanding. With the complexity of clinical pharmacy roles, the expansion of drug design and the widening discovery of disease states and subsequent treatment, it is not possible to 'learn' everything for a pharmacist's subsequent career during a pharmacy degree (Angelo et al., 2022). Hence, as the role of a practising pharmacist will involve caring for a range of new patients daily; problem solving previously unseen issues (ACPE, 2016) is an essential skill. Pharmacists and pharmacy students therefore need to understand the integrated knowledge of science and practice rather than rote learn knowledge as this is unrealistic given the enormity of the modern pharmaceutical field. (Pearson & Hubball, 2012).

This thesis aims to explore students' learning chemistry with understanding and application, as opposed to solely rote learning information. As part of learning with understanding and application, students should be able to link to clinical practice to science knowledge. Having a clearer understanding due to this underpinning chemistry supports solving problems in case study scenarios (Krol et al., 2024). These required skills were borne in mind when planning the research within the thesis.

3.2 Philosophical assumptions and world view

Having defined the reasons behind the chosen research area, the researcher considered their philosophical position which will inform how these issues would be researched (Cresswell & Cresswell, 2018). Ontology (the nature of reality) and epistemology (how knowledge is acquired) were defined first before using these assumptions to inform the methodology (Guba, 1990), A worldview considers the epistemological stance taken by the researcher, i.e. how the world is seen and how it is understood, which then informs the research and the selected methodologies (Crotty, 1998). It is a philosophical assumption presenting an underlying belief on how issues are understood and also how they can be addressed (Guba, 1990). The appreciation of how reality and understanding are linked together informs a researcher's thinking with multiple approaches presented within the literature (Cresswell & Cresswell, 2018). These approaches have been considered with the most appropriate one selected and justified.

In terms of ontology, this study assumes that students create their own reality from their individual experiences which explains why students have different opinions and understanding even if they have attended the same teaching sessions. There is no single reality with regard to learning experiences so multiple realities need to be acknowledged and are meaningful to each individual student (Crotty, 1998).

Adopting a constructivist epistemology stance, this study assumes that knowledge is constructed and developed through a student's understanding of taught material, which is influenced by their experiences, interactions with others as well as prior knowledge that this new information may link to (Bodner, 1986). Several of the concepts in chapter one support this position. For example, working memory theory and the information processing model which suggests that learners may process information differently, resulting in different students reaching different answers (Johnstone & El-Banna, 1989; Reid, 2009). Also, the evidence that suggests novice learners will process and learn new chemistry material differently when compared to experts (Kozma & Russell, 1997). These examples highlight that learning can be subjective and individual rather than there being one single objective truth.

This thesis has understanding and application of knowledge at its core. As such, the theory of constructivism is arguably the most appropriate concept informing this research because as a concept, it underpins the theory of active rather than passive acquisition of knowledge (Bodner, 1986). Crotty (1998) describes this theory as "the making of meaning", highlighting that meaning is actively constructed rather than passively discovered. Using a constructivist approach, students routinely attempt to link and build on any knowledge that they have already, trying to construct meaning from newly acquired information (Bodner & Orgill, 2007). Learning is influenced by individual experience, thus cannot be achieved independently from a student's previous experiences (Vygotsky, 1978). These previous experiences influence understanding and can lead to misconceptions in chemistry, which is well documented (see e.g. Taber, 2002). In addition, the social aspect of constructivism is pivotal to learning with understanding (Hodson & Hodson, 1998; Vygotsky, 1978) with construction and understanding of knowledge being influenced by social interactions, alongside discussions which allow for further construction of meaning. The concept of constructivism states that although students may participate in the same teaching sessions, it will not result in the same outcome in terms of their learning and understanding, with the students' ability to engage and actively experience the learning affecting the outcome (Dewey, 1938). The impact of any educational interventions must therefore be evaluated rather than their impact being assumed.

In conclusion, constructivism is the most appropriate research paradigm for this research area as students do not all gain the same objective knowledge and understanding from a given curriculum. It can be assumed there is no objective reality, this is individually created and constructed by students themselves. This research will be influenced by the interactions of the students and researcher and the context that this takes place (Cresswell & Cresswell, 2018). The rigour of each method will be considered in each section as well as the position of the researcher.

3.3 Researcher subjectivity

Alongside subjective reality of the learners, the subjective reality of the researcher should also be considered. The researcher designing, leading and conducting the research has their own beliefs and experiences which may influence the research, this is particularly important during qualitative data collection as they are a key instrument within this type of research (Cohen et al., 2018).

At this point, it is important to recognise that the researcher is part of the wider context and world where the research is being conducted. They need to be reflective, considering their own experiences, values and background which could have an impact on the research and therefore should be considered in terms of potential researcher bias (Mortari, 2015). The researcher needs to consider their role at each stage and their interactions with the data. An account of the researcher is written below to highlight their place with the context of research.

> I was brought up in a family where there was always a keen interest and appreciation for the UK education setting. My undergraduate degree was completed as a three-year Bachelor of Pharmacy Honours programme just before the integrated four years Master programme was introduced. It was completed at a time when education was free at the point of delivery and student grants were available, meaning my sibling and I were able to attend university

and we were grateful for this opportunity, appreciating it was not available for earlier generations of our family.

The change in teaching style and increase in class sizes at university were challenging and with no support for transition, it took time to adapt. The relevance of chemistry was not always clear at university which caused frustration as chemistry was the reason for my initial interest in pharmacy. On reflection, we were expected to make the connections ourselves as newly independent, critical thinking adult learners. My pre- registration year [foundation year] was completed in a community setting but upon qualifying I moved to a hospital setting and completed a structured basic grade rotational pharmacist role with the associated completion of a part time clinical diploma. Once in practice the importance of science underpinning practice was often clear through examples on the wards as well as during post graduate practice teaching.

My roles since qualifying were initially within hospital settings, including specialist oncology and palliative care settings followed by a short time working in primary care. In each role, I always took the opportunity to train and mentor other members of staff which included completing an MSc where my dissertation focused on training junior pharmacists in symptom control to support palliative care patients on general wards.

I have now worked in academia over the last 14 years. This path has included roles within module leadership and programme management then a more strategic academic quality role. In addition to the university academic role, I have been an academic panel member with a regulatory body for the last 5 years which has allowed me to gain an insight into a range of curriculum design approaches which all adhere to the standards but in different ways.

There are several steps that will be taken to help ensure the validity of the research. As a lecturer, I recognise that I am not a neutral observer and may have preconceived ideas and expectations of the students. With the collection of qualitative data, there will be other researchers intentionally involved in some of the data collection. There will be discussions to challenge assumptions and interpretations from a critical friend [PhD supervisor]. Data will be anonymised prior to analysis for the qualitative data and during the collection phase for quantitative data. I will be reflective during each study and will reflect on design decisions; thoughts and any assumptions being made.

3.4 Research approach - A mixed methods structure

Justifying a structure which incorporates both qualitative and quantitative research has been documented previously within the discipline of science and engineering education (Borrego et al., 2009). These authors suggest that the desire to fully answer a research question should inform the decision when selecting methodology and no particular method "is privileged over any other" (Borrego et al., 2009 page 53).

Although this thesis has a focus on chemistry, it is specifically investigating the complexities of successfully educating people in this discipline. Experiments within a laboratory environment allow controlled conditions with variables being changed iteratively. However, when considering the effects of teaching and learning as well as exploring the perceptions of students and academics in "complex, real-world environments", using a mixed method approach allows these complexities to embraced more readily than using solely qualitative or quantitative methods (Bazeley, 2018; Schulz, 2014).

This thesis focuses on education so also considers the use of educational intervention tools as part of the research. Choosing a mixed methods design for intervention research allows multiple objectives to be considered as well as providing the flexibility of having several types of data collection to more comprehensively address the research questions (Cresswell & Plano Clark, 2018). Choosing a mixed methods approach does not imply that there are inherent weaknesses in either qualitative or quantitative methods, the decision is justified by the more thorough and richer data collection it allows (Miles et al., 2020). Overall, a mixed method design was utilised to allow a more comprehensive understanding through a more thorough analysis into the overarching research questions (Bazeley, 2018).

The selection of mixed methods as the most appropriate approach to the whole thesis led to reflection and further justification of the worldview. Although a pure constructivist worldview is traditionally linked to qualitative approaches (Crotty, 1998), it is also important to consider all methodological approaches and identify and select those which would be able to answer the research questions most appropriately (Cresswell & Cresswell, 2018). Selecting a single methodology to align to a very pure definition of the philosophical worldview may not provide a balanced conclusion to the research questions (Borrego et al., 2009). Although the constructivist viewpoint lends itself to the generation of qualitative data collection and analysis, the collection of quantitative data can be used in addition to this as its subsequent numerical analysis added to the overall findings of the study.

A comparative strength of quantitative data is that the analysis of a large data set from a cohort can facilitate the analysis of demographic influences and how these possibly impact on an assessment or task. Qualitative data allows a different and much more in depth exploration of students and staff perceptions and lived experience in this specific area (Bazeley, 2018). Following thematic analysis, this can provide a deeper understanding of the phenomena being studied. In line with the constructivism worldview, although students may participate in the same teaching and assessments, their own learning, understanding and feelings are influenced by multiple factors based on how they have experienced the world so far (Bodner, 1986). Qualitative data collection allows the exploration of some of these aspects in more detail and clearly links to the philosophical assumptions of the researcher.

3.5 The mixed methods study design

As both qualitative and quantitative approaches are used in the study, further design considerations are needed with the significance of each approach being considered and the priority and sequencing of studies reflected upon (Cresswell & Plano Clark, 2018; Greene, 2008). Using mixed methodologies requires consideration of how these types of data can be integrated and analysed to comprehensively answer the research questions, as when done effectively, this is one of the main advantages of adapting a mixed methods approach (Bazeley, 2018; Bryman, 2006; Cresswell & Cresswell, 2018).

There are several key concepts that inform the design of a mixed method study, acknowledging that this approach can be more challenging and complex to plan. The literature discusses a range of typology-based approaches to the design across several disciplines (Greene, 2008; Hadi & Closs, 2015; Morse, 1991; Tashakkori et al., 2021), but it is acknowledged that every mixed methods study is ultimately unique, meaning its design should be tailored to answering its specific research questions (Cresswell & Plano Clark, 2018).

A range of typologies have been discussed, categorised and have evolved within the field of mixed methods by many respected researchers (Cresswell & Cresswell, 2018; Fetters & Freshwater, 2015; Greene, 2008; Morse, 1991; Tashakkori et al., 2021). A recent iteration of typologies by Cresswell & Plano Clark, (2018) divides them into three core designs; (i) explanatory sequential design, (ii) exploratory sequential design and (iii) convergent design.

A more complex mixed methods evaluation design is used in this study, employing a series of sequential phases then combining them to allow the conceptualisation, development and evaluation of a specific intervention (Cresswell & Plano Clark, 2018).

The key elements of this mixed method study have been considered (Greene, 2008) with the project split into three phases with data collection points and subsequent analysis informing the next stage of the project. The initial phase is a quantitative study leading to phase two which has two studies that took a qualitative approach. This sequential model of qualitative data collection following a quantitative study allows the researcher to explain any findings from the variables analysed in the quantitative study as well as explore the perceptions of the participants in their own context in relation to their teaching and learning experience. This specifically acknowledges constructivism and the individual realities experienced by individual participants.

The third and final phase of this study is a mixed method study (a quantitative questionnaire embedded with a qualitative strand) (Bryman, 2006) which evaluated a teaching intervention. This embedded mixed approach was used as opposed to using a singular approach potentially allowing richer and detailed findings for the research questions.

Phase one and phase two form an explanatory sequential design (Hadi & Closs, 2015) with the first quantitative phase providing an understanding of any binary influencing factors with regard to attainment. The second phase provides rich qualitative data where influencing factors are explored that were meaningful to the students and staff as participants and could potentially explain the findings from the initial quantitative phase. The final phase three investigates the impact of the teaching intervention with a primarily quantitative focus but with a qualitative strand to corroborate the quantitative data findings (Bryman, 2006).

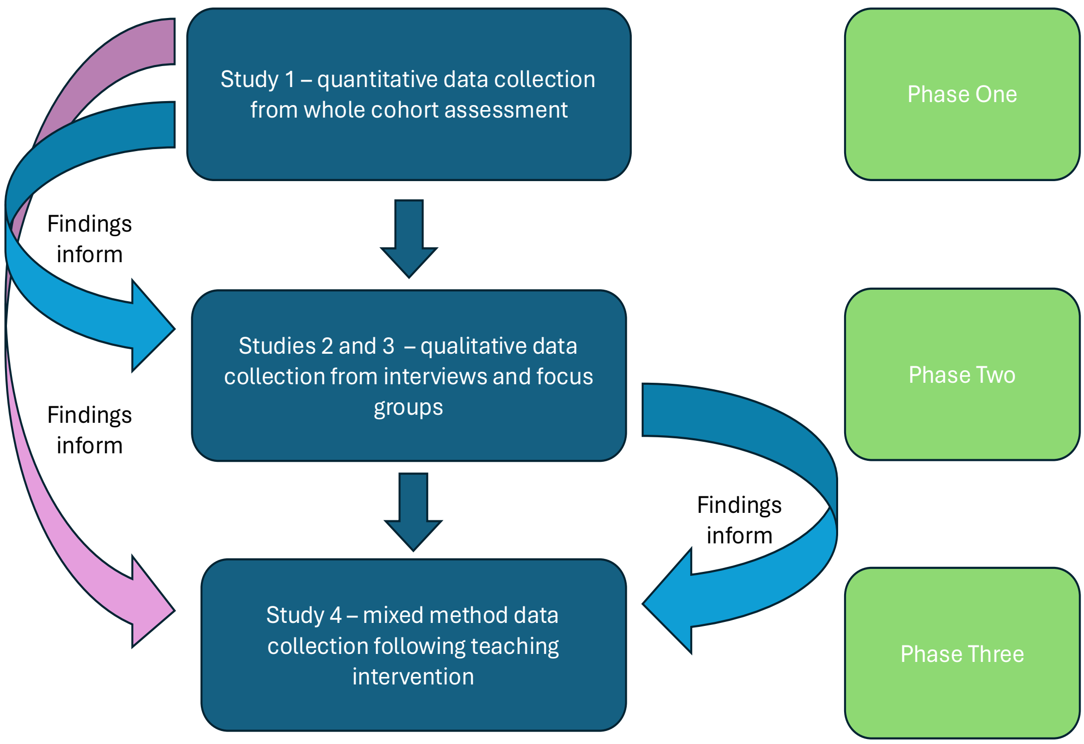

Figure 8-The mixed methods design of the overall research project

Figure 8 illustrates the overarching design of this multi-phase mixed methods study for clarity. Although this design variation is a more complex design structure than some documented core design suggestions, it allows for a more deep and meaningful exploration of the research questions and a more comprehensive evaluation of the newly implemented teaching intervention.

3.6 Relationship between qualitative and quantitative elements within the study

As part of the overarching design, there was consideration as to which approach is given prioritisation or whether both are equally important (Bazeley, 2018; Greene, 2008). In this thesis, they are considered complementary to each other. When considering the overarching research questions of this thesis, both quantitative and qualitative methods are essential in answering them comprehensively. The quantitative data allows a broad overview of whole cohorts, while the qualitative data adds rich depth and further context. With the overarching philosophy being constructivism, it highlights that reality is constructed through the learners' experiences, prior knowledge as well as interactions with staff and other students. Consequently, this means that the qualitative data elements and subsequent analyses have the most significant impact (Cresswell & Plano Clark, 2018).

The quantitative data collected in phase one allowed the identification of any patterns within participants' demographics impacting on learning and assessment, with the qualitative data from interviews and focus groups providing a better understanding of participants individual experiences with teaching and assessment. This qualitative data aligns more closely with the belief of multiple realities.

The questionnaire in phase three included both qualitative and quantitative elements, with the quantitative sections providing descriptive statistics to describe any potential patterns and qualitative elements demonstrating students' individual experiences and interactions with the teaching intervention.

This integration between these two components ensures that the findings are reliable and valid whilst being grounded in real-world experience as constructivism is kept as the philosophical focus. Together, they provide a more complete understanding of the research topic (Tashakkori et al., 2021).

3.7 Research strategy

Qualitative data collection and analysis is used as a significant part of this study to explore individual perceptions towards the learning and teaching of chemistry. This research was phenomenological rather than experiential in design. Controlling the environment, which would be required for an experiential approach, was not appropriate or possible, whilst by adopting a phenomenological stance, experiences and perceptions could be observed and analysed in the natural and less controlled environment of the university (Cresswell & Poth, 2018).

Such a phenomenological approach considers the lived experience of a group of individuals, who have experienced the phenomenon so takes into account their individual subjective experiences but at the same time acknowledges there is a shared objective reality as all individuals have experienced the same thing (Cresswell & Poth, 2018).

The qualitative aspects of this thesis intentionally use both interviews and focus groups as a data collection tool depending on the participant group and the specific research question. Although phenomenological studies often use only interviews as a sole source of data collection, there can be clear justification for incorporating focus groups for this research strategy (Bradbury-Jones et al., 2009), as individual experience can still be represented within group discussions with valuable phenomena emerging. Focus groups allow participants to discuss their shared experiences from their individual point of view and group interactions can reveal insights and themes which may not have emerged from individual interviews (Vella, 2025). However, caution does need to be taken when planning focus groups to ensure participants are not intimidated by others or feel their experiences may be less valid so may remain quieter when compared to an interview (Smith, 2010). These challenges are considered in the relevant study and planning of each focus group explained and justified within the applicable chapter. In addition, focus groups may provide richer data from a social context allowing for exploration and deeper understanding of their experience, in a similar way to how social interaction with others can impact on learning in line with Vysotsky's theory on social constructivism (Hodson & Hodson, 1998).

3.8 Defining the aims and objectives

There is evidence justifying the importance of science within healthcare education, first in a seminal report by Flexner (1910) then in more recent papers emphasising a need to also link to a caring ethos (Duffy, 2011; Finnerty et al., 2010). This thesis aims to investigate more specifically chemistry learning within pharmacy as the central underpinning science for this profession's pivotal clinical knowledge. It also aims to consider learning with understanding and application (Gilbert, 2006) which may not happen consistently with each student depending on their individual experience (Hodson & Hodson, 1998; Vygotsky, 1978).

As discussed in chapter 1, the teaching of chemistry and clinical pharmacy practice within the undergraduate pharmacy degree programme has been discussed and debated for many years (Bandiera et al., 2018; Florence, 2011; Smith & Darracott, 2011). Chemistry teaching has been adapted and pharmacy programme curricula design have been reviewed in an attempt to successfully integrate these areas (Husband et al., 2014; Wensel et al., 2014).

Although there is a clear body of evidence and research in this subject area, the issue of chemistry content and clinical content continues to be debated, and the ‘problem’ is yet to be fully solved in the developed world where pharmacists have a significant clinical role (Faruk Khan et al., 2011; Kearney & Larrañeta, 2021; Wall et al., 2022).

In line with the affective domain as identified by Benjamin Bloom (Anderson & Krathwohl, 2001; Bloom et al., 1973), students’ attitudes may have an impact on their engagement with study material, assessments and general understanding of chemistry, so this has also been taken into account within this thesis by considering and exploring students attitudes. Some relevant teaching examples have already been discussed during the literature review in chapter 2. Whilst the literature review focused on the narrower search of chemistry teaching examples in pharmacy degrees, it is acknowledged there are some excellent relevant examples seen within chemistry major degrees. As an example, Galloway & Burns, (2015) reported on the use of a peer-led support tool with high engagement from the students as a support to their preparation for summative exams, highlighting that methods of teaching can also impact students’ motivation and engagement. A systematic review by Byusa et al., (2022) found that using a game based approach for chemistry students increased their motivation to learn in the 24 studies they reviewed, with the benefits coming from actively engaging with other students as well as the teaching materials. The theme of student engagement as well as an agreed definition has been discussed further in the literature review, chapter 2. (For the purpose of this thesis, student engagement is defined as ‘a student’s commitment to their academic study in order to improve their learning, understanding and application.’)

In terms of chemistry teaching interventions, a large proportion of the research into educational interventions have taken place in student cohorts who are registered on a chemistry ‘major’ degrees (Cooper et al., 2019; Galloway et al., 2016; Taber, 2000; Williams, 2022). This research provides very valuable insights into chemistry teaching but cannot be considered automatically transferable for students on a different (and vocational) degree where chemistry is only considered a minor component. The attitudes and experience of students on chemistry ‘minor’ degrees may influence their engagement and learning (Bloom et al., 1956; Bodner, 1986) in a way that differs to those wholly focussing on the subject during their studies. There are also different potential motivations for study, different entry criteria, arguably different skill sets needed and different career prospects for students in pharmacy cohorts when compared to cohorts studying on a chemistry major degree.

Finally, academic staff attitudes have not been considered in depth in previous literature, so these are investigated in this thesis. There is evidence at secondary school level (Cents-

Boonstra et al., 2021; Corso et al., 2013) to show that teaching staff have a direct impact on student engagement. Exploring the staff perspectives of academics who teach chemistry within pharmacy will provide valuable insight in this area at a higher education level and allow the exploration of similarities and differences between those teaching in compulsory (secondary schools) versus those teaching in higher education.

The general aims of overall project are:

1. Identify and analyse in detail factors affecting chemistry learning in the context of a non – chemistry major degree programme from a staff and student perspective
2. Identify understanding of contextualisation, its importance, relevance and implications within the MPharm student population at the University of Hertfordshire
3. Develop and implement an approach to effectively contextualise chemistry within a pharmacy context and evaluate its impact on learning

3.9 Overarching Research questions for the doctorate

The gaps in the current research were considered in addition to the specific interests of the researcher when developing the research questions   Consideration was given as to who may influence the learning process, so both the teachers (i.e. academics) and learners (i.e. students) were considered when developing these questions.

1) What influences students' understanding and application of knowledge of chemistry within the MPharm degree?
2) What are MPharm students' attitudes towards the relevance of chemistry within the MPharm degree as well as their motivation and most effective ways to learn and understand chemistry?
3) What do University of Hertfordshire staff understand to be the student perceptions regarding chemistry on the MPharm programme?
4) What strategies can support students' application of chemistry and integration with practice learning within the MPharm degree?

3.10 Structure of the thesis

The structure of the thesis, in terms of its three phases, is discussed here with a summary that provides justification of the selected methods and an outline of the planned data analysis. The planning of analysis is important in terms of integration between data types as it is one of the aspects which makes the mixed methods approach very effective (Bazeley, 2018).   Each results chapter will also justify the appropriateness of the methods used and analyses conducted.

3.10.1 Phase one – rationale for quantitative data collection

Factors which have an impact on attainment at a higher education level are multiple and complex (Casanova et al., 2005; Farsides & Woodfield, 2003). Although some of these have found to be genetic or linked to specific personality traits, (which is outside the scope of this study), there is data linking demographic factors and previous academic achievement to attainment (Hackett et al., 1992). This data, however, may not relate directly to the discipline of chemistry at tertiary education level. In addition, this group of students differs in several respects including studying a subject at tertiary level that their degree does not major in. Studying attainment on a chemistry task within this population of students who are studying chemistry as part of a non-chemistry major degree will provide further insight into which, if any, measurable factors are influencing their performance.

The results of this data analysis will potentially help identify key influencing factors on attainment and engagement. These insights could enhance understanding of the underlying factors affecting engagement and outcomes, highlight any barriers to success, and inform the development of targeted support strategies. It could provide justification for these strategies which is data driven and evidence based. It is also acknowledged that results could potentially be shared with students, so they reflect on their own learning and their study habits. This can encourage metacognition (Tanner, 2012) and also encourage them to reflect on their own learning and experiences. (The terms attainment, engagement and motivation were defined and discussed in chapter 2).

3.10.2 Design and analysis of phase one

This initial study allowed analysis into and therefore possible identification of a range of factors that may be influencing attainment in chemistry within non-chemistry major degrees. The student factors that could be identified and that were studied were: age, gender, prior study and ethnicity. This data from the use of PeerWise as formative support and the summative assessment results specifically lend themselves to quantitative analysis. PeerWise is a collaborative online education tool which allows students to independently create multiple choice questions and also allows them to participate in answering and evaluating questions written by their peers (PeerWise, 2025). This tool was utilised on a first-year chemistry module when assessing the knowledge and understanding of students.

The PeerWise tool can produce a range of data that explains how much engagement each student has had with the tool. In addition to the student demographic data mentioned above, summative assessment results were available as a measure of their attainment.

This combined dataset for each student was divided into several subgroups to facilitate comparison and establish whether differences in the results were because of the demographic factors or whether they had arisen by chance. Excel (version Office 365) was chosen to analyse data using the Cochran-Mantel-Haenszel method (CMH method). This statistical method was chosen as it allows the examination of any possible association between the data whilst controlling for the confounding variables which may lead to incorrect association or bias. This would not be possible using a more simplistic chi-squared test (Kirkwood & Sterne, 2003).

3.10.3 Phase two – rationale for qualitative data collection

In phase one of this study, the data analysis provided an insight into the whole student cohort and objective evidence regarding any factors affecting attainment in a chemistry assessment. Phase two was a subsequent qualitative study which allowed further exploration into relevant detailed perceptions and was divided into two parts. The first part looked at learning chemistry within the pharmacy degree from both a staff and student perspective. It provided further context and therefore improved understanding of this research area. Chemistry is a core science within the pharmacy degree, but students are taught and assessed on a range of disciplines so the research questions for this part focused on collecting detailed rich data specifically on the learning of chemistry. During the literature review, there was little research found from an educators' perspective on chemistry in the pharmacy degree so bringing their lived experiences into this research contributed a further dimension and richness to this data collection.

Consideration of the curriculum design as well as appropriate integration of taught materials (Harden, 2000; Husband et al., 2014) can help highlight relevance and encourage application of knowledge of underpinning chemistry. The second part of phase two investigated and explored students' understanding of thinking integratively, combining their science and practice knowledge to fully understand the relevance and subsequently applying it. From their research into an integrated curriculum Mawdsley & Willis, (2019) found that students required some scaffolding to fully understand what integration was and how to integrate so this is worthy of further exploration in this phase.

3.10.4 Students as partners in research

As discussed in chapter two, the current literature base in this area of education research lacks student involvement and an acknowledgement of the student voice. There is evidence that incorporating students into educational research can provide a unique perspective and have a beneficial effect on the research (Cook-Sather, 2006). Acknowledging this, students were involved in the student interviews and focus groups in terms of helping design the questions and carrying out the research. Students were not involved in the staff interviews as it was felt that their presence may have influenced the staff participants and affected the depth of the data collected.

For the interviews and focus groups involving students, consideration was given to the researcher's position as a lecturer and the discussion topic for this project. The interviewer's role as a part of the research tool (Lincoln & Guba, 1985) and the concept of the interviewer effect (Denscombe, 2017) was considered when preparing to conduct the interviews. It was acknowledged that the choice of interviewer can potentially impact the quality of the data collected. Rich data collection may be impaired by the power dynamic between student and lecturer and the authentic student voice may be lost (Seale, 2010). Canning, (2017) highlights the possible flaws in gathering the student voice through a tutor- centred approach where they are facilitating the dialogue and conversations, and as such, alternative methods to eliminate such bias, including using students, should be explored. The pedagogical approach of 'students as partners' was researched, with case studies demonstrating the positive impact of direct student voice involvement in academic research (Ayres & Wilson, 2018; Bohnacker-Bruce, 2019). The benefits of staff student partnership in research within higher education has been recognised by Advance HE (Walkington, 2015). In addition to this, the importance of open and honest dialogue from participants was a key factor when considering the interviewer status. Using students to help gather research data from other students is named participatory research (Fielding, 2004). Participatory research as a methodological approach (Cornwall & Jewkes, 1995) was utilised as way of collaborating effectively with the student voice, using students to collect rich authentic data without the potential power dynamic of the lecturer-student relationship impacting on it (Seale, 2010). Engaging with the principles of this type of research, a group of fourth year MPharm students were involved in the design of this section of the doctoral study and the conducting of the student interviews and subsequent focus groups to gather data.

3.10.5 Design and analysis for phase two

Interviews were chosen as the most appropriate method of data collection for the first part of phase two. Semi-structured interviews were used to allow participants to openly discuss their experiences and perceptions using the open ended questions of the interview protocol as a guide (Cresswell & Poth, 2018). An interview can be interactive and adaptive, allowing the participants to talk freely without the constraints of a predetermined format of a questionnaire (Cresswell & Plano Clark, 2018). The skill of the interviewer is also relevant to the quality of the data collected so comprehensive training as well as practice interviews took place prior to interviewing the participants, to ensure consistency and quality of the data collection (Denscombe, 2017).

For the second part of phase two, focus groups were deemed the most appropriate method of data collection. This would allow the collection of rich and detailed data like interviews, but the participants would benefit from discussing their thoughts and their shared experiences with their peers (Morgan, 1996). This learning from peers and interacting with them is in line with the principles of meaningful learning (Bryce & Blown, 2024). Sharing of thoughts and individual experiences can highlight shared aligned opinions or can emphasise differences with their experiences (Denscombe, 2017). Acknowledging there are multiple realities rather than one, due to individual experiences, is a key element of constructivism (Cresswell & Cresswell, 2018) which is the philosophical framework for this thesis. Morgan, (1997) highlighted another advantage of focus groups is they can provide “direct evidence about similarities and differences in participants’ opinions and experiences” (Morgan, 1997 p 10).

Cohen et al., (2018) describes focus groups as often being contrived groups of participants who are also often unknown to each other. However, Morgan, (1996) highlights that focus group research can be organised with participants that are already part of an existing group. Cresswell & Poth, (2018) describe focus groups being “advantageous when the interaction amongst interviewees will likely yield the best information, when interviewees are similar and cooperative with each other” (Cresswell & Poth, 2018 p 164). It is acknowledged that focus groups can be used for a wide variety of research and subject areas. For this area of research, the shared experiences of being in the same pharmacy programme was important, with their discussion focusing on their perceptions of this experience and it was seen as an advantage that they were not strangers. Morgan, (1996) highlights that in one to one interviews, the participants may feel they have to clarify and justify their perceptions to the researcher; focus groups can help reduce this potential burden. It was also anticipated that students would perhaps struggle with the concept of integration and the interaction and discussion with peers would produce more meaningful data (Morgan, 1996) (Vella, 2025). Individual experiences are important to this research so this could be seen as a disadvantage for focus groups which can show insight into group experiences. However, Bradbury-Jones et al., (2009) argues that phenomenological research can still be accomplished using focus groups as they are still exploring lived experiences within a group of peers in this instance.

There is literature discussing whether one to one interviews and focus groups may produce different data (Morgan, 1997). However, it is acknowledged that topics do not usually align purely with individual or solely with group behaviours (Morgan, 1997). There can be drawbacks with focus groups, with the dynamic of the group and any dominant voices affecting the data produced (Cohen et al., 2018). This was considered when training and preparing the researchers for conducting the focus groups as well as when planning the composition of the focus groups. How to facilitate a focus group is markedly different to conducting an interview, with the researcher encouraging interaction and discussion within the group and ensuring their role is one of a facilitator rather than the leader (Denscombe, 2017).

The differences between focus groups and group interviews were also considered when finally deciding on the research tool. Group interviews may aim to gather and analyse the view of the whole group rather than considering individuals (Cohen et al., 2018) but this research specifically wanted individual voices to be heard as well as identifying overarching themes. Morgan, (1996) argues that when the researcher directs the discussion and the participants are part of an existing group (in this case, cohorts within a specific programme at a specific university), then it is defined as a focus group.

The questions for each section of this phase were developed, reviewed and piloted with adjustments made following this process. The final question schedules with relevant justification are presented in each relevant chapter (chapter 5 for staff and student interviews, chapter 6 for student focus groups).

Although rich data can be gained from interviews and focus groups, it does require preparation and organisation from its original raw form to be meaningful (Denscombe, 2017). Using a process of organised, consecutive steps ensures the analysis of the data is transparent and thorough (Cresswell & Cresswell, 2018).

Several strategies to analysing qualitative data have been published with no absolute gold standard (Cohen et al., 2018; Cresswell & Cresswell, 2018; Cresswell & Poth, 2018). The qualitative data in this project were analysed using the thematic analysis approach outlined by Braun and Clarke (Braun & Clarke, 2006, 2021). This approach is not inherently linked to a specific philosophical framework but acknowledges the researcher can drive the analysis and so should consider their own beliefs during this process (Braun & Clarke, 2006). This analysis considered the constructivist philosophical approach in line with the overall framework of the thesis.

Table 3- Description of the thematic analysis approach from (Braun & Clarke, 2006)

Phase	Description
1	The researcher familiarises themselves with the data
2	Initial codes are generated by the researcher
3	Themes are searched for
4	The themes are reviewed
5	Themes are defined and named
6	The report is produced

The phases of the thematic analysis process outlined by Braun & Clarke, (2006) were followed closely with the researcher continually returning to an earlier phases to continually improve familiarisation of the data (see table 3).

The transcription of data is time consuming but a very important part of the process because it ensures the researcher is immersed in the data, with not only the words spoken but the changes in tone of voice and the pauses within the interview (Denscombe, 2017).

Although the student researchers were given the opportunity to analyse the data and codes were also discussed with supervisors, the final presentation of findings and analysis of these data was intentionally undertaken solely by one researcher in line with the reflexive approach described by Braun and Clarke. It also acknowledges the constructivist approach, where the experiences of one researcher, alongside their philosophical belief, is able to examine the meanings expressed within the data set (Braun & Clarke, 2006).

The acknowledged gap in the literature focuses on both staff and students' perceptions so the final stage of analysis for phase two, part one did consist of developing the themes from the whole data text. It was acknowledged that these were two distinct data sets where individual themes could be identified but themes may be seen across both the staff and student groups. Themes that were common to both groups and distinct to either group are clearly identified in the results section.

3.10.6 Phase three – rationale for teaching intervention and subsequent analysis

Following the literature review (in chapter two), it was observed that current published literature on teaching interventions tended to focus on a specific discipline with a related case study rather that consideration of applying a range of relevant scientific concepts. It was also noted that decision making and providing advice should be backed up with evidence-based justification. These tasks are a pivotal aspect of the pharmacist's role, and their underpinning science knowledge could achieve this. Ensuring that students appreciate this knowledge from the beginning of their degree was important, so this teaching intervention was to be added to the first-year curriculum. It was also specifically taught within the Transition to Higher Education (THE) module. This module aims to teach the skills needed to successfully study at a tertiary level so incorporates many study skills needed to successfully complete a university degree (rather than being focused on a particular discipline needed for pharmacy). The workshops all focused on caring for the "patient" at the centre of the task and linking the questions to teaching across the year which included both specific science and practise teaching elements.

3.10.7 Design and Analysis of phase three

Using the concept of students as co-creators (Bovill et al., 2011), fourth year research project students were involved in the development of a series of three workshops. Students worked within a group (with significant support from the researcher) to provide the initial ideas for the workshop case studies, bearing in mind the common drugs and conditions seen in practice. They had the opportunity to reflect on their own integrative skills and their work. All the case studies focused on keeping the "patient" at the centre of the teaching, linking to other learning across the year which included both specific chemistry as well as pharmaceutics and pharmacology elements. Consultation and communication skills were also used in the workshops for simulated interactions with the "patient", so students were able to use knowledge learned within practice modules.

Prior to using these case studies on the module, staff from multiple disciplines provided clarification and critical feedback to ensure that the teaching clearly aligned with learning within the year. In addition, staff from both science and practice backgrounds provided general feedback and comments on the suitability of these case studies.

To evaluate the impact of these workshops, an online questionnaire with a combination of closed questions and some free text questions was used. Discussion and justification of this questionnaire as well as piloting and refinement of it is provided in chapter 7. The use of Likert scale questions was chosen for some of the closed questions as this type of scale helps to ascertain the strength of feeling towards each statement. One advantage is that it is a well-established scale and often used to investigate opinions and attitudes. It is likely that respondents are already familiar with it and will understand how to correctly complete the questionnaire (Cohen et al., 2018).

The raw data was downloaded following the online submission of completed questionnaires which reduced human transcription errors. Once checked and cleaned, descriptive statistics were carried out on the data sets to gain a better understanding of the data and allow basic interpretation of the demographic data and Likert scale questions. The data in the open-ended questions was also read multiple times, reviewed and analysed. This allowed the researcher to present the data in a more detailed and accurate manner.

3.11 Deductive and inductive approaches

Consideration was given to how data was analysed, acknowledging the differences between deductive and inductive approaches. Using mixed method research does mean the research is not adapting one single approach with “the inductive- deductive research cycle”, a combination of different methodologies being an important concept in a mixed methods research methodology (Tashakkori et al., 2021). Using both inductive and deductive logic adds to the rigour of the mixed methods approach (Cohen et al., 2018).

Phase one followed a deductive approach where the gathered data was analysed to test whether there is any relationship between several factors and student attainment. The deduced logical results allowed the confirmation or rejection of the hypothesis from the objective calculations conducted (Cresswell & Cresswell, 2018).

Phase two, with both interviews and focus groups had an inductive approach. This approach provided more freedom to delve into participants’ thoughts and opinions with rich, descriptive data being produced. The specific themes identified from this phase allowed for broader generalisations in this population to be hypothesised.

The final phase, phase 3, was a survey which had a predominately deductive approach but some open text questions allowing the students to respond more freely (Cohen et al., 2018). These qualitative comments allowed any emergent themes to be discovered and provided further insight into the students’ thoughts following participation in the teaching intervention. The hybrid approach of this survey meant any themes identified could be related to the quantitative data collected which enhanced the overall research (Proudfoot, 2023).

3.12 Impact of COVID 19

As a PhD study with a part time structure and a realistic longitudinal approach, this project has spanned over a pre and post COVID era as well as continuing during the pandemic. Collection of data following the teaching intervention for one cohort was taken during movement restrictions which impacted the teaching of this, but there were adaptations made because of this. These are discussed in that specific chapter (chapter 7) and reflected and further discussed in the conclusion chapter (chapter 8).

3.13 Participants across each project

A purposive sampling technique was used for the qualitative data collection with focus groups and interviews in this doctoral study. For student data collection, students in the

Master of Pharmacy programme at the University of Hertfordshire were invited to participate. No other universities or programmes were involved.

The University of Hertfordshire is a Higher Education institution which actively supports the widening participation agenda. Students admitted to the Master of Pharmacy programme have a range of prior qualifications with the large proportion of them having an Access qualification or a foundation year qualification as opposed to the traditional route to university via the successful completion of A levels at School or college. The student population of UK students at the university is comprised of approximately 70% with from families on low income, Black, Asian, or Minority ethnic (BAME) heritage or first in family (University of Hertfordshire, 2024).

For staff interviews, chemistry academic staff were emailed directly and invited to voluntarily take part in an interview whilst students registered on the MPharm programme in all years were sent details of the study through the university's virtual learning environment (VLE). It was made clear that involvement was voluntary.

For the PeerWise data collection, the data generated from the whole cohort was anonymized and reviewed (following appropriate ethical approval.)

3.14 Ethical approval

All research conducted within this doctoral study involved human participants, so each study required ethical approval. The researcher considered multiple factors prior to designing each research study (BERA, 2018) and applying for ethics. These factors included:

- Consideration of what data would be valuable to collect
- Any risks of distress to the participants
- Any risk of identification of participants so protection of confidentiality
- Educational interventions should involve a whole year group rather than a control and an intervention group

The University of Hertfordshire guidelines were followed and ethical approval gained before the commencement of any study. All participants received written information about the study, informed consent was sought and recorded. Participants were also aware that they could request removal from the studies at any point. Ethical approval was sought and approved by the University of Hertfordshire Ethics committee (with delegated authority).

When using quotes from interviews and focus groups through the data analysis and discussion, unique codes rather than names were used to ensure anonymity was maintained.

Table 4- Summary of studies with relevant ethical approval numbers

Chapter topic	details	Ethics number
Staff interviews - Exploring factors which affect learning chemistry in non-chemistry degrees from a staff perspective	Six participants	LMS/PGR/UH/02947
Student interviews- Exploring factors which affect learning chemistry in the MPharm programme.	Twenty participants across the year groups	LMS/SF/UH/03462
PeerWise data – Student generated content using PeerWise to support chemistry learning in Year 1	Data from all cohort- Results of formative task and midterm results	aLMS/SF/UH/03467(1)
Focus groups The integration of science within the MPharm curriculum	Fourteen participants	LMS/SF/UH/03939
Questionnaires Investigating students' perception of the relevance of science within clinical pharmacy practice	70 responses across three cohorts	LMS/PGR/UH/04581

3.15 Research rigour

Ensuring the research rigour of a doctoral thesis which incorporates several studies as part of a mixed methods approach requires careful consideration of several factors. When considering the quantitative elements in this doctoral study, the ways to ensure that the reliability and validity of the processes were reflected on (Denscombe, 2017). Consideration was given to the sample size used in each study and the most appropriate statistical tests to be used were discussed and justified. The raw data was anonymised to help prevent bias and cleaned with any assumptions made as well as any possible limitations clearly highlighted in a transparent manner (Kirkwood & Sterne, 2003). The survey instrument used in phase 3 was developed with clear objectives in mind and reviewed for clarity and consistency. It was piloted and further reviewed and revised prior to sharing with participants (Cresswell & Cresswell, 2018). Adhering to these points helps to ensure the results are reproducible.

With the qualitative elements of this doctoral study, it is acknowledged that a different approach is needed to be assured of its quality (Seale, 1999). It is important that the data and its analysis is trustworthy and truthful (Lincoln & Guba, 1985). The researcher took steps to ensure the research is credible so therefore valid (Denscombe, 2017). Cresswell & Poth, (2018) highlight the importance of being immersed in the data with extensive time spent reviewing it, developing a closeness and clear understanding of the participants from the researcher's perspective as a possible step to ensure credibility.

Other elements that were also considered were dependability (i.e. how reliable is the research) and the conformability of the data collection (i.e. how objective the research was) (Denscombe, 2017). An inductive approach, exploring ideas rather than testing a hypothesis is a means for the researcher can remain openminded without a preconceived idea of potential results. Ensuring that the researchers were adequately trained and so confident and skilled to carry out the research helps to ensure dependability. Immersion into the data with detailed notes of the analysis with coding and the development of themes also helps ensure this

As discussed earlier, being a reflective researcher and being acutely aware of the relationship between subject area and participants builds confidence in the conformability of the research. Reflections at each stage were made and are presented in each chapter, most specifically in the phases with qualitative data collection.

Finally, the factor of transferability which refers to how generalisable the research was reflected upon (Denscombe, 2017) This is a challenging concept to consider with qualitative data when small numbers of participants are used when compared to the relevant population. Braun & Clarke, (2013) explain that clearly providing the context and conditions with regard to the participants in the qualitative study ensures the reader can consider the scope of the themes and if they are relevant to their population. Lincoln & Guba, (1985) explain transferability as the reader of the research themselves taking the responsibility to decide if the results 'transfer' to their own contexts.

The process of appropriately combining quantitative and quantitative data can strengthen the research rigour with the results are integrated and interpreted, maximising the strengths of the respective approaches and not being bound to one approach which could be considered a weakness (Cohen et al., 2018).

3.16 General limitations of this overarching research

The limitations of this specific research approach are considered in this section with limitations relating to each specific study in each of the three phases being considered and discussed in the relevant chapters.

A mixed methods structure aims to reduce the limitations of using only one method but there are still limitations that should be acknowledged. Mixed methods, although now established and respected, is still relatively new so there is limited experience and expertise when compared to other methods (Fàbregues et al., 2021). Using multiple methods means that the researcher is unlikely to be an expert in all methods which could impact on the quality of the research (Cresswell & Plano Clark, 2018). As this research was carried out during academic study, the novice researcher participated in training and independent study prior to developing and analysing any data for all methods.

There has been criticism of the typology definitions for mixed methods research and presentation of results (Fàbregues et al., 2021) but it is acknowledged that this is a complex and time-consuming approach which required extensive research and planning before embarking on it (Cresswell & Plano Clark, 2018). It is a suitable approach when both qualitative and quantitative methods are needed to adequately answer research questions (Borrego et al., 2009). With appropriate engagement with this approach, the presentation of the findings and integrated analysis (Bazeley, 2018) can be seen as an important advantage (Cresswell & Plano Clark, 2018)

This research is linked solely to one higher education institution so is not representative of all pharmacy programmes in the UK. However, it is a type of pharmacy programme that is not regularly represented in the published literature with a significant majority of students arriving via the widening participating route. It is important to recognise that the structure of the pharmacy programme continues to evolve, and it is not clear what impact these continued changes will have with a growing emphasis on prescribing skills. In the context of this study, it was conducted in a longitudinal approach and was part of a part time PhD so has taken many years to complete. During this time, there has been a significant update in the UK educational standards due to the introduction of the independent prescribing element within the pharmacy undergraduate degree. The impact of possible potential bias and conflict in researchers' analysis should also be considered although this concern has been contemplated at each stage to attempt to reduce this.

Even with the limitations and potential weaknesses, the mixed methods structure is the most appropriate to allow a deeper understanding of the area and a more balanced conclusion to the research questions. Consideration is given to the limitations of each individual study in each results chapter and within the conclusion chapter.

3.17 Chapter summary

This chapter's purpose was to set out the worldview of the overarching research. The research paradigm was discussed, reviewed, and reflected on. It was confirmed that a constructivist approach was the most appropriate underpinning paradigm. The research tools that were most appropriate for addressing the research questions were justified and explained to be consistent with this philosophy.

Specifically, how data would be collected and reviewed as part of this PhD study was discussed. This study is sub divided into three phases, with phase one being a quantitative study of the cohort's results from the use of a peer support tool in a formative and summative setting. Phase two consisted of two studies with interviews and focus groups collecting qualitative data using thematic analysis, using Braun and Clarke's framework (Braun & Clarke, 2006). The final phase, phase three, was the evaluation of teaching intervention using a quantitative questionnaire with some free text questions providing a qualitative component.

Chapter 4 - Investigation into the impact of students' demographic factors on their engagement and attainment using a peer support tool

4.1 Introduction

This chapter describes phase one of this doctoral study. It details the investigation into students' interactions with a peer learning tool (PeerWise) as well as a subsequent summative assessment to consider factors influencing learning chemistry within chemistry non-major degrees. The participants of this study were students in their first year of study, with the cohort consisting of Master of Pharmacy students as well as students studying on the Bachelor of Pharmaceutical Science programme.

4.1.1 The research questions

For this phase of the study, the influence of demographic factors on contribution to a peer support tool within the discipline of chemistry was investigated. This differs from previous research on this tool which often focused on the link between engagement and subsequent achievement (e.g. Casey et al., 2014; Fergus et al., 2021; Kay et al., 2020). Engagement, motivation and attainment with the added context of available demographic factors will be discussed following data analysis.

Whilst the overarching research aims of this thesis are to provide a deeper understanding of learning and understanding of chemistry, this phase of the study specifically looks at a range of identifiable factors which may potentially influence learning and attainment.

The research questions for this phase of the study are:

- Are students' contributions to a peer learning support tool within a 1st year chemistry module affected by age, gender, prior learning and/or ethnicity?
- Is student attainment in a first-year chemistry module influenced by age, gender, prior learning and/or ethnicity?

4.1.2 The use of a peer- support learning tool

PeerWise is an internationally available online peer-learning tool (PeerWise, 2025). This collaborative environment allows students to create multiple choice questions (MCQs) and answer other questions written by their peers. The difficulty of the questions can be rated, and feedback provided. Students are encouraged to provide explanations on their questions to support each other's learning and understanding. This learning with and from peers encourages cognitive development, supporting Vygotsky's theories (Vygotsky, 1978) and his concept of the zone of proximal development (Eun, 2019). There is also a scoring system through the tool to provide encouragement via gamification to students, with a range of virtual badges awarded for different types and levels of student contribution. The approach does appear effective with several institutions finding that students submit more questions than suggested in the task instructions (Denny et al., 2008; Fergus, Hirani, et al., 2021; Galloway & Burns, 2015).

The use of PeerWise has been researched over many years and has been considered in relation to attainment. Hancock et al., (2018) found that incorporating this tool within a science module improved academic performance of the cohort. In contrast, Hudson et al., (2018) found that generally answering a large number of questions was not enough to produce an improvement in academic results. Further analysis found that this was related to the quality of the questions in relation to Bloom's cognitive domain (Anderson & Krathwohl, 2001). Answering multiple recall questions was not beneficial but writing higher level questions which were given higher ratings showed a positive correlation in academic performance (Hudson et al., 2018).

Many researchers have looked at using this tool on a range of programmes with 132 example articles listed via the PeerWise website (PeerWise, 2024). However, the focus for this thesis is its use within chemistry in higher education so the critique and discussion will mainly focus on articles from this area. Some of the research has considered the impact on the students' approach to learning and the depth of learning, so this is discussed further below.

4.1.3 Learning approaches

A student's approach to learning can influence how much learning and understanding is achieved. Several distinctions between learning approaches have been identified (Ramsden, 2003). They have been categorised primarily as surface or deep learning approaches. A surface learning approach is associated with a low amount of effort and rote learning the material rather than understanding it (Biggs & Tang, 2011). A student may use a surface approach to their learning for several reasons; for example, a desire to only achieve a minimal pass, limited time to study, a very high workload or an inability to understand the topic (Biggs & Tang, 2011). On the other hand, a deeper learning approach is associated with a more active and meaningful engagement with the subject material (Marton & Säljö, 1976). Students tend to adopt a deeper learning approach if they perceive the understanding and application of the material as important (Dunn et al., 2003). A combination of both these two approaches has been identified in students and categorised as a strategic approach (Race, 2019). Given the challenges faced with balancing studying with other commitments, strategic learners adapt their learning approach at their discretion, and they prioritise what they perceive to be important. The different ways students approach learning has an impact on attainment. Amongst the different methods, studies have shown that self-testing is an effective way to successfully improve performance (Geller et al., 2018). It can allow students to think and reflect on their learning and develop the skill of metacognition (Livingston, 2003). Metacognition is the ability to think about, reflect and regulate knowledge and understanding during studying (Livingston, 2003). Self-testing is a key feature of the peer support tool used in this study.

Students often use a range of different ways to learn in relation to their overall approach although the effectiveness of these methods can be varied with different impacts on the depth of understanding developed. Their approach is also influenced by the time available to them, perceived benefits as well as their general attitude and approach to learning (Bunce et al., 2017). Rather than being a predetermined genetic trait, evidence suggests that learning approaches are a dynamic attribute that can be adapted depending on the context, perceived difficulty and workload demands (Ramsden, 2003). This point is very important for educators as it means teaching and assessments can be designed which require critical thinking and applying knowledge to a problem and therefore need a deep-learning approach (Entwistle & Ramsden, 2015).

In higher education, chemistry topics build in complexity alongside the complexity of chemical structures being considered. A deep understanding rather than rote learning is needed to successfully progress. As new ideas and concepts are added to students' existing knowledge and understanding, the risk of misconceptions forming has been identified. This can mean that concepts are not only misunderstood but a clear alternative concept idea can be formed (Taber, 2000). If a student has not fully understood an initial concept, it is more likely that a misunderstanding of a later concept can occur. This will have a cumulative impact on a students' progression if not addressed (Levy Nahum et al., 2010).

Research into peer review and assessment is relevant to this support tool with Topping (2009) finding that peer review elements within modules encourage the development of critical thinking skills and metacognition; students reflect deeply on their own learning. Galloway & Burns (2015) looked at two cohorts in year-long chemistry modules using PeerWise and found the standard of the questions created to be generally high overall. Students wrote creative questions with clear explanations and 'plausible' distractors which demonstrated a deepening understanding of the topic through their deep learning approach.

4.1.4 Student motivation

One of the factors explored in this thesis, student motivation, has been discussed and defined in chapter 2 as "the drive students have to participate in learning and strive towards academic success".

A common categorisation of motivation suggests that it can be classified broadly as intrinsic and extrinsic (Ryan & Deci, 2000), but there is evidence that argues this label is too simplistic. Covington & Mueller, (2001) concludes that motivation is interwoven with self-worth resulting in students working towards the specific end goal of success in assessments to actively avoid failure. To ensure that students' application of knowledge is a priority, this needs to be considered in the delivery, teaching and assessment of a programme (Biggs & Tang, 2011).

Cook & Artino (2016) provided an overview of the main motivational theories relevant to learning. They highlighted and discussed five different theories with some recurring themes. Using this knowledge, educators can consider the key concepts in these with an aim to applying them during teaching. To encourage motivation, consideration should be given to tasks and assessments that promote mastery, improve a student's self-efficacy, support the development of their autonomy and allow social interaction with peers in an inclusive environment.

4.1.5 Student demographic factors

As well as study approaches, students' intrinsic characteristics may have an impact on academic achievement. Although these attributes may not be mutable, identifying and highlighting the challenges within these groups of students could mean that further support can be provided and raise their attainment.

The continuing issue of gender equality is an international one and it is acknowledged there are often complex factors involved (Meinck & Brese, 2019). Following a detailed study in England and Wales, Mcnabb et al., (2002) concluded that differences in academic attainment between genders is not solely linked to gender itself.

In this study, ethnicities were considered individually to ensure that no group was overemphasised or excluded as recommended by Gov.uk, (2024) However, some of the analysis did group students into the previously used term of BAME to allow comparison to important previous research to ascertain its place in the literature. The Black, Asian minority and ethnic (BAME) 'attainment gap' has also been highlighted in recent years with white students more likely to achieve a first or upper-class degree (UUK, 2019). Subject specific data analysis has found that there was a 12% awarding gap between White students when compared to BAME students with pharmacy degrees in the UK (Kam, 2020). However, awarding gaps within pharmacy schools themselves were found to be between 37% in favour of White students and 5% in favour of BAME students (Kam & Connelly, 2020). These awarding gaps have been found to have widened during the COVID-19 pandemic (Connelly, 2025). An RPS report (RPS, 2024) investigated the awarding gaps in degrees and registration assessment for Black trainees suggests that other contributing factors are influencing this meaning that initiatives can and should be implemented to reduce these gaps.

In addition, there has been a clear correlation found between prior learning and subsequent exam success at university within the subject of chemistry (Seery, 2009). However, a detailed study of the student population at the University of Bristol found that students from disadvantaged backgrounds performed at a similar level at university despite having lower admission qualifications (Hoare & Johnston, 2011). The study looked at data relating to 4305 undergraduate students. Despite the in-depth nature of this analysis, there was no statistical difference arising when comparing students from disadvantaged backgrounds to other students with respect to attainment on the two hundred degree programmes investigated which were spread across the arts, social science, engineering and science. It highlights the importance of the widening participation agenda as the lack of opportunity as well as barriers to success in secondary education did not create a barrier at university level. These students achieved well in the tertiary setting when this opportunity is provided.

Although this study investigated the influence some of these demographic factors have on engagement and attainment, it is important to note that other student factors have been proven to influence this in the United Kingdom. This includes socio-economic factors (Tan, 2024), caring responsibilities (Xue et al., 2023) and disability (which can include mental, physical and learning) (OfS, 2021). These are extremely important factors which warrant further research and investigation but are outside the scope of this project.

4.1.6 Effective Assessment Design

The educational philosophy of constructivism can be used as a starting point to explain how students learn chemistry (Bodner, 1986). This viewpoint explains that students do not categorise new knowledge separately when learning but attempt to construct meaning to it and link it to previous knowledge. With this construction of knowledge, understanding is needed and can be demonstrated in appropriately constructed assessments. The level of cognitive achievement during learning can be classified using Bloom's taxonomy (Bloom et al., 1956; Krathwohl, 2002). This framework described a hierarchy of learning with the lowest level of learning categorised as 'remembering' which could be achieved by a surface level approach. A student demonstrating knowledge at the level of application and above is working at a level that shows both knowledge and comprehension. Similarly, when asking students to analyse or evaluate information, this requires a deeper level of understanding and cognitive processing when compared to simply remembering facts.

The terminology in Bloom's taxonomy has undergone critical discussion and revisions by researchers over the years (Anderson & Krathwohl, 2001; Krathwohl, 2002) since their first publication, with an acknowledgement that it is meant as a framework rather than a strict instructional model. A revised version of this framework which amended the noun descriptions to verbs as well as some re-ordering of the hierarchy was published by Anderson & Krathwohl, (2001). In addition to this, these authors presented a case for the top three levels of the hierarchy to be parallel rather than ranked which is illustrated below in figure 9.

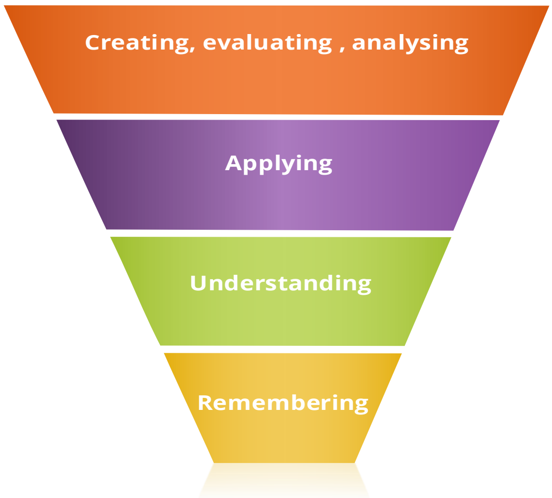

Figure 9- Revised structure of Bloom's Taxonomy adapted from (Anderson & Krathwohl, 2001)

This taxonomy describing the process of learning included more than just this cognitive process. The second domain Bloom outlined was an affective domain of learning (Anderson & Krathwohl, 2001; Bloom et al., 1973) which referred to an attitude which has a direct impact on learning. This attitude impacts on the amount of active involvement the student chooses to have with the learning, time spent actively participating in the process of learning and organising this newly learnt information. Ryan, (2013) described the use of PeerWise on a first-year foundation organic chemistry module and found that the students enjoyed the interaction and support with it, specifically learning with and from their peers.

Attainment in assessments within the higher education setting should be linked to a thorough knowledge and understanding across the subject area (Race, 2019). This academic success is important for both students' future careers as well as future learning. In addition to measuring performance, one of the core purposes of assessment is to motivate students to fully engage in learning (Race et al., 2005). Success in assessments is associated with much more than just the teaching content. The process of achieving well in an assessment has been linked to many factors in both the students themselves as well as the teaching and assessment methods employed (Biggs & Tang, 2011).

Whilst assessments are used to check that students have learnt and understand the taught material, the use of assessment is pivotal, especially formative, for their learning (Brown, 2005). Being clear about the reasons why this area is part of the assessment as well as constructive and comprehensive feedback (Nicol & Macfarlane-Dick, 2006) is important. The functionality allowing feedback from the peers and this feedback cycle is fundamental to the students' learning with this tool (Carless, 2006).The importance of effective assessment design is a topic that continues throughout this thesis and continues to be discussed in future chapters.

4.2 Methods

4.2.1 Data Collection

The use of this peer- learning support tool (PeerWise) was incorporated as a homework task which formed the formative assessment in a compulsory first year chemistry module in both the pharmacy and pharmaceutical sciences programmes at the University of Hertfordshire. Foundations in Pharmaceutical Chemistry (FPC) is a 30 -credit module taught across semesters A and B in an academic year.

Students were required to create two questions on two pre-assigned topics and answer at least five questions submitted by their peers. They were given deadlines to complete these tasks, but it was also made clear that these were minimum standards for the assessment and students could continue to create and answer questions for their own benefit and development.

To set expectations for this assessment and provide support, students participated in an introductory workshop which explained how to use the online tool as well as the specific requirements of the task. Although this task was formative, the benefits of using this tool as preparation for the summative midterm assessment were clearly explained in this workshop and repeated in email communications with the students.

Ethics approval for this project from the University of Hertfordshire Ethics Committee was sought and granted (aLMS/SF/UH/03467).

4.2.2 The overall data set

The peer- learning support tool allocated scores to students in relation to the quantity and quality of their individually generated content as well as their ability to answer and feedback on other questions within the tool. An explanation of these various scores can be found in table 5.

These raw scores from the cohort were accessed via the PeerWise database and exported to Excel. The student factors of age, gender, ethnicity, and educational background were sought from university student data as well as student performance data from the midterm test results and matched to the PeerWise scores. A summary of all data collected can be found in table 6.

Table 5- Explanation of scores produced from engagement with peer- support tool(*PeerWise - Documentation*, 2018)

Score title	**Explanation**
Reputation score	This score uses an algorithm that aims to give an overarching indication of the students' performance. It incorporates the score of three components: author score, question answering score and rating score. Students are also rewarded by early engagement with the tool.
Author score	This is linked to the questions that the student has written. They gain increasing marks when other students grade the questions as "good, very good or excellent".
Questioning answering score	This score is related to the number of questions the student has answered correctly. (The score decreases if answers are incorrect).
Rating score	This is linked to the students rating of other questions and the fairness and consistency across the cohort.
Total answer score	This score multiplies the number of correct answers the students gives by 10 but there is also a reduction penalty if incorrect answers are given. The size of this penalty is related to the number of distractors in the multiple-choice question.

Table 6- Summary of data collected for each student participant

Data		
Scores from peer support tool	**Demographic data**	**Student attainment on module (all as %)**
Reputation score	age	Progress test overall results
Author score	gender	MCQ section results
Question (answering) score	Entry qualifications (i.e. prior learning)	SAQ section results
Rating score	ethnicity	
Total answer score		

Demographic information was expressed as a percentage in addition to numbers in the results section to aid discussion and analysis. General engagement with the tool within the student population was also presented and analysed before further statistical analysis.

4.2.3 Stratification of the data

To investigate whether there was any association between individual factors and the outcomes (i.e. academic results and peer support tool scores), stratification analysis was used. This allowed control over any confounding factors and appropriately attributed any differences found to the correct specific factor (Kirkwood & Sterne, 2003). With the use of this stratification and the Cochran-Mantel- Haenszel method (Agresti, 2002), a thorough investigation into each of the demographic factors could take place to ascertain whether they have a statistically significant impact on the outcomes. (Justification of the statistical method chosen is discussed in section 4.2.5).

4.2.3.1 Age

Age was calculated from dates of birth and recorded as the age of the student at the start of the programme. Students were then categorised as 'young' or mature in accordance with the Higher Education Statistics Agency (HESA) definition (HESA, 2019) or undergraduate students, students under 21 years of age are classed as young, whereas students who are 21 years and over are categorised as mature students.

4.2.3.2 Entry qualification

Using the information from the national discussion around entry qualifications (UCAS, 2021) students were grouped into either entry via traditional routes or entry via widening participation routes. With reference to this dataset, routes that were classed as traditional were A levels, Irish Highers and international baccalaureates. Widening participation routes included foundation years, initial years (level 0) and BTEC qualifications.

4.2.3.3 Gender

The recording of gender categories was taken from student record data where students self-selected this information. Within this dataset, no student chose not to answer so all data fitted in the two categories of either male or female.

4.2.3.4 Ethnicity

Students self-declared ethnicity on admission (out of 17 categories), so the stratification of this data aimed to respect this decision as much as possible. Table 7 shows the details on how students were grouped together in this characteristic.

Table 7-Explanation of how ethnicity categories were grouped together

Ethnicity	Students included
Arab	This was selected where students selected 'Arab' if this is how they self-identify.
British Asian/Asian	This includes students who identify as Asian - Bangladeshi, Asian -Indian and Asian - Pakistani, Other Asian and Chinese.
British Black/black	This includes students who identify as Black African and Black Caribbean and Black Other.
White	This includes students who identify as White British, White Welsh, White Irish and White Other.
Other	This includes students who identify as mixed other, other ethnic, mixed white/Asian, mixed White/Caribbean.
Not stated	This category includes students who chose 'information refused'.

This level of stratification of data also ensured the data was sufficiently anonymised to prevent identification of individuals arising from analysis of these demographic factors.

4.2.4 Cleaning the data

During analysis, data from the demographic factors mentioned earlier were compared with scores from PeerWise as well as assessment results from the first-year chemistry module. There were no entries with missing demographic data but there were missing assessment results and PeerWise scores. These were excluded from analysis. These missing entries were due to students' early withdrawal from the programme or because of them switching to dormant status. This was not investigated further as it was outside the scope of the study.

4.2.5 Data analysis and justification of chosen statistical method

The dataset was divided into subgroups to facilitate comparison and establish whether differences in the results were as a consequence of the demographic factors or by chance. Excel (version Office 365) was chosen to analyse data, with the Cochran-Mantel-Haenszel (CMH) method being the statistical approach selected. This statistical method was chosen as it is a robust method that allows the examination of any possible association between the data whilst controlling for the confounding variables which may lead to incorrect association or bias (Kirkwood & Sterne, 2003).

A range of statistical tests were considered prior to choosing the CMH method. The statistical approach needed to evaluate any association between two variables while accounting for the possible effects of confounding variables. The simple chi- squared test method was considered but quickly ruled out as controlling for confounding variables would not be possible (Kirkwood & Sterne, 2003). One possible approach that was considered was logistic regression (Cohen et al., 2018; Howell, 2007). However, this approach is considered more appropriate with very large datasets (Agresti & Finlay, 2009), and it was noted that some data groups were small following stratification in this study. In addition, when compared with logistic regression, the CMH test is less complex and provides results that are easier to interpret (Kirkwood & Sterne, 2003) so makes it a more suitable statistical approach for this phase of the thesis research questions.

Next, the use of the mean or the median was considered for this study. For interpretation of this data, calculation of the median was deemed the most appropriate as this prevents skewing of the data due to outlying extreme scores at either end of the dataset (Hofer & Murphy, 2000).

4.2.6 Summary of results presentation

The cleaned dataset was stratified into the subgroups shown in table 8 for analysis.

Table 8- List of stratified dataset with the relative subgroups per factor

Factor(s)	Sub group
Age	Group 1 – students within HESA definition of mature student Group 2 – students within HESA definition of young student
Entry requirements	Group 1 – Students following the traditional entry route Group 2 – Students following the widening participation route
Gender	Group 1 – students who identified as male Group 2 – students who identified as female
Ethnicity	Group 1 – students who identified as white Group 2 – students who identified as BAME Group 1 – students who identified as Black African and Black other Group 2 – students who identified as white Group 1 – students who identified as Asian Group 2 – students who identified as white Group 1 – students who identified as Arab Group 2 – students who identified as white Group 1 – students who identified as Black (all) Group 2 – students who identified as Asian Group 1 – students who identified as Arab Group 2 – students who identified as Asian
Age and gender	Group 1 – mature females Group 2 – young females Group 1 – mature males Group 2 – young males Group 1 – mature females Group 2 – mature males Group 1 – young females Group 2 – young males
Ethnicity, age and gender	Group 1- young white females Group 2 - young BAME females Group 1 - young white females Group 2 –young BAME females

Finally, although not a demographic factor, the separate cohorts of the MPharm and the BSc Pharmaceutical Science programme were compared to ascertain if there were any differences between them. The MPharm students were classed as group 1 and the BSc Pharmaceutical Science were group 2.

These subgroups were compared with respect to the individual scores reported in the PeerWise dataset and the mid-term assessment results. To achieve this, median values in each subgroup for each of the scores were calculated and results were divided into the two categories needed for the contingency tables that inform the CMH analysis. The categories were classed as 'positive' or 'negative' responses, where a score that was lower than the median score was classed a 'negative response' and a score that was the median score or above this was classed 'positive'.

4.2.7 Calculation of unadjusted odds ratio

Two by two contingency tables were constructed from the stratified datasets.

	positive response	**negative response**
Group 1	a	b
Group 2	c	d

Figure 10- Example of a two by two contingency table used to calculate unadjusted odds ratio (OR) and the confidence interval

The unadjusted odds ratio for each group was calculated by using the formula

OR = $(a \times d) \div (b \times c)$

Where:

a is the results from group 1 and the positive score sub group

b is the results from group 1 and the negative score sub group

c is the results from group 2 and the positive score sub group

d is the results from group 2 and the negative score sub group

95% confidence intervals were calculated using the following formulae:

- Upper 95% CI = e ^ [ln(OR) + 1.96 √(1/a + 1/b + 1/c + 1/d)]
- Lower 95% CI = e ^ [ln(OR) - 1.96 √(1/a + 1/b + 1/c + 1/d)]

90% confidence intervals were calculated using the following formulae

- Upper 90% CI = e ^ [ln(OR) + 1.645 √(1/a + 1/b + 1/c + 1/d)]
- Lower 90% CI = e ^ [ln(OR) - 1.645 √(1/a + 1/b + 1/c + 1/d)]

Differences between groups as demonstrated by the odds ratio was classed as statistically significant where the odds ratio does not equal 1 and the calculated confidence interval does not contain the value of 1 (Agresti & Finlay, 2009).

4.2.8 Calculation of adjusted odds ratio

The independence of the stratified data was considered regarding any potential confounding variables within the demographic factors being considered. When the data was analysed, it was found that there was a greater than 10% difference between the categories of HESA mature students and young students. There was also a greater than 10% difference between males and females. Because of this, adjusted odds ratios were calculated adjusted for age and for gender (separately) were calculated.

To consider the confounding variable of gender, adjusted odds ratios were calculated. The two by two contingency tables were separated into two further tables (named X and Y). Table X contained male data and table Y contained female data (Kirkwood & Sterne, 2003). A template for these contingency tables can be found in figure 11 and full data can be found in appendix A.

Table X (male)
Tx =total number

	positive response	negative response
Group 1	aX	bX
Group 2	cX	dX

Table Y (female)
Ty =total number

	positive response	negative response
Group 1	aY	bY
Group 2	cY	dY

Figure 11-Example of the contingency tables used to calculate adjusted odds ratio (aOR)

The adjusted odds ratio was calculated using the formula:

$aOR = [(aX\ dX \div Tx) + (aydy \div Ty)\ ] \div [(bx\ cx \div Tx) + [(by\ cy \div Ty)]$

Where a, b, c, and d represent the different categories of the Contingency tables X and Y, and Tx and Ty represent the total number of respondents in Contingency Table X and Y respectively.

This method was followed again adjusting for age, with table X containing data for age categorised as HESA young (i.e. less than 21 years) and table Y containing data for age categorised as HESA mature (i.e. 21 years and older).

4.2.9 Validity and reliability of this phase of the research

Multiple steps were taken to be assured that this data collection and analysis was valid and reliable (Denscombe, 2017). The statistical test was considered and researched prior to its selection to ensure it was appropriate and suitable (see section 4.25). The data was fully anonymised to prevent any potential bias and cleaned for missing data or errors (Kirkwood and Sterne, 2003).

In terms of reliability, the calculations were completed using Excel. They were completed by the PhD student but were also checked independently by one of the supervisors. Calculation formulae and methods were checked prior to the data being analysed (Cresswell & Cresswell, 2018).

4.3 Results

4.3.1 Number of students

A total of 138 undergraduate students were initially enrolled on the Year 1 module FPC. During cleaning of the full dataset, it was found that 21 students (15%) had withdrawn early from the programme and not engaged with the peer support tool. Reasons for their removal from the course were not investigated as this was outside of the research question remit. This resulted in a total of 117 students being included in the cleaned data analysis. From this cleaned data, the following results were calculated.

4.3.2 Age

Age was calculated as the students' ages at the start of the programme. The median age was 19 with an age range of 18 to 39 years. There were 72 students 19 years of age or below (median and below) and there were 45 students above 19 years of age. (This works out as 62% and 38% respectively). Using the HESA categorisation (HESA, 2019), there were 29 mature students (25%) and 88 students classified as young (75%) within the cohort.

4.3.3 Gender

There were 32 males (27%) and 85 females (73%) participants. (Participants self-reported their gender)

4.3.4 Routes to Higher Education

Widening participation was defined in line with the UCAS definition (UCAS, 2021). Students who were identified as having international qualifications or a previous undergraduate degree were excluded from this categorisation. For international qualifications, it was not possible to ascertain whether their pre- admission course fitted within the widen participation agenda as the UCAS definition is specifically linked to the UK only. For students with previous undergraduate degrees, there was not sufficient data to ascertain if their initial entry criteria for their first degree was via the non A-level progression route. (11 students were excluded from this section of the analysis).

There were 50 students (47%) who were identified as having taken the traditional qualification route and 56 (53%) who had widening participation qualifications.

4.3.5 Ethnicity

When categorising the data, ethnicities were grouped together as explained in table 7 in the methods section. The distribution of ethnicities is shown in table 9 below.

Table 9- Distribution of ethnicities across categories provided by admissions data

Ethnicity		**Number of participants (%)**
Arab	Includes Arab category only	13 (11%)
British Asian/Asian	Includes Asia Bangladesh, India and Pakistan, other Asian and Chinese.	47 (40%)
British Black/black	Includes African and Caribbean and other black.	28 (24%)
White	Includes White British, White Welsh, White Irish and White other.	16 (14%)
Other	Includes mixed other, other ethnic, mixed White/Asian, mixed White/Caribbean.	9 (8%)
Not stated	Include information refused	4 (3%)

When analysing the ethnicity data, four were excluded as they chose to not state ethnicity. Students who identified as Chinese were categorised within the Asian overall group. There was only one student in this category so it would be inappropriate to have a separate group as it would no longer be anonymous.

Some students identified as mixed race and have grouped themselves as: mixed other, other ethnic, mixed white/Asian, mixed white/Caribbean. These have categorised in a group together called 'other' which fits with the same named category on the admissions form.

4.3.6 Median scores

Median scores for each of the PeerWise scores and mid-term test results were calculated in order to be able to compare and analyse them.

It should be noted that the pass mark for the midterm test is an overall mark of 40% or above.

Table 10- Attainment score medians, ranges and standard deviations from all attainment categories being analysed

Score type	Median value	Range
PeerWise reputation score	380	6-2017
PeerWise author score	8	0 - 54
PeerWise question (answering) score	29	2- 294
Rating score	9	0 - 98
Total answer score	49	-2 - 1820
Progress test overall results	60%	12 - 88.02%
Progress test – MCQ component	66.7%	6.7 - 100%
Progress test – SAQ component	57%	0- 90%

4.3.7 General engagement with the peer-support tool

100% (117) of students within the cohort who completed the full year engaged with the tool to some extent, but not all completed the specified task which was to write at least 2 questions and answer at least 5 questions. In all, 10% (12 students) of students did not complete the task to the exact instructions set. Of those 117 students, 3 students did not answer enough questions, and 9 students did not write enough questions as instructed. As all 117 students used the tool to some extent, all were included in the analysis.

4.3.8 Statistical analysis

4.3.8.1 Results of calculation of unadjusted Odds Ratios

Using the stratified groups, unadjusted odds ratio in relation to each demographic category were calculated (Kirkwood & Sterne, 2003). These were calculated first with a 95% confidence interval and then with a 90% confidence interval. These are presented in tables 11 and 12 below. Odds ratios are highlighted in yellow for if they are statistically significant within 95% confidence interval (and therefore also the 90% confidence interval). They are highlighted green if they are only statistically significant for 90% confidence interval.

Table 11-Unadjusted Odds ratio for age, education and gender factors with a 95% confidence interval and 90% confidence interval

(The confidence interval is shown in parentheses – 95% is shown in black and 90% is shown in blue underneath)

Attainment score	**Stratifer**						
	Age (HESA)	**Education**	**Gender (males v females)**	**females and age**	**Males and age**	**Mature females v mature males**	**Young females v young males**
reputation score	2.79 (1.1-6.8) (1.3-5.9)	1.08 (0.5-2.3) (0.6-2.1)	0.20 (0.1-0.5) (0.1-0.4)	2.46 (0.8-7.5) (1.0-6.3)	0.59 (0.1-6.2) (0.1-4.2)	15.20 (1.0-168.0) (2.0-114.2)	3.66 (1.4-9.7) (1.6-8.3)
author score	1.66 (0.7-4.0) (0.8-3.4)	1.21 (0.6-2.6) (0.6-2.3)	0.49 (0.2-1.1) (0.2-1.0)	1.39 (0.5-3.7) (0.6-3.2)	2.18 (0.3-15.3) (0.4-11.2)	1.33 (0.2-9.7) (0.3-0.7)	2.09 (0.8-5.3) (1.0-4.5)
question answering score	2.28 (1.0-5.5) (1.1-4.7)	1.35 (0.6-2.9) (0.7-2.6)	0.33 (0.1-0.8) (0.2-0.7)	2.90 (1.0-8.3) (0.7-3.6)	0.50 (0.0-5.2) (0.1-3.5)	12.00 (1.1-129.4) (1.6-88.3)	2.07 (0.8-5.3) (0.9-4.6)
total answer score	1.42 (0.6-3.3) (0.7-2.9)	0.75 (0.3-1.6) (0.4-1.4)	0.37 (0.2-0.9) (0.2-0.7)	1.59 (0.6-4.3) (0.7-3.6)	0.43 (0.0-4.4) (0.1-1.0)	8.00 (0.8-83.9) (1.1-57.5)	2.14 (0.8-5.4) (1.0-4.7)
question rating score	1.79 (0.8-4.2) (0.9-3.7)	1.01 (0.5-2.2) (0.5-1.9)	0.38 (0.2-0.9) (0.4-1.7)	1.70 (0.6-4.3) (0.7-3.9)	1.33 (0.2-9.5) (0.3-6.9)	3.00 (0.4-21.7) (0.6-15.8)	2.36 (0.9-6.1) (1.1-5.2)
progress test score	0.89 (0.4-2.1) (0.4-1.8)	1.17 (0.5-2.5) (0.6-2.2)	0.86 (0.4-1.9) (0.4-1.7)	0.67 (0.3-1.7) (0.3-1.5)	2.18 (0.3-15.3) (0.4-11.2)	0.56 (0.1-4.0) (0.1-2.9)	1.83 (0.7-4.6) (0.8-4.0)
progress MCQ score	0.85 (0.4-2.0) (0.4-1.7)	1.47 (0.7-3.2) (0.8-2.8)	1.11 (0.5-2.5) (0.6-2.2)	0.77 (0.3-2.0) (0.3-1.7)	1.39 (0.2-9.7) (0.3-7.1)	0.56 (0.1-4.0) (0.1-2.9)	1.02 (0.4-2.5) (0.5-2.2)
progress SAQ score	0.81 (0.4-1.9) (0.4-1.6)	1.37 (0.6-2.9) (0.7-2.6)	0.89 (0.4-2.0) (0.4-1.8)	0.67 (0.3-1.7) (0.3-1.5)	1.62 (0.2-11.3) (0.3-8.2)	0.56 (0.1-4.0) (0.1-2.9)	1.36 (0.5-3.4) (0.6-2.9)

Table 12-- Unadjusted Odds ratio for ethnicity factors with a 95% confidence interval and 90% confidence interval

(The confidence intervals are shown in parentheses – 95% is shown in black and 90% is shown in blue underneath)

Attainment score	**Stratifer**								
	White v BAME	**Black v white**	**Asian v white**	**Arab v white**	**Black v Asian**	**Black v Arab**	**Arab v Asian**	**Young white v BAME ♀**	**Young white v Black ♀**
reputation score	0.98 (0.3-2.8) (0.4-2.4)	0.71 (0.2-2.4) (0.3-2.0)	1.00 (0.3-3.1) (0.4-2.6)	2.25 (0.5-10.4) (0.6-8.1)	0.71 (0.3-1.8) (0.3-1.5)	0.31 (0.1-1.3) (0.1-1.0)	2.25 (0.6-8.3) (0.8-6.7)	0.95 (0.2-3.8) (0.3-3.0)	4.50 (0.6-34.6) (0.8-24.9)
author score	0.55 (0.2-1.6) (0.2-1.3)	1.20 (0.4-4.1) (0.4-3.4)	1.96 (0.6-6.2) (0.8-5.1)	4.29 (0.8-21.8) (1.1-16.8)	0.61 (0.2-1.6) (0.3-1.3)	0.28 (0.1-1.2) (0.1-1.0)	2.18 (0.5-9.0) (0.7-7.2)	0.39 (0.1-1.6) (0.1-1.2)	0.67 (0.1-4.4) (0.1-3.2)
question answering score	0.73 (0.3-2.1) (0.3-1.8)	1.04 (0.3-3.6) (0.4-2.9)	1.29 (0.4-4.0) (0.5-3.3)	2.89 (0.6-13.5) (0.8-10.5)	0.81 (0.3-2.0) (0.4-1.8)	0.36 (0.1-1.4) (0.1-1.2)	2.25 (0.6-8.3) (0.8-6.7)	0.35 (0.1-1.5) (0.1-1.2)	1.29 (0.2-10.5) (0.2-7.5)
total answer score	2.49 (0.8-8.3) (0.9-6.8)	0.27 (0.1-1.0) (0.1-0.8)	0.36 (0.1-1.3) (0.1-1.0)	1.11 (0.2-6.2) (0.3-4.7)	0.75 (0.3-1.9) (0.3-1.6)	0.24 (0.1-1.1) (0.1-0.8)	3.07 (0.7-12.5) (0.9-10.0)	0.15 (0.0-0.8) (0.0-0.6)	0.42 (0.1-3.4) (0.1-2.4)
question rating score	1.26 (0.4-3.7) (0.5-3.1)	0.73 (0.2-2.5) (0.3-2.0)	0.66 (0.2-2.1) (0.3-1.7)	0.91 (0.2-4.0) (0.3-3.1)	1.10 (0.4-2.8) (0.5-2.4)	0.80 (0.2-3.0) (0.3-2.4)	1.38 (0.4-4.7) (0.5-3.9)	1.33 (0.3-5.3) (0.4.-4.2)	4.50 (0.6-34.6) (0.8-24.9)
progress test score	1.02 (0.4-2.9) (0.4-2.5)	0.81 (0.2-2.8) (0.3-2.3)	1.29 (0.4-4.0) (0.5-3.3)	0.86 (0.2-3.7) (0.3-2.9)	0.63 (0.2-1.6) (0.3-1.4)	0.95 (0.3-3.5) (0.3-2.9)	0.67 (0.2 -2.3) (0.2-1.9)	0.30 (0.1-1.3) (0.1-1.0)	0.43 (0.1-3.0) (0.1-2.2)
progress MCQ score	0.94 (0.3-2.7) (0.4-2.3)	1.23 (0.4-4.2) (0.4-3.4)	1.09 (0.4-3.4) (0.4-2.8)	1.17 (0.3-5.1) (0.3-4.0)	1.13 (0.4-2.9) (0.5-2.5)	1.05 (0.3-3.9) (0.4-3.2)	1.07 (0.3-3.7) (0.4-3.0)	0.32 (0.1- 1.4) (0.1-1.1)	0.43 (0.1-3.0) (0.1-2.2)
progress SAQ score	0.73 (0.3-2.1) (0.3-1.8)	1.38 (0.4-4.7) (0.5-3.9)	1.40 (0.4-4.4) (0.5-3.6)	0.80 (0.2-3.6) (0.2-2.8)	0.99 (0.4-2.5) (0.5-2.1)	1.71 (0.5-6.5) (0.6-5.3)	0.58 (0.2-2.0) (0.2-1.6)	0.30 (0.1- 1.3) (0.1-1.0)	0.14 (0.00-0.12) (0.1-0.8)

4.3.8.2 Post hoc analysis - Adjusted odds ratios calculations

Age and gender were identified as potential compounding factors. Using the HESA definition for age of undergraduate students in the UK (HESA, 2019). The total number of participants that were classified as ‘young’ were 88 and total number that were classified as ‘mature’ was 29, meaning there was more than a 10% difference in these groups.

Again, with gender, it was found that the total number of participants that were female were 85 and total number of males was 32, meaning there was more than a 10% difference in these groups.

Tables 13 and 14 show the results of the adjusted odds calculations.

Table 13- Adjusted Odds ratio (adjusted for age as confounding factor) with a 95% confidence interval and 90% confidence interval

(The confidence intervals are shown in parentheses – 95% is shown in black and 90% is shown in blue underneath)

Attainment score			
	Education (ie A levels v widening participation)	**Gender (males v females)**	**Ethnicity (white/BAME)**
reputation score	1.46 (0.5-2.3) (0.6-2.1)	0.21 (0.1-0.5) (0.1-0.4)	1.20 (0.3-2.8) (0.4-2.4)
author score	1.49 (0.6-2.6) (0.6-2.3)	0.52 (0.2-1.1) (0.2-1.0)	0.60 (0.2-1.6) (0.2-1.3)
question answering score	1.93 (0.6-2.9) (0.7-2.6)	0.36 (0.1-0.8) (0.2-0.7)	0.86 (0.3-2.1) (0.3-1.8)
total answer score	0.86 (0.3-1.6) (0.4-1.4)	0.37 (0.2-0.9) (0.2-0.7)	2.69 (0.8-8.3) (0.9-6.8)
question rating score	1.15 (0.5-2.2) (0.5-1.9)	0.40 (0.2-0.9) (0.2-0.8)	2.34 (0.4-3.7) (0.5-3.1)
progress test score	1.20 (0.5-2.5) (0.8-2.8)	0.70 (0.4-1.9) (0.4-1.7)	1.61 (0.4-2.9) (0.4-2.3)
progress MCQ score	1.15 (0.7-3.2) (0.8-2.8)	1.10 (0.5-2.5) (0.6-2.2)	1.43 (0.3-2.7) (0.4-2.3)
progress SAQ score	1.33 (0.6-2.9) (0.7-2.6)	0.65 (0.4-2.0) (0.4-1.8)	1.11 (0.3-2.1) (0.3-1.8)

Table 14 - Adjusted Odds ratio (adjusted for gender as confounding factor) with a 95% confidence interval and 90% confidence interval

(The confidence intervals are shown in parentheses – 95% is shown in black and 90% is shown in blue underneath)

Attainment score	**Age (HESA) (mature v young)**	**Education (i.e. A levels v widening participation)**	**Ethnicity (white/BAME)**
reputation score	3.51 (1.1-6.8) (1.3-5.9)	0.95 (0.5-2.3) (0.6-2.1)	0.96 (0.3-2.8) (0.4-2.4)
author score	1.41 (0.7-4.0) (0.6-2.0)	1.33 (0.6-2.6) (0.8-2.3)	0.57 (0.2-1.6) (0.2-1.3)
question answering score	2.78 (1.0-5.5) (0.7-2.4)	0.97 (0.6-2.9) (0.2-2.6)	0.49 (0.3-2.1) (0.3-1.8)
total answer score	1.54 (0.6-3.3) (1.2-11.0)	0.56 (0.3-1.6) (0.4-1.4)	0.9 (0.8-8.3) (0.9-6.8)
question rating score	1.69 (0.8-4.2) (0.7-2.4)	0.85 (0.5-2.2) (0.5-1.9)	1.51 (0.4-3.7) (0.3-1.8)
progress test score	0.69 (0.4-2.1) (0.4-1.4)	1.33 (0.5-2.5) (0.6-2.2)	0.63 (0.4-2.9) (0.4-2.5)
progress MCQ score	0.78 (0.4-2.0) (0.5-1.8)	0.91 (0.7-3.2) (0.4-1.7)	0.69 (0.3-2.7) (0.4-2.3)
progress SAQ score	0.69 (0.4-1.9) (0.5-1.8)	1.93 (0.6-2.9) (0.7-2.6)	0.63 (0.3-2.1) (0.3-1.8)

4.3.8.3 Comparison of cohorts

Although not a demographic factor, the data were separated into specific cohort groups to investigate whether there was any difference between the cohorts themselves, a BSc Pharmaceutical Science group and a MPharm programme group were analysed.

Table 15 - Unadjusted Odds ratio with a 95% confidence interval and 90% confidence interval

(The confidence intervals are shown in parentheses – 95% is shown in black and 90% is shown in blue next to it)

Attainment score	
	MPharm students versus BSc Pharm sci students
reputation score	1.62 (0.7-3.8) (0.8-3.3)
author score	2.73 (1.1- 6.5) (1.3-5.6)
question answering score	0.93 (0.4-2.2) (0.5-1.9)
total answer score	1.23 (0.5-2.8) (0.6-2.5)
question rating score	0.81 (0.3 -1.9) (0.4-1.6)
progress test score	3.62 (1.4-9.1) (1.7-7.8)
progress MCQ score	3.79 (1.5-9.5) (1.8-8.2)
progress SAQ score	2.15 (0.9-5.1) (1.0-4.4)

4.4 Explanation of results

4.4.1 Students' contribution to the peer support tool

Despite the PeerWise task being formative, contributions were high with 90% of students engaging fully with the task instructions. Previous studies at other universities using PeerWise have seen much lower engagement. Walsh et al., (2018) reported 40% to 57% engagement when using PeerWise as a formative tool in several cohorts of undergraduate medical school students. Howe et al., (2018) used this tool in a cohort of second year psychology undergraduates and although all students answered some questions, only 20% of them wrote any questions at all. The academic leading on this educational initiative at the University of Hertfordshire ensured all students attended a compulsory workshop to explain the task and were able to practise using the tool. The benefits of the exercise were also explained, and they were taught how to write multiple-choice questions. Motivational messages were also communicated throughout the term. This approach may have had a positive effect on the engagement with the tool. Fergus et al., (2021) found similarly high engagement levels with 97.8% of students creating questions. Although these students are from different cohorts, they had the same academic support and were studying at the same university.

It was also noted a wide range of PeerWise scores were achieved across the cohort. These scores are linked to how much students contribute, and they often exceeded the task instructions (see table 10 in section 4.3.6). It is argued that students appreciate the value of this task and its role in revision and thus attainment so utilised it as a beneficial revision tool. From previous research, questionnaires completed by a first-year university cohort studying pharmacy (Fergus, 2019) showed that students discovered it improved their understanding and they also appreciated this learning community, valuing the positive feedback they received for their authored questions. Although these students studied at the same university, they were a different cohort to those in this study. However, a case study with medical students in New Zealand (Smith et al., 2020) found the opposite where students were disengaged with this type of learning task when they did not understand or appreciate the immediate benefit. This suggests the awareness of the benefits of this peer support tool are not always recognised by students.

The different scores generated by PeerWise are linked to different aspects of the task. A basic explanation can be found in table 5 in section 4.2.2. These scores are however also influenced by other factors, and it is beneficial to have a better understanding of these before discussing the results in more detail. Table 16 provides a detailed explanation:

Table 16 - Further explanation of score components given by PeerWise for data analysis

Title of score	Explanation
PeerWise reputation score	This score is a combination of a number of factors. Students' score will increase if they answer questions early, they write questions that their peers rate well and if they rate questions that their peers also rate the same way.
PeerWise author score	This is influenced by peers' rating of their questions but also linked to early submission.
PeerWise question (answering) score	This is linked to answering an increasing number of questions but is also linked to other students agreeing with the student answers. It will benefit students who participate early.
Rating score	This is linked to the number of questions a student rates (in agreement with peers) but this score also increased if work is done early compared to peers (This is therefore also linked to rating questions fairly)
Total answer score	This score is the number of questions a student gets correct (it assumes that the author's suggested answer is correct).

4.4.2 Impact of demographic factors

4.4.2.1 Age

The stratified analysis used to calculate both the adjusted and unadjusted odds ratio (aOR and uOR) found that older students were significantly more likely to achieve a median or above reputation score (aOR = 3.51 uOR = 2.79, 95% CI 1.1, 6.8).

There were no other significant differences noted at a 95% confidence interval. However, at a 90% confidence interval, it was found that older students also achieved a higher question answering score (aOR = 2.78 uOR = 2.28, 90% CI 1.1, 6.8).

This reputation score incorporates several factors (see table 16) but essentially was higher in students who are authoring and answering a larger number of questions early in the course (when compared with their peers). In a similar vein, the answer score also benefits students who use the tool earlier when compared to their peers. Previous research found that mature students were more likely to adapt a deep approach to learning rather than a surface approach (Richardson, 1994). The reasons for this can be hypothesised; it is found that mature students are more likely to have family or caring responsibilities as well an employment commitments when compared to their younger student counterparts (HEPI, 2021). This may mean they have less flexibility in terms of when they can complete the tasks which will impact on these scores (as studying earlier would result in a higher score). However, this hypothesis cannot be tested further in this study as caring responsibilities was not available. Despite a higher performance in these PeerWise scores, there was no difference in attainment in the summative midterm test.

4.4.2.2 Educational background

There were no significant differences found within this category using either a 95% or 90% confidence interval. This may provide reassurance that despite students being admitted with a range of prior educational experiences, the different types of qualifications are not advantaging or disadvantaging any particular sub-group. From lived experience as an academic, students coming from a non-traditional route have often vocalised that they perceive A-level students to be ‘better’ academically at university. This current analysis could not investigate the factor of prior attainment further due to the lack of visibility of full admissions data for students results in the central system but is indicative that this perception does not hold true for this cohort of students at least.

4.4.2.3 Impact on programme of study

Post-hoc analysis was carried out to compare the cohorts on the different programmes. There were 88 students on the MPharm programme (75%) and 29 students (25%) on the BSc Pharmaceutical Science programme. These two programmes have different admissions criteria. Students on the BSc Pharmaceutical Science pathway require at least a C grade in A level chemistry or equivalent in an alternative qualification. Students on the MPharm programme are required to achieve at least a B in A level chemistry or alternative equivalent (University of Hertfordshire, 2025a, 2025b). (This cohort did not contain any students with a BTEC qualification).

From analysis, it was found that there was a significant difference in the PeerWise author score, with the MPharm cohort gaining a higher score (OR 2.73, 95% CI 1.1, 6.5). The MPharm cohort also performed better in the summative midterm test overall (OR 3.62, 95% CI 1.4, 9.1) and the MCQ component (OR 3.79, 95% CI 1.5, 9.5). This is consistent with other research which specifically linked the author score to attainment in summative tests (Denny et al., 2008; Hancock et al., 2018; Hudson et al., 2018). It can be hypothesised that authoring questions requires students to think deeply about the topic area and fully understand it. Students have not been required to author questions before and find it to be a challenging and time-consuming task and fulfilling this task required a better understanding of the topic (Fergus, 2019). They also needed to provide a clear explanation and plausible extractors which continue to build their metacognitive skills and a deep understanding of the topic. The use of PeerWise on a chemistry programme at the University of Bristol (Adams, 2021) found that students developed a better understanding of a topic when specifically tasked with authoring ‘good’ multiple choice questions. The differences between the programmes could be linked to prior knowledge which has been shown to be a factor in predicting success in chemistry at university (Hailikari et al., 2008; Seery, 2009). However, as students may have gained higher than admission requirements and as both programmes may have accepted students through the UCAS clearing process, it is not possible to draw definitive conclusions regarding prior attainment in this study.

4.4.2.4 Gender

This cohort had substantially fewer males than females with 32 males (27%) and 85 females (73%). It was found that females were significantly more likely to achieve a median or above score in several of the PeerWise metrics; reputation score, question answering score, total answer score and question rating score. This was shown by both the adjusted and unadjusted odds ratio calculations (aOR and uOR) shown below:

Reputation score (aOR = 0.21 uOR = 0.20, 95% CI 0.1,0.5).

Question answering score (aOR = 0.36 uOR = 0.33, 95% CI 0.1, 0.8).

Total answer score (aOR = 0.37 uOR = 0.37, 95% CI 0.2, 0.9).

Question rating score (aOR = 0.40 uOR = 0.38, 95% CI 0.2, 0.9).

It is of interest to try and understand why these differences may arise. Research into motivations and self-esteem has found significant differences between the genders. Females are more likely to be intrinsically motivated and more likely to have a lower self-esteem than their male counterparts, and this is even more common in mature females (Murphy & Roopchand, 2003). This low self-esteem can have the impact of increasing engagement with tasks due to the fear of poor academic results otherwise and may help to contextualise the observations made in this study. There is further evidence that male students are more confident in their abilities. A three-year longitudinal study researching male psychology students (Sanders et al., 2009) found that a significant proportion had high self-esteem and expected higher marks than (female) peers although Sanders found that results across the genders were comparable with course marks actually slightly lower in the male groups.

Interestingly, despite the clear higher contribution in the female group in our cohort, there was no difference seen in the summative assessment results, which on first reading may appear counterintuitive. However, it is important to note that females did not achieve higher scores in the author score category, meaning they were not creating more questions than their male counterparts which requires more effort and understanding. The type of questions being answered within the tool is also important to consider. There is evidence that the type of question that students write, and answer has an impact on their academic performance.

For example, having many low-level Bloom's Taxonomy questions to practise does not improve a student's ability to answer higher level questions, which may predominate in the final assessment (Hudson et al., 2018). The types of questions written by the participants in this study, and to which level of Bloom's Taxonomy they fit have not been investigated as this was outside of the research question remit. Although this was a formative task for students, and this may have impacted on student engagement with the activity, previous research found that there was not a significant difference between questions written for a formative task when compared with a summative one (Fergus, Hirani, et al., 2021).

4.4.2.5 Ethnicity

The statistical analysis comparing different groups of ethnicities did not find any significant differences at 95% confidence interval. When using 90% confidence interval some were found which are discussed below (data being referred to is found in table 12)

Arab students were found to score significantly higher in the author score category when compared to White students (uOR 4.29, CI 90% 1.1-16.8). In a previous study, (Hudson et al.,2018), this category was found to be the biggest predictor of a good performance in the summative test. This is an interesting observation for this subgroup as it does not correlate to a higher performance in the summative midterm test for these students. This also seems to contradict the lack of overall award gap evidence previously discussed (Kam, 2020). It is clear that these students are engaged, so what is preventing them from attaining needs to be investigated further. The quality and cognitive level of the questions they are writing could be considered; if the type of questions written are at a consistently lower level of Bloom's taxonomy, students may not gain as much benefit from this with regards to increasing their understanding of the subject matter. Repeatedly creating questions that are based on facts rather than understanding or application will not help a student in a test where they are required to show understanding and apply their knowledge rather than recognise and reproduce facts. The possibility of academic misconduct and use of artificial intelligence has been considered but the research suggests that its functionality at the time of this study would not be sufficient to answer higher level chemistry questions or provide suitable justification for the correct answer (Fergus et al., 2023).

One further difference between ethnicities was seen. Both White students (uOR 0.27 90% CI 0.1,0.8) and Arab students (uOR 0.24 90% CI 0.1,0.8) were found to score higher in the total answer score when compared to Black African/Caribbean students. However, none of these groups showed a significant difference in attainment when the midterm test results were analysed. The PeerWise total answer score relates to the number of questions a student is answering correctly. These students are clearly contributing more than required for the assigned task. However, this is not being reflected in significant improvements in their summative results compared to the group demonstrating lower engagement with the formative exercise. It should be considered that solely answering many questions, which are often written at low cognitive level, is not enough. Although students are engaging, this could be considered as a superficial type of engagement when compared to students who create questions required a deeper understanding and effort. A previous study, Hudson et al., (2018), found that a high total answer score in students did not correlate to a higher course grade performance.

4.4.2.6 Further subgroup analysis

Further analysis of smaller sub- groups to consider age, gender and ethnicity intersectionality was completed.

When comparing young White females and young BAME females, there was a difference seen in the total answer score with BAME students achieving a high score (OR 0.15, 95% 0.0, 0.6) but no difference in summative midterm results. This has been seen already in some of the ethnicity data and also in previous studies where there was no relationship found between the total answer score and summative results (Hudson et al., 2018).

Between young White and young Black students' groups, there was a significant difference in the progress SAQ score, with BAME students scoring higher (OR 0.14, 95% 0.1, 0.8). Although there was no significant difference in the contribution within the PeerWise scores, this could be expected as the skills required to structure a short answer question are different compared to answering an MCQ answering.

The most significant differences in this subgroup analysis were found in the comparison of mature females and mature males. It was found that mature females scored significantly higher than the mature male group in the following scores: reputation score, author score, question answering score and total answer score.

Reputation score (OR = 15.20, 95% CI 2.0,114.2).

Author score (OR = 1.33, 95% CI 0.3,0.7).

Question answering score (OR = 12.00, 95% CI 1.6, 88.3).

Total answer score (OR = 8.00, 95% CI 1.1, 57.5).

Looking at the analysis of the midterm test in this group, there was no significant difference between mature males and females.

A less pronounced difference was seen with young females and young males where young females outperformed young males on reputation score, (OR = 3.66, 95% CI 1.6, 8.3) and question rating score (OR = 2.36, 95% CI 1.1, 5.2).

These results (for both these intersectionalities) contradict previous studies which found the reputation score as a predictor of attainment in summative tests. Students often have many roles and commitments outside of their university studies and this is particularly more pronounced for mature females (Markle, 2015) . This can impact on the engagement and involvement they have with their studies, with these students often taking a strategic approach so engaging more with summative rather than formative tasks (Race, 2019). Despite this 'inter-role conflict', these students often show great persistence to complete their studies (Markle, 2015). This may be linked to their motivation where research has shown mature students to be more likely intrinsically motivated, encouraging them on to complete their studies (Murphy & Roopchand, 2003). National data from the Office of Students (OfS, 2020) shows that mature students have poorer degree outcomes when compared to younger students. However, this does not acknowledge the barriers that have been overcome to study and finish the degree journey. As there are many barriers faced by these mature female students with regard to studying, institutions should consider what support can be provided to overcome some of these barriers (Bowl, 2001). Non-traditional students do not have an equal experience to school leavers entering with A-Levels whilst at university (Bowl, 2001). Extra support like communicating clear expectations of higher education, specific first in the family support, timing of teaching sessions, accessible and affordable childcare and all potentially ways to reduce barriers (Morgan, 2013).

Having low stakes assessment early in the first year of university and providing feedback prior to more high stakes assessment is beneficial to all students. This can have an added benefit to non-traditional backgrounds by setting clear expectations of the level needed in higher education (Sambell & Hubbard, 2004). Although this support is beneficial, evidence from this cohort study shows that it is clearly not allowing them to attain to the same level as their colleagues. Consideration needs to be given to the types of assessment chosen throughout degree programmes. Being able to perform well in one timed assessment does not necessarily correlate to being consistently competent in this area (Rethans et al., 2002).

4.4.3 Limitations

The data available limited the analysis that was possible to carry out. As outlined above there are several other factors that can impact attainment but were not easily available for analysis. Although the range of demographic factors that were investigated are meaningful and relevant to education, there are other relevant factors which are known to impact on education and could be influencing this student population and their attainment. These include disability status, employment commitments, socio-economic status and caring responsibilities. It would be interesting and pertinent to look at these data, where available, in the future.

When interpreting the data in this study, the median was calculated to compare the data between demographic groups, this was used instead of the mean to ameliorate the extreme scores within the data sets (Hofer & Murphy, 2000). However, it is acknowledged that this causes some limitations. Comparing the mean of the datasets instead of the median would allow the data to be more reproducible in further studies and allow for more meaningful comparison in the future. Alternatively, consideration could be given to categorising the data in other ways, for example, high and lower achievers in each degree classification, which could reflect the richness of the data when there is wide variation in scores.

With the demographic factors that were considered, some of the subsequent datasets contained small sample sizes which influences the power of the study thus has an impact on the validity of some of the conclusions.

The quality of questions submitted, and their explanations and comments could have given an indication of the depth of their learning and understanding as well as the development of metacognitive skills. In addition, further qualitative data from students to explore their perceptions on contribution as well as performance in the summative test would be a beneficial addition to the narrative.

4.4.4 Reflective context from the researcher

As outlined in chapter 3, the researcher should be reflective considering experiences and values which may potentially cause any bias in the research (Mortari, 2015). Although this phase was quantitative, the researcher did engage with the data and analysis so reflected on their place with the topics considered in this research phase.

> This peer support tool was originally introduced to the university by (Fergus, 2019). I have used this tool within a different module and was pleasantly surprised with how engaged students were with the formative tasks, producing more questions than requested in the workshop.
>
> Within our cohorts, I am aware of many students with family commitments and caring responsibilities and have been told of student family members encouraging them to ensure their studies to take the lowest priority. Religious observations mean that the structure of the national student loan system is not acceptable to all students and means they may have significant paid work

commitments in order to pay for their studies. This in turn can impact on their academic attainment by limiting the amount of time they can engage with the programmes. With these observations, I was expecting certain gender and certain ethnicities to engage less and perform less well on the summative assessment (due to competing commitments rather than academic abilities). Identifying and reflecting on this bias helped me identify that these issues will not affect all students within specified ethnicities and to remain open-minded when analysing the data. It ensured I was more open to any results and using statistical analysis which is an inherently objective approach helped achieve an unbiased approach. Several other steps were taken to maintain the objectivity of this study. The quantitative nature of the analysis does assist this, but the analysis of the data was also checked by a critical friend (one of the supervisors). Any conclusions were compared to published data.

4.4.5 Phase one summary

This phase investigated the impact of students' demographic factors on their engagement and attainment using a formative peer support tool and subsequent summative assessment. Alongside phase two of the thesis, it aimed to answer the research question "what influences students' understanding and application of knowledge of chemistry within the MPharm degree".

Although the analysis of this data did not statistically demonstrate any specific single factors which influence both formative homework and summative assessment scores, there were some interesting findings.

One finding from this research was the marked difference in performance between genders, with females contributing more to the PeerWise tool. This was even more pronounced in the intersectional mature females to mature males comparison. Previous research into the use of PeerWise has not reported on gender and age in terms of engagement with the tool, so this finding adds to the existing literature base. However, it is acknowledged that other factors could be influencing these students' ability and desire to engage well with the tool and assessment. Phase two of this thesis may help explore these findings further,

The general engagement with using this tool as a formative method of support and assessment was high, supporting the findings in other literature looking at its use in chemistry (Fergus, Hirani, et al., 2021; Galloway & Burns, 2015) as well as molecular biology and biochemistry (Hancock et al., 2018). The results are in contrast to Howe et al., (2018), who researched psychology students use of the tool and Smith et al., (2020) who used it with several cohorts of medical students. This high level of engagement from the pharmacy students may be related to their approach to subjects with complex concepts like chemistry and biochemistry when compared to some other subjects. This theory can be explored further in phase two with the qualitative data collection being used to gain a better understanding.

The analysis of this data did not demonstrate a consistent correlation with general engagement with the tool and the summative results on the same module. In contrast to other studies, (eg Galloway & Burns, 2015), pharmacy students' performance in PeerWise did not correlate to an improved attainment in the module's midterm test despite the higher authoring score. A factor which may possibly affect this lack of correlation could be the level of questions written in PeerWise when compared to those within the summative test. Hudson et al., (2018) found that writing higher level questions requiring understanding rather than solely recall showed a higher positive correlation in performance when compared to solely answering recall questions.

This dataset also compared students on the vocational course (ie pharmacy) and the more purely scientific course (ie pharmaceutical science). When comparing the MPharm and Pharmaceutical Science programme cohorts, the analysis found that the MPharm cohort, who contributed more to the authoring of questions performed better in the summative midterm test. This is consistent with prior research (Denny et al., 2008; Hancock et al., 2018; Hudson et al., 2018). However, this research carried out a further level of stratification and found other significant results when delving deeper into the student groups and subgroups found in the dataset.

The effect of ethnicity was investigated which has not been previously researched in relation to this online tool. There were variations seen between different ethnicities when further stratification was completed and their clear contributions to the tool was not reflected in the performance in the midterm test. The data does suggest that the complexity of students' backgrounds and other factors may be affecting their studies. As the findings do not indicate that any single demographic consistently performs exceptionally well or has poor outcomes, they imply that assessment-related challenges may be distributed across the diverse student population. This suggests that additional support strategies should be considered addressing the needs of students from a range of backgrounds allowing all students to thrive in the university setting.

The data analysis from this study does not reflect national data about degree outcomes regarding a range of characteristics (OfS, 2024). This could potentially mean this type of student cohort are different when compared to others which is somehow impacting on their learning, it could be diversity is a strength in terms of preventing differential degree awarding gaps. In addition, the affective domain of Bloom's taxonomy (Bloom et al., 1973) and its impact on attainment should be considered as this task and assessment benefits from interaction with peers and learning with and from them.

4.4.6 Informing the next phase of the doctoral study

Although this phase produced some interesting findings, it did not identify a clear distinct pattern within the demographic factors that were analysed so it cannot categorically state which (if any) demographic factor is an objective influencing factor on attainment within the chemistry module. It suggests the influencing factors are complex and multi-layered, supporting the need for further explanation using qualitative data collection and analysis. One acknowledged limitation of quantitative data (Cresswell and Cresswell, 2018) is the lack of context available to help explain the numerical results. This limitation can be mitigated slightly by following up with qualitative research within the same cohort of students and chemistry academic staff that teach these students. Phase two of this doctoral study is qualitative in nature and will facilitate detailed exploration of these students' perceptions to gain a better insight into their learning of chemistry within their degree. Exploring students' perceptions on the importance of this subject area will be beneficial as well as academic staff lived experience teaching these cohorts of students.

The high level of engagement seen with this formative tool was pleasing to see. It would be interesting to find out if students approach the study of chemistry differently when compared to some other subjects. Their different approaches between rote learning of information that can be re-called and developing in depth understanding can also be explored further. This links to the development of higher order thinking skills like problem solving and answering multi step complex questions. It may help explain the lower summative test scores when compared to high level of answering questions using the PeerWise platform.

Using the qualitative approach in phase two in combination with this quantitative approach in phase one will help provide a deeper understanding of these statistical findings. In line with the constructivist philosophical approach, reality is individually constructed and students experiences are dependent on multiple factors and contexts.

Chapter 5: Exploration of the learning and teaching of chemistry with perspectives from academics and undergraduate pharmacy students

5.1 Introduction

This chapter presents the data for phase two (part one) of this mixed methods study and its subsequent analysis. The study focuses on both staff and students on the Master of Pharmacy programme and explores their perspectives of teaching and learning chemistry respectively on this programme of study.

There is little research comparing student and staff perceptions around the learning and teaching of chemistry, specifically on pharmacy degrees. Although there have been previous studies on students' perceptions towards or relating to chemistry learning in pharmacy (Jesson et al., 2006; Prescott et al., 2014; Smith et al., 2017), currently there is little research regarding chemistry academic staff perceptions on important factors affecting teaching (and learning) of chemistry and any differences between students and academics (Mawdsley & Willis, 2018, 2019). This research aims to add to the existing literature in this area.

5.1.1 The research questions

It is important that the continued significance of science within the pharmacy programme curriculum is acknowledged despite the increasingly complex clinical requirements, in line with the UK's statutory pharmacy educational standards (GPhC, 2021). The aim is to ensure students finish their degree scientifically literate, with an understanding of key concepts and an ability to apply this knowledge to clinical problems (Husband et al., 2014). A more detailed understanding of both staff and students' perspectives regarding chemistry should help achieve this.

The following research questions were developed and investigated:

For academic staff:

- What do chemistry academic staff consider and understand regarding student perceptions of chemistry on the MPharm programme?
- What do chemistry academic staff think influences MPharm students' learning of chemistry?

For MPharm students:

- What are MPharm students' perceptions towards chemistry within the MPharm degree?
- Do students experience any difficulty in specific chemistry topics?

- Do MPharm students identify effective ways to learn and understand chemistry?

5.1.2 Consideration of Master of Pharmacy curriculum design

Historically, science and practice topics were taught in silos by discipline-specific staff. There has been a clear argument for this initial theory component to be delivered prior to starting practice (Winch & Clarke, 2003). However, there needs to be a way of appropriately combining these subjects to help ensure an underpinning conceptual understanding, as well as problem solving skill development needed in practice.

The challenge of how to achieve this science understanding to underpin clinical knowledge has been considered widely (Alsharif & Galt, 2008; Husband et al., 2014; Kearney & Larrañeta, 2021; Talasaz et al., 2023) and may be attained by an integrated curriculum design. Integration can be organised into teaching disease states and their management, incorporating both science and practice teaching, rather than to remove science from the curriculum. This authentic teaching and assessment approach, encourages meaningful rather than rote learning (Husband et al., 2014). The importance of meaningful learning as opposed to rote learning has been frequently discussed and defined (see e.g. Bretz, 2001; Mayer, 2002; Novak, 2010).

Curriculum design and the implementation of an integrated structure impacts on the delivery and interpretation of the curriculum and so may influence students' understanding of the importance of this integration (Kulasegaram et al., 2013). Acknowledging the principles of constructivism, students routinely attempt to link and build on any related knowledge that they have already, constructing meaning from newly acquired knowledge (Bodner, 1986). This can be beneficial in terms of understanding but can highlight differences in students' development of knowledge and understanding. There is also evidence that construction and understanding of knowledge is influenced by social interactions (Hodson & Hodson, 1998). For example, workshops which encourage peer to peer discussions and interactions allowing students to develop problem solving skills are an integral part of this curriculum design (Hubball & Burt, 2007).

Gaining a deeper understanding of both staff and student perceptions in the pharmacy programme about learning and teaching will help develop and positively influence the curriculum approach to help students succeed in understanding and application of chemistry.

5.1.3 Curricular overload

With the content expansion of the curriculum due to the extended role of the pharmacist, as well as the need to develop a range of higher order skills, there is risk of an overloaded curriculum. Neither the overall programme length nor term length has increased so appropriate assessments, experiential learning in addition to the increased content leads to this overload which has a direct impact on both staff and students (Kelley et al., 2023). Being mindful of this issue when designing overarching curricula as well as planning individual teaching sessions is important.

The concept of cognitive load theory is important to highlight here (Sweller, 2011) which acknowledges the limited capacity of the working memory and its impact on learning. To understand taught material, this information needs to move to the long term memory, and link to previous knowledge within schemas (organised areas of knowledge). If students are required to handle large volumes of information at the same time, which may be new and often complex, this may result in cognitive overload, and it becomes challenging to process all this information into a more meaningful form within schema in the long term memory.

The strategic issue of curricular overload thus has an operational impact on students and staff. Students are more prone to use surface learning approaches when faced with overwhelming amounts of material (Biggs & Tang, 2011).

The issue of overloading is acknowledged in literature (Trujillo & Cain, 2023) with solutions being described and evaluated (Chen et al., 2023). From Chen and colleagues review, there were common themes seen that were addressed when effectively managing the challenge of an overloaded curriculum. This included communicating well across all teams teaching on the programme, reviewing previous content which is no longer linked to the competencies being developed and using active learning strategies to support the development of deep understanding.

Sun et al., (2023) highlight the need for appropriate sequencing and design as they can potentially help reduce repetition but true integration with embedded themes and co-discipline teaching could help to reduce overload within the curriculum. To further support having appropriate content within the curriculum, Sobieraj et al., (2024) designed a toolkit linked to several areas of the US pharmacy curriculum to support universities in streamlining and prioritising teaching. This concept could be expanded to more topic areas and different countries.

On an operational level, staff need to be aware of the risk of cognitive overload and its impact. Whilst experts may find some content and problem solving straight forward, students who are discovering this information for the first time and need to organise and understand this knowledge, may find it more challenging (Sands & Overton, 2010).

Cognitive load theory is also relevant to academic staff and assessors (Wilby & Paravattil, 2021). Assessment criteria need to be clear and concise otherwise there is a risk to the reliability and quality of the marking.

5.2 Methods

Focusing on academic staff working on the MPharm programme, and students registered on the Master of Pharmacy programme at the University of Hertfordshire, this study takes an in-depth qualitative approach with semi-structured interviews of these academics and pharmacy students.

5.2.1 Choosing the research tool

Consideration was given to the most appropriate way to collect data to fully answer the research questions. Questionnaires could potentially result in a higher number of participants but interviews would allow topics to be explored at greater depth providing rich data (Denscombe, 2017). Given that the research questions for both the staff and student-centred study were aiming to further understand opinions and lived experiences, interviews were deemed most appropriate for both studies (Denscombe, 2017). Interview questions offer more freedom for the participants to provide their own in depth answers as opposed to answering a multiple-choice format question in a questionnaire (Cresswell & Plano Clark, 2018; Gillham, 2005). One to one interviews (as opposed to group interviews) were deemed to be the most appropriate research tool to allow participants to have a detailed discussion on the topic (Denscombe, 2017). The staff group's dynamic was already established, and individual interviews avoided any potential hijacking of discussions by specific staff members. In the same way, students may have felt influenced by their peer group to answer questions in a certain way.

As discussed in section 3.11.4, students were involved in the interviewing of student participants due to the potential positive impact of direct student voice involvement in this type of academic research (Ayres & Wilson, 2018; Bohnacker-Bruce, 2019). For staff interviews, the same considerations were made. Because of the possible power dynamic between staff and students, the PhD researcher, who was a peer from a separate discipline within the department was deemed the most appropriate to conduct staff interviews.

It was important to have appropriate skills as an interviewer as this can also directly impact on the quality of the data collected (Cohen et al., 2018). Training sessions were attended to develop these skills, and the PhD researcher also ensured the student interviewers were appropriately trained. In addition to attending taught theory sessions, this involved conducting practice interviews and directly supporting the students in developing these skills.

The researcher also needs to recognise their potential prejudices (Gillham, 2005) prior to conducting the interviews to consider their behaviour, responses and interactions during the interviews. The researcher aimed to be reflective in their approach, and a reflective account can be found later in this chapter (section 5.4.6). The student researchers were also encouraged to be reflective as a key instrument in this data collection (Cohen et al., 2018) and this topic was specifically addressed during their regular research meetings.

5.2.2 Question development for the staff interviews

Distinct interview questions were developed for each group of participants recognising the valuable nature of their different experiences, for example, staff taught students across a range of programmes so were asked about any disparities they noticed between vocational and non-vocational programmes. Both sets of interview questions were designed to allow the research questions to be answered. They were created then reviewed by the dissertation supervisor who suggested improvements and modifications. The questions were piloted to ensure they were clear and there was no ambiguity.

The initial part of the staff interview contained closed questions to gather specific details of the academic's experience in teaching. This study explored staff perceptions of learning and teaching chemistry in this higher education setting which they had lived experience of, so this detail was helpful to provide context for the researcher. The question design structure for these interviews was informed by the literature (Gillham, 2005) with the closed questions first, followed by the more open-ended questions. It was beneficial to see what concerns were also considered an issue on a non-major chemistry degree like the Master of Pharmacy programme. The phrasing and order of questions were discussed and reviewed prior to the finalised schedule, with a pilot with one sample participant used to help refine and provide feedback on the schedule (Gillham, 2005). The full interview schedule can be found in table 17.

Table 17- The question schedule for staff interviews

Introduction • Brief introduction of myself, thank them for participating in the research. • Remind and explain the purpose of this project (all participants have already consented and been sent a participation information leaflet). • Explain that as much detail as possible would be appreciated as it helps with understanding of academics' perceptions in this area • First closed question – confirm how long they have spent teaching in higher education
1. What factors affecting learning chemistry do you feel are most important? Possible prompts: Can you explain why you feel this way?
2. In what teaching environments do you feel the students learn chemistry most? Consider lectures, workshops, practicals Possible prompts: Can you explain why you feel this way?
3. What type of teaching activities do you feel the students enjoy most? Consider lectures, workshops, practicals Possible prompts: Can you explain why you feel this way?
4. Thinking about student learning, how do you believe students learn best in the discipline of chemistry? Follow up question: What approaches to learning do you think are most effective?
5. When teaching undergraduate students, a) Do you notice differences between year groups within a degree? b) Do you notice differences between students on different degrees eg pharmacy, pharmaceutical science, bio sciences programmes? Possible prompts: Can you explain in what ways these are different?
6. Previous research suggest that academic staff have a range of concerns regarding first year undergraduate students who are studying chemistry. Do you share any of the following concerns for new students embarking on a degree with chemistry in it? a) Basic concepts b) maths ability c) IT ability d) problem solving skills e) Coping with different teaching methods used at university (Note: previous research : (Sözbilir, 2004; Symington & Kirkwood, 1996). f) Any other concerns that you feel are an issue and that you would like to discuss? Note for researcher – address each topic here individually, ask the participant to consider examples and why they agree or disagree with the issue.
7. Finally, is there anything else you wish to add regarding issues for students studying chemistry?

5.2.3 Question development for the student interviews

These interviews were conducted by the student co-researchers with two final year MPharm students working with the PhD researcher. These students were directly involved in the question planning for the student interviews using their own lived experience as well as the relevant literature.

A set of 14 questions were developed for the students to link directly to the research questions (found in table 18). These questions had additional prompts to help scaffold the discussions and ensure that the resulting dialogue addressed the objectives and research questions. A relatively large number of questions were incorporated into the student interview schedule as it was considered likely that less in-depth answers from students would be given as they have less background knowledge of pedagogy, so scaffolded questions were built into the process.

Similar to the staff interviews, the initial questions were short questions which identified several different demographic factors where there was published research highlighting their influence on learning, study approaches and attainment. These were age (Richardson, 1994), gender (Meinck & Brese, 2019) and prior study (Seery, 2009). As discussed in the previous chapter, ethnicity is known to be a potential influential factor however this data was not collected in these interviews. There was a concern this may compromise anonymity, especially when combined with the other demographic factors. The year of undergraduate study was confirmed as previous research into pharmacy student perceptions found opinions differed between year groups (Prescott et al., 2014; Smith et al., 2017).

A series of open-ended questions followed to build on previous research including the transition to university (Leong et al., 2021), career choices following undergraduate experiences (Willis et al., 2006, 2008; Willis & Hassell, 2007), attitudes (Dalgety et al., 2003) and perceived relevance (Kember et al., 2008). A summary of the interview questions for students is presented in table 18.

Table 18 -The question schedule for student interviews

Introduction • Brief introduction of myself, thank them for participating in the research. • Remind and explain the purpose of this project (all participants have already consented and been sent a participation information leaflet). • Explain that as much detail as possible would be appreciated • Some short questions – age range, gender, year of study and prior study • Remind them they will remain anonymous and be allocated a letter rather than using their name when analysing the data
1. Could you tell me a little about why you chose pharmacy as a career and what area of pharmacy you would like practise in?
2. Can you tell me how you felt about studying chemistry in school/college?
3. Do you feel differently or the same about studying chemistry now that you are at university? Possible prompt – can you explain or expand on this
4. Can you tell which chemistry topic or area is your favourite at university and why?
5. Can you tell which chemistry topic or area is your least favourite at university and why?
6. Is there a type of teaching that you prefer when it comes to chemistry? Consider lectures, workshops, practicals Possible prompts: Can you explain why you feel this way?
7. Do you feel you learn most in your preferred type of teaching session? Consider lectures, workshops, practicals Possible prompts: Can you explain why you feel this way?
8. How relevant do you think chemistry is to being a pharmacist? Prompt: can you explain why you think this
9. Do you think the type of chemistry taught on the degree is relevant to being a pharmacist? (Prompt: Please explain why you think this)
10. What do you think about contextualisation of chemistry teaching? (Possible prompt/clarification- its linking the chemistry to relevant pharmacy practice)?
11. Can you tell me about your strategy for studying chemistry at university?
12. Is this different to how you study for other topics?
13. Do you think that there are any specific changes that could be made to further support students studying and understanding chemistry?
14. Finally, is there anything else you would like to add?

5.2.4 Recruitment and data collection

Ethical approval was sought and obtained to conduct semi-structured interviews with both staff and students in the pharmacy department (Ethics protocol numbers: LMS/PGR/UH/02947 and LMS/SF/UH/03462).

Chemistry academic staff and pharmacy students were approached in different ways due to the different communication routes available. Staff were emailed directly to their registered university email address and invited to voluntarily take part in an interview whilst students registered on the MPharm programme in all years were sent details of the study through the university's virtual learning environment (VLE).

Interviews took place face to face on the university campus as a familiar and safe environment for both interviewer and participant. A quiet private room was used to ensure confidentiality. University meeting rooms were used rather than individual staff offices to ensure a neutral environment for both the interviewer and interviewee (Denscombe, 2017). The interviews were audio-recorded so they could be transcribed for data analysis.

Pseudo anonymity was maintained for both groups of participants and although contextual background information was collected, the risk of being able to identity a participant was specifically considered. Certain demographics were combined or omitted to reduce the risk of compromising participants anonymity. It was made clear to participants that their anonymity would be maintained throughout the study with recordings and transcriptions suitably encrypted and stored securely.

5.2.5 Data analysis

The qualitative data was analysed to identify themes using the thematic analysis method described by Braun & Clarke, (2006)

Braun and Clarke's approach advises researchers to actively search, analyse and interpret the data (Braun & Clarke, 2006). The analysis of qualitative data started by becoming familiar with the data, transcribing the recordings as thoroughly as possible and as soon as possible after the interviews (Braun & Clarke, 2013). Time was scheduled to transcribe the interviews very soon after they had taken place, and the audio recordings were listened to multiple times to allow familiarisation of the content and then were transcribed verbatim by the researcher.

The phases of the thematic analysis process outlined by Braun & Clarke, (2006) were used, with the researcher continually returning to earlier phases to continually improve familiarisation of the data. Table 19 presents these phases in the context of this research.

Table 19- Thematic analysis in the context of this research (Braun & Clarke, 2006)

Phase	Description	In the context of this dataset
1	The researcher familiarises themselves with the data	The audio recordings was listened to and transcribed, then listened to and re-read multiple times
2	Initial codes are generated by the researcher	The transcripts were reviewed in organised manner to identify codes within the data
3	Themes are searched for	The generated codes were reviewed and grouped together into themes
4	The themes are reviewed	The transcripts were reviewed again to checked codes had not been missed and review overall themes
5	Themes are defined and named	Themes are refined, taking into account any new codes from phase 4. The story that the analysis tells is considered
6	The report is produced	The writing phase provides a final opportunity for analysis. The findings are presented with the report (chapters 5 and 6).

A manual approach to data analysis was taken as opposed to using a computer software package. The literature comparing these methods highlights benefits and challenges of each, with the researcher's own preferences being one of the factors to consider (Basit, 2003; Mattimoe et al., 2021). From this experience of using a manual method, this researcher's perceptions are like those documented by the researchers in the literature. For example, repeated reading and listening of the transcripts allowed the researcher to stay close to the data and remain immersed in it. The repeated listening to the transcripts meant the nuances of language and tone were frequently noted. Using a physical hands-on approach with annotation of the paper transcripts felt more appropriately creative and helped develop understanding of the process and the data. It was noted that this manual approach was possible because of the size of the dataset, and it may have proved much more challenging if there had been a larger number of interviews and focus groups and longer recordings.

The whole dataset was searched to identify repeated patterns, those with the same meaning were given the same code. Once the responses were coded, then the key themes were generated (Braun & Clarke, 2006, 2013). Coding was completed on each set of interviews as distinct datasets (staff and students) and then themes developed from them.

The presentation of findings and analysis of these data was intentionally undertaken solely by one researcher (the PhD student) in line with the reflexive approach described by Braun & Clarke, (2006). This type of approach is compatible with the constructivism philosophy which underpins this thesis.

5.2.6 Assurance of rigour with this data analysis method

The research quality for this qualitative data analysis method is assured in a number of ways. The Braun and Clarke method (Braun & Clarke, 2006) was transparently adhered to using the full six phases as described in section 5.2.5 above. This helps provide assurance that the analysis and interpretation is trustworthy (Lincoln & Guba, 1985). Multiple reflexive activities were undertaken as part of this method. For example, the data was listened to many times, it was transcribed and then listened to again. Codes were first identified which were then grouped together in themes following another review. This iterative process ensured that the researcher was fully immersed in the data to help bring credibility to the analysis (Cresswell & Poth, 2018; Denscombe, 2017).

The themes identified were clearly linked to the participants' answers making them credible and truthful. Multiple quotations are included in the presentation of results to demonstrate these themes, making the analysis reliable and dependable (Denscombe, 2017).

The context within which this research took place has been clearly described as well as who the participants were which allows the reader to understand how transferable the research is to their own context and population (Lincoln & Guba, 1985; Denscombe, 2017)

In line with Braun and Clarke's methodology (Braun & Clarke, 2006), the data analysis presented is intentionally from one researcher's interpretations rather than multiple researchers. This is consistent with the study's constructivist stance. Themes do not passively emerge as objective ideas, the researcher is an active interpreter of the data constructing meaning from the participants interviews to identify these themes (Braun & Clarke, 2006).

5.3 Results

Six chemistry academic members of staff (out of nine eligible participants) and twenty MPharm students across all four-year groups took part in the interviews

5.3.1 Demographic data

The demographics of both groups of participants are shown in table 20 and table 21.

Table 20- A summary of academic staff interviewed and their characteristics

Staff ID	Gender	Time spent in teaching
A	Male	30 years
B	Female	6 years
C	Female	12 years
D	Male	9 years
E	Male	30 years
F	Female	6 years

Table 21- A summary of the students interviewed and their characteristics

Student ID	Gender	Prior qualification	Year of study
S1Y1	Female	A levels	1st
S1Y2	Female	A levels	2nd
S2Y2	Female	A levels	2nd
S3Y2	Female	A levels (international)	2nd
S4Y2	Female	A levels	2nd
S5Y2	Female	A levels	2nd
S6Y2	male	Foundation year	2nd
S1Y3	female	A levels	3rd
S2Y3	female	BTEC/A level	3rd
S3Y3	female	Foundation year	3rd
S4Y3	female	A levels	3rd
S5Y3	female	Foundation year	3rd
S6Y3	male	A levels	3rd
S1Y4	Female	A levels	4th
S2Y4	Female	A levels	4th
S3Y4	Female	A levels	4th
S4Y4	Female	A levels	4th
S5Y4	female	Foundation year	4th
S6Y4	female	A levels	4th
S7Y4	Female	Foundation year	4th

Students were asked to confirm their age in line with HESA definitions (HESA, 2019) of young (aged 18 to 21 years of age) and mature (aged 22 years and over) at the start of the study period. All students stated they were within the 18 to 21 years of age bracket.

5.3.2 Themes identified

Nine themes were found during the analysis of the interviews (presented in figure 12). Four themes were identified which were common to both staff and student participants, with three further themes identified solely in the staff group and two further themes identified specifically within the student group. Quotes from themes are shown in tables 22-24.

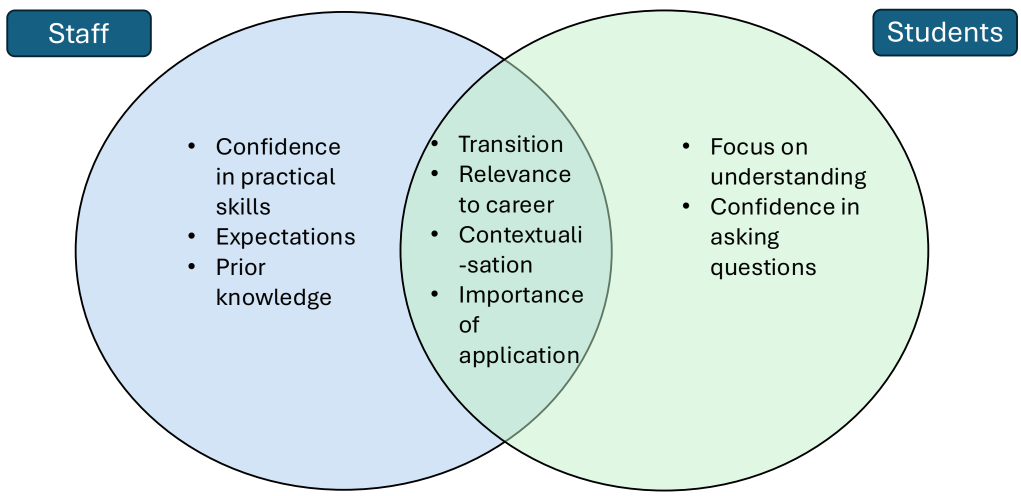

Figure 12- Venn diagram representation of the identified themes

5.3.2.1 Staff themes:

(i) Confidence in practical skills – There was a perception amongst the staff interviewed that pharmacy students were lacking in confidence in chemistry and specifically when it came to practical skills when compared to peers at an equivalent level on a similar but non-vocational course. Interestingly, this was not an issue that students specifically identified or realised was a concern.

(ii) Expectations

Academic staff discussed how they perceived pharmacy students views of the chemistry content on their degree programme, which they felt was often negative.

(iii) Prior knowledge and skill development

Academic staff had a range of experience in education and had often witnessed changes to entry qualifications over the years, explaining they perceived a reduction in understanding and skills over time.

Table 22- Themes from academic staff interviews with example quotes

Theme identified	Quote/evidence
Confidence in practical skills	Staff C – "it's the fear factor…I think there is a lack in confidence, and their perception of chemistry is that it's quite difficult". Staff B – "…whereas I think pharmacy students are a little apprehensive of just going in {to practicals} and making mistakes. They're always concerned that they're doing something wrong. Staff B: "I think pharmacy students are a little more apprehensive of just going in and making mistakes...they're always concerned that they're doing something wrong whereas the biosciences and pharm sci lot, they want to go in and do the practical". Staff D: "{the pharmacy students} are trained as almost dual professionals, they're scientists and they are clinicians and they, from a very early stage in their training, they are told that any mistakes for them can have serious consequences in terms of their patients and unfortunately that pervades their scientific explorations."
Expectations regarding chemistry on the degree programme	Staff C- "I would say...they've {pharm sci students} chosen a science-based degree and so they are anticipating that that {degree} will contain lots of lab classes, whereas perhaps pharmacy students aren't thinking that they're going to be doing lots of lab classes." Staff F - "I think that the students in pharm sci [pharmaceutical sciences] and biosciences are a lot more up for chemistry...there's a general acceptance that chemistry is an integral part of the course... whilst in pharmacy it becomes a secondary tool that they then need to pass just to, you know, to satisfy some regulations but really, it's not their main line of interest".
Prior knowledge and skill development	Staff C – "….so we are concerned that they don't have the concepts, that they learn facts and reproduction of those facts…maybe because it is very prescriptive {i.e. A level}, taught to a test". Staff A "they don't have the manipulative skills they used to have and that's primarily because practical classes have been cut back in schools".

5.3.2.2 Student themes:

When interviewing, students seemed to be a more homogenous group in terms of perceptions and fewer themes were identified despite more participants when compared to staff. Students made similar comments across questions. Perhaps this is unsurprising as the students have a significant common experience whereas the staff members have a rich range of varied experiences and research interests prior to teaching on this specific programme.

(iv) Focus on understanding - deeper learning approaches:

Many students discussed how they revised for chemistry topics and the importance of understanding fully in order to be successful

(v) Confidence in asking questions

Many students mentioned feeling uncomfortable asking questions in large lectures despite having queries but instead would leave their questions until a workshop or email the lecturer directly to ensure they were not the focus of attention.

Table 23- Themes from student interviews with example quotes

Theme identified	Quote/evidence
Focus on understanding - deeper learning approaches	Student S1Y4 – "I used to watch videos to try and understand better concepts, then I always used to use the worksheets that we got from workshops – to try and, like, see what I've understood…you can learn the theory but if you can't apply it, then it's not very beneficial". S1Y1 – "I think with chemistry, you can't learn it parrot fashion, you actually have to practise it and actually understand it"
Confidence in asking questions	Student S5Y2: "{I like workshops} because you have more time to ask questions and it's a smaller group as well, so you don't feel as worried about asking questions, like, everyone is listening to you" S1Y4 "I think lectures [are] kind of pointless, because you can't ask the lecturer questions…at A level…we were in a class, and I could just ask my teacher anything I didn't understand".

5.3.2.3 Themes across both groups

(vi) Transition to a new learning and teaching environment

Academic staff interviewed were very conscious that students have undergone a significant change to their environment which had an impact on how they interacted and coped. Students in turn also noticed the change when compared to school or college.

(vii) Relevance to future career:

A recurring topic within all the staff interviews was the perception of relevance within this group of students. Some staff linked this to a lack of engagement and motivation from the students, some clearly finding it almost disheartening.

Students consistently discussed their thoughts regarding relevance within the topic areas. There were however inconsistencies regarding which topics were perceived as relevant across the cohort, suggesting that this is very subjective.

(viii) Contextualisation

Both staff and students consistently highlighted the value and importance of contextualisation. Students routinely gave a range of relevant contextualized examples.

(ix) Importance of application

Staff and students alike stressed the importance of application, highlighting workshops being a type of teaching session where this is possible and the area where they felt they learnt the most.

Table 24- Themes from both student and staff interviews with example quotes

Theme identified	Quote/evidence
Transition to a new learning and teaching environment	Staff A - "The large-scale lecture theatre…its quite different because there is just a mass of faces and they're {not made to feel} important whereas at school, they weren't in a group of 150 plus so yeah, they were actually important, and people knew who they were". Staff B "there is quite a lot of lecture material… there's a lot of self-directed study; I think that's where one of the problems lie. I also think that up until undergraduate level, they are almost taught to just learn for the sake of learning whereas, at undergrad level it's more at the application of knowledge and that's one of the major problems that we have in terms of chemistry". Student S6Y3: "I would say there is a different approach to chemistry at university, than in A level… in an A level environment, it is more one to one with the teacher". S2Y2 – 'in first year, we would have exemplar answers...a good version and a poor version so you would understand if that was what you were planning to write, you wouldn't have gotten a good mark…but we haven't had any of that in second year". S4Y2 – " I think [A levels] have more of a structure, so you knew what you had to know- whereas in uni, it's a bit, like, vague. You don't really know what you need to know for the exam".
Perception linked to relevance linked to career	Staff A: "one of the problems with teaching chemistry to pharmacy students is trying to get across the relevance…you couldn't do that in year one, but you could certainly do in years two and three" Staff C – "Pharmacy students are very driven generally aren't they…also perhaps more goal focused rather than the learning journey". Staff D "You have to tell them why what you're trying to explain to them is important, in the grand scheme…an inability to do that can make them turn off quite quickly". Staff E – "Suddenly, you know, if they don't see the relevance then they are switched off again aren't they...they will ask you, what's the point of this?"

	Student S1Y4: "I think its relevant to a certain extent, like [student explains the relevance of pH to medication absorption] but when you're working as a pharmacist, you're not thinking about the theory anyways, behind everything, a lot of the time". S1Y2- "The only work experience I've done so far is in community… I didn't realise that I applied a lot of my chemistry knowledge into it – but, um I went to a hospital placement once and I did realise that they go back to the core of why they picked a certain medicine…. I saw this case…. we had to actually explain the basic pharmacology behind it and the chemistry behind it." S3Y2: "I suppose there are some aspects of chemistry on this degree that would probably be more um, focused on if you're going into industry…but...people already know from working in hospital or community and they are set on working on hospital or community" S4Y3 "[chemistry] is very relevant…mainly because we learn about the drugs and how the drugs work and stuff. We have to know that for being a pharmacist". S2Y2: "I feel like a lot of the chemistry is targeted towards industry. Um, 'cos when I've had experience in hospital and community, we haven't used any of the chemistry at all? But I'm sure if I have experience in industry, I'll be able to apply those chemistry skills".
Contextualisation	Staff C– "it's not just chemistry, it is chemistry for a reason, why is chemistry here, what it is for…I hope that's something I've tried to put across". Student S3 Y4: "I think its {contextualisation} really helpful, because then at the end of the day, we have to link it into practice because that's where the majority of pharmacists go". S4Y3: "I think it {contextualisation} starts to be done in third year but before then I don't think it is…I would like for them to make it more clinical before third year, that would be helpful".
Importance of Application	Staff B: "in a lecture environment I think, me personally, I like to use lectures that {….} that every couple of lecture slides, I'll stop, and I'll ask a question and then I'll try and encourage a group discussion and just try to understand, get them to understand I have taught you this concept, now let's try and apply it." Staff C – "I think they enjoy workshops…I think everyone enjoys 'doing' more than a passive experience...you've got to see it and apply it"

	Student S2Y2 – “I would say I prefer workshops…in a workshop, you are able to use the knowledge that you gained in the lecture and actually apply it to the questions”. S3Y2 – “I love workshops...it’s like kind of practising...it’s putting the lectures into practice what you’re learning…when you’re actually in the workshop- you’re doing questions, you kind of understand, you kind of realise ‘oh, yeah this is why I’m doing it and it kind of helps you understand.” S1Y3 – “more workshops, having more workshops would be better” S6Y4 – “you need to apply the knowledge; you need the understanding and lecture slides aren’t enough. You need to develop the knowledge”.

5.4 Explanation of results

This study sought to gain a deeper insight into both staff and students' perspectives regarding chemistry learning by allowing them to discuss their lived experience of the pharmacy programme. The research questions also considered influences, difficulties and effective ways to learn chemistry. The analysis of the data interestingly identified more common themes than themes specific to each group. The identified themes will be discussed first then the research questions will be addressed in section 5.4.4.

5.4.1 Discussion of staff themes

There were three themes that were identified solely in the staff interviews (see table 22 for example quotes). Six out of nine of employed chemistry academic staff members were interviewed so a high proportion although not all staff had the opportunity to provide their opinion. As she was directly involved in the planning as well as primary supervisor on this project, Professor Fergus was intentionally not interviewed as part of the chemistry academic staff.

(i) Confidence in practicals

Staff mentioned the lack of student engagement with practicals. The consensus amongst staff and therefore an identified theme was that they felt this was linked to a lack of confidence in practicals. Due to the vocational and clinical nature of the programme, the importance of patient safety is highlighted to students from the beginning and the potential magnitude of clinical errors. This was suggested as a reason behind this cautious approach and does not appear to be discussed in previous research on confidence in pharmacy students (Bond & Cone, 2012). This was not an issue identified by the students.

Very few students talked about the enjoyment of practicals, with some mentioning that they felt they did not help their understanding. However, the design of practicals with compulsory pro formas to probe the theory and understanding which encouraged knowledge and understanding seemed to be more appreciated. Students specifically mentioned the aspirin synthesis (Olmsted, 1998) practical and pH absorption practical (Hickman & Neill, 1997) (in relation to a later theme). This suggests a focus on this type of structure for practicals would be beneficial for engaging the students. These practicals guide the students through each step and explain its relevance; students clearly appreciate this. Previous research (Galloway et al., 2016) has also highlighted how the students' affective domain can impact their engagement and individual experience of a laboratory session. Providing opportunities to critically analyse and find relevant links during practical sessions will be beneficial for optimising students' learning experiences.

(ii) Student expectations

Several staff members discussed their concerns about student expectations of chemistry on the course, citing it as a possible reason for the lower levels of motivation and engagement. Although staff thought this was an issue, interestingly, the students interviewed in this study did not specifically discuss any unrealistic expectations regarding the chemistry content.

Staff did also seem to link this to students' attitude and engagement to chemistry taught sessions. For example, Staff D stated that "a student has to have an interest in the subject matter in order to be an effective learner simply because its challenging on many different levels". Staff F stated, "I think there's a sort of negative perception to chemists, you know, something for geeks, they think it's too difficult, not relevant."

(iii) Prior learning and skills development

Staff raised concerns about fact regurgitation as part of the A level structure. Lack of organisation and ability to adapt to the concept of adult learning requiring problem solving skills as opposed to rote learning was highlighted by academic staff.

Staff B explained "that's an issue {i.e. lack of problem solving skills}. I think it is related to the styles of teaching they have had before university. They would go into a classroom, learn and then leave". Staff D had the same concern saying, "they are really poor {at problem solving}, especially in the first year, they want to be passive recipients".

They noticed a gap in knowledge in terms of chemical representation. Staff C mentioned that "I was concerned so spoke to some sixth form students, they would only be experienced with one specific way of drawing it {the chemical structure}". Staff A also had the same perception saying, "nomenclature terminology is not taught as rigorously as it used to be in A level, so they come in not being precise enough."

There were concerns about lack of practical skills, with staff A saying, "they do not have the manipulative skills that they used to have and that's primarily because practical classes have been cut back in schools". A recent report by The Royal Society (Royal Society, 2023) highlighted that access to practical science in schools continues to decline.

Importantly, staff often mentioned historical discussions or knowledge of these courses which question whether their understanding of the current structure of pre-university study is correct and up to date, with secondary school assessments and programme specifications changing over the years (Gov.uk, 2021).

It is important to recognise the role of individual experience and prior learning as it will impact a student's understanding and interpretation of new knowledge (Bretz, 2001). As educators, this significance should be recognised and considered when planning teaching, to ensure all students have understood this newly acquired knowledge independent of previous experience. If there is a consistent identified gap with knowledge and skills once starting on the programme, adapting the course can help bridge that gap, with a more scaffolded approach to practical skills as well as the design of the course overall. Student success and progress has been linked to their individual prior knowledge and misconceptions (Södervik et al., 2020).

5.4.2 Discussion of the student themes

There were twenty student interviews across the year groups but there was unequal representation over the year groups with only one student volunteering from first year and a large proportion from fourth year. Some individual students did not go into a lot of detail when answering the interviewer questions, so their interviews were short and did not generate a lot of data. Participation was voluntary rather than compulsory in line with the ethical approval, so it is unclear why there were limited contributions from some participants. It could be related to a lack of detailed opinion in this area, or it could have been challenging to articulate their feelings due to a lack of pedagogical knowledge and terminology. The experience from this phase was considered when planning the research tool in phase two where further qualitative data is to be collected.

There were two themes identified solely from the student interviews which are discussed here. Example quotes can be found in table 23.

(i) **Focus on understanding**

Students discussed their study methods for chemistry, often mentioning it consisted of watching videos, for clarification and understanding. This could perhaps link to levels of understanding during the term and their reticence to ask questions when confused during lectures. They did show an appreciation of the importance of understanding, practising workshop questions and explaining concepts to peers to check understanding. How students approach their learning will have a critical impact on their academic success and it is pleasing to see that students are recognising this. However, embedding teaching on study habits for all students will be beneficial (Fergus, Heelan, et al., 2021) to those who have yet to develop these skills. With the increasingly complex and number of clinical settings, it is now not possible to teach all knowledge that may be required for post qualification so knowledge alongside core concepts and development of problem solving should be deemed as a sensible and realistic approach (Angelo et al., 2022). This makes the successful development of appropriate study skills even more important.

(ii) Confidence in asking questions

Although not mentioned directly, the lecture class size compared to school seems likely to have an impact on asking questions in a lecture (Sander & Sanders, 2009), with the change in environment compared to school clearly an issue. Although this matter does link to the wider issue of transition to university, which was identified as a common theme for both groups, it was considered a separate theme by the researcher. This was because of its specific nature, the frequency of it being raised by the students and the lack of this topic being mentioned in the staff interviews. Students stated that one of the reasons for liking workshops was linked to being more comfortable with asking questions due to the smaller, possibly less intimidating groups. For example, student S6Y4 said “but in lectures, you can’t really ask questions. You can engage in that way {in workshops}, the lecturers can go into more depth”.

This confidence phenomenon has been found to be widespread in higher education settings with it more commonly affecting students entering from non-traditional backgrounds and can be improved by structured support (Donovan & Erskine-Shaw, 2020).

5.4.3 Discussion of common themes from both groups of interviews

Four themes were identified that were seen in both groups of participants. Example quotes can be found in table 24.

(i) Transition to university

Staff acknowledged the demanding change in environment when transitioning to university education and observed a lack of independent study skills across undergraduates. This lack of development of essential skills needed for university education is a commonly seen issue (Wingate, 2007), which some universities have sought to address by specifically teaching both required practical skills (Smith, 2012) and problem solving skills (Williams, 2017). It is unrealistic to assume that all students will automatically develop these skills so embedding them into the curriculum and chosen teaching methods is important.

Students also highlighted the challenges faced when starting university. Whilst some acknowledged the scaffolding they had received at the start of their university journey, they mentioned they would appreciate continuation of this throughout the programme. Students suggested that they struggled with the change in the learning environment and how teaching is structured and remembered this feeling throughout their undergraduate programme. Research by Leong et al., (2021) looking at students’ preparedness for studying chemistry at university level found a mismatch between what knowledge and skills were expected of them from academics and what students thought they required. There is clearly further work needed to ensure students have a more comprehensive understanding of this new environment to support them reaching their full potential.

(ii) Relevance to future career

With this relevance to future career theme, staff perceived a difference between students on the MPharm programme as a vocational course when compared to other programmes they taught on. Staff observed that pharmacy students appeared to be more focused on future paid work and their current chosen branch of pharmacy after their degree than those on other non-vocational programmes. They realised that focusing on relevance helps improve engagement with staff E stating “if you can relate it to drug examples then, suddenly, they are more interested in that when compared to just learning chemistry for the sake of learning chemistry...they can see the relevance”.

Interestingly, staff acknowledged the importance of relevance, but some did not believe it was possible to ensure this from the beginning of the course due to the volume of teaching material needing to be taught from each discipline. (Although not named by staff, this concept of ‘curriculum overload’ is a common concern with pharmacy programmes globally and was discussed further in section 5.1.3)

The theme of relevance was discussed repeatedly in the student interviews. There were some positive comments with students acknowledging the importance of longer-term goals and their undergraduate education supporting them in their future career. Students often focused on their career goals in their interviews, tending to identify one branch of pharmacy they planned on working in. Although national data shows community pharmacy is the most common sector for employment (Cameron, 2019), careers often span multiple sectors over a lifetime which students did not seem to have insight into. Students often found it challenging to categorically say if all chemistry taught was relevant, but they were able to come up with examples which they thought were directly relevant from specific teaching sessions across the years. These examples were very much linked to times when science and practice teaching had been clearly integrated. For example, students discussed antibiotic resistance and chemical structure, and the structure of statins and their mode of action. This perception was also related to their lived experience so far within the profession. The short placement opportunities on the programme give some students their only direct experience of what the typical job may be like. This clearly has influenced their views; some could instantly think of relevant integrated examples, but others could not.

Students were all asked about topics that they felt were their favourite and their least favourite. Interestingly, there was no consistent theme with this. Students had to be prompted with a reminder of topics. Previous research looking at difficulties with learning chemistry has found the factors influencing this were related to the abstract nature of chemistry and the perceived volume of information to learn (Johnstone, 1991). An appreciation of these factors enables educators to connect more effectively with their learners and adjust their teaching methods, for example using approaches like relevance-driven examples in teaching (Parchmann et al., 2020).

(iii) Contextualisation

All students appeared to appreciate the importance of contextualisation, but the lower years seemed to find it harder to think of examples in the programme so far. Staff perceived the chemistry content to be contextualised earlier in the programme, but students did not seem to realise this. Ensuring taught material is contextualised can be difficult. The term ‘contextualisation’ is not clearly defined and what is deemed relevant is clearly subjective. Educators have considered this challenge over the years, (Gilbert, 2006; Stuckey et al., 2013) recognising that a student must individually identify with and appreciate the example for them to individually consider it ‘relevant’. This is challenging for the educator, as a student wishing to pursue a career in the pharmaceutical industry compared to one with a sole community focus may disagree with this perspective of what is a ‘relevant’ context.

The importance of contextualisation was mentioned frequently and identified as a theme in both groups. However, within the staff group, it seemed more related to generally engaging the students rather than a wider strategic approach to the development of clinical pharmacists with a solid clinical grounding. This potentially could be related to only one dual professional within the group (both a chemist and pharmacist) or that the overarching purpose of this curriculum design had not been fully communicated to all staff. Previous research by Mawdsley & Willis, (2018) has shown that a lack of understanding of the overarching curriculum design by the educators teaching it can undermine the possible benefits it was designed to deliver. Overarching curriculum design was not identified as a theme which was surprising, although it was not directly asked about. An integrative approach to curriculum design will be discussed further in future chapters.

A contextualised approach to teaching can help students to think and apply their knowledge holistically rather than compartmentalise new knowledge under specific silos or topics (Gilbert, 2006). Research has suggested that sometimes students fail to appreciate the relevance of science to their chosen career path, therefore teaching students so they can see the relevance through the application of knowledge is a sensible approach to take (Fergus & Kostrzewski, 2011). Aiming to ensure that graduates of the MPharm programme can problem solve by drawing on their solid foundation in chemistry and the sciences is a prudent aim. Rather than solely increasing a student's knowledge of chemistry, the MPharm programme should aim to produce graduates that are able to problem solve by drawing on their strong foundation in both chemistry and clinical knowledge and understanding (Faruk Khan et al., 2011).

(iv) Application

A recurring discussion point with both the staff and the student interviews was the importance of the application of knowledge rather than the acquisition of it. Together these results provide some interesting insights into attitudes within the staff and student population on the MPharm programme.

The importance of application of knowledge was repeatedly mentioned by staff without prompting, with a consensus that there should be less focus on theoretical teaching and more on small group teaching sessions like tutorials and workshops. Staff D stated that "after introducing them to a topic, you need to get them to apply it quite quickly in terms of a question, if I relate it to something that is more meaningful to them, they engage with it much better".

There was however an acknowledgment that a curriculum re-design to only small group teaching is potentially unrealistic in terms of cost, resources, available teaching spaces and large cohorts. The adaptations to teaching which were essential during the COVID peak pandemic have provided an opportunity to develop novel approaches to programme delivery which can continue to be used. Recent research has found a blended approach is appreciated and often preferred by students in a post-lockdown era (Broad et al., 2023). In the meantime, some staff have adapted to a more application approach style in teaching by changing the structure of their on-campus lectures to make them more interactive. The benefits of a blended approach have been highlighted through this analysis, which is more acceptable and possible in a post COVID era. Experiences from this period and the need to develop new teaching methods during a pandemic can continue to be utilised. This is supported by recent research (Senhaji-Tomza et al., 2023) across three US schools of pharmacy which found that remote learning in some form, specifically the didactic elements of a course are preferred.

Students in all year groups consistently stated that they enjoy workshops and linked this to their active learning approach and helped to achieve meaningful learning. Staff also identified that students engaged more in this type of teaching session. A cross-discipline study by Breen & Lindsay, (2002) which used questionnaires across cohorts in combination with academic performance data found that motivation was seen to be higher in those undergraduates with better academic results in science and health care specific disciplines.

Potentially using teaching that encourages student motivation and engagement may lead to an improvement in academic achievement although it is acknowledged that motivation is one of many factors influencing attainment (OfS, 2022).

There is evidence that the skill of applying knowledge i.e. problem-solving needs to be cultivated over time following the embedding of knowledge to solve these problems as opposed to the perception that it is a simple skill that can be taught in isolation (Sands & Overton, 2010). When asked about improvements or changes to the programme, students consistently stated that they would appreciate more workshops and more practice at application. This highlighted that they feel they have not fully had time to develop these problem skills appropriately. Using a problem based learning approach highlighting examples which have a relevant and meaningful context to the students helps to deepen their understanding as well as develop problem solving skills required in practice (Overton, 2016).

5.4.4 Discussion of the data analysis in relation to the research questions

The interviews and the subsequent analysis allowed the research questions for both data sets to be answered. As a reminder, the research questions related to these specific interviews were:

- What do chemistry academic staff consider and understand regarding student perceptions of chemistry on the MPharm programme?
- What do chemistry academic staff think influences MPharm students learning of chemistry?

The research questions for the student interviews were

- What are MPharm students' perceptions towards chemistry within the MPharm degree?
- Do students experience any difficulty in specific chemistry topics?
- Do MPharm students identify effective ways to learn and understand chemistry?

The presence of shared themes between both groups indicates that staff often understood students' perspectives, which is encouraging. The influencing factors of relevance and contextualisation was clearly acknowledged in both groups. Application of knowledge was identified as an important process to demonstrate effective understanding by the staff whilst students also appreciated its importance, although they did not fully articulate why. There was a lack of discussion of pedagogical underpinning which was not expected within the student group but was surprisingly absent within the staff group. This could be due to many chemistry academics being heavily research focused and teaching on a variety of programmes with differing graduate outcomes to focus on. It was noticeable that academic staff who were more teaching focused would refer to relevant pedagogy, but it is acknowledged that the interviews were not explicitly focused on this pedagogical underpinning.

Different pedagogical approaches to address the challenges highlighted were not discussed in detail. Recognition of the importance of pedagogical content knowledge (Shulman, 1986) to ensure academics can communicate complex chemical concepts using appropriate teaching strategies is noted and could be explored further in future research.

Students were not able to articulate which specific topics were rewarding or challenging. However, organic chemistry was never reported as being a 'least favourite' topic, with some students highlighting its relevance to drug structure and function learning, possibly accounting for the acceptance of its importance.

The students discussed the importance of understanding when exploring how they effectively learn which was encouraging. However, their approaches to study could be probed more to consider if higher order thinking and learning is achieved with integration of taught material (Mawdsley & Willis, 2019). This will be explored further in the second part of this phase in chapter 6.

5.4.5 Limitations

This is a small study at one school of pharmacy so although it is not appropriate to generalise. It does, however, represent the lived experience of pharmacy students studying and academics teaching on this programme.

Because of the nature of research and appropriate adherence to ethics, participants were interviewed on a voluntary basis. It is acknowledged that those who volunteered are likely to have an interest and opinions on the matter, be that positive or negative. The student interviews would be a self-selecting group of students out of a larger cohort who are likely to be interested in and engaged with chemistry or at least have strong feelings towards chemistry on their degree programme. From the discussion and analysis of the phase one data, it would have been beneficial to interview mature students, but none volunteered. In addition, identification of ethnicities could have enhanced the discussion following on from phase one results. However, it is acknowledged that from small sample qualitative data, it would be inappropriate to draw further conclusions from an even smaller subset of the data. For the same reasons, conclusions could not be drawn from any differences in perspectives within individual year groups due to the varying numbers per year group.

This study focused on perceptions so did not look at attainment in relation to student perceptions of an area and their perceived engagement with it. It is not clear whether perceptions have a direct impact on academic success.

The rigour of the selected methods for the whole doctoral study have been discussed and justified in section 3.16 and also in this chapter (section 5.2), but it is acknowledged that the final presentation of findings is the thematic analysis of a sole researcher in order to be truly aligned with the approach of Braun & Clarke, (2006).

5.4.6 Reflective account of researcher

For this chapter, the researcher's reflections were considered during the methods as the researcher's position was considered throughout the question design phase as well as the qualitative analysis phase.

> I acknowledged that this qualitative part of the doctoral study could be more easily influenced by prejudices so was careful to consider these when planning the initial interview schedules as well as the analysis of the collected data. I was also aware of discussing possible prejudices with the student researchers to help prevent bias creeping into their research technique.
> Expectations of the results were reflected on. This was an area I was very interested in, but I was very conscious it was an area that I knew little about when I first started the research. I was expecting students to be more consistent and clearer with which topics they enjoyed and what they found more difficult. I was expecting them to be unsure about the value of practicals but was pleased to see specific practicals (pH absorption and aspirin synthesis) highlighted and appreciated. I had expected staff to discuss the curriculum design more and pedagogy, but on reflection, their interests tended to focus on other specific areas of science research so I should not have been surprised. I was surprised about the lack of confidence in practicals and their hypothesis behind which makes sense but was never considered by the practice team teaching patient safety. I was saddened to see some lecturers felt students did not engage with their teaching and the disheartened feelings this produced. I am used to students generally being interested in the topics I teach (for example oncology) and had not considered this issue in detail before. I used an inductive approach to the analysis without pre-coded themes to fit the data to.

5.4.7 Summary of phase 2 part one

This research adds to the scarcity of qualitative data in this area and gives an insight into how the teaching of chemistry on a pharmacy programme is received. In line with the thesis aim, it considers how this teaching impacts students' understanding and application. Whilst the overall design of the pharmacy curriculum directly influences the subject content, how both educators deliver it as well as how students interpret this, will define how the content is taught, learnt, understood and applied (Pearson & Hubball, 2012). The curriculum is aiming to produce graduates who can problem solve using their underpinning science knowledge and become confident and competent pharmacy practitioners (Faruk Khan et al., 2011). Previous literature has concluded that there needs to be a clear strategic approach with a focus on contextualisation from the beginning of the course and an emphasis on application of skill rather than solely knowledge acquisition (Husband et al., 2014; Pearson & Hubball, 2012). Some of the sentiments of the academic staff on the integrated curriculum and contextualisation were similar to issues highlighted by Mawdsley & Willis, (2018). In support of this previous literature, it highlights that a clear strategy should be communicated with staff on the programme's integrative approach rather than assuming it is understood and adhered to.

A lack of confidence in practicals not identified before in literature but was a clear theme from the staff interviews in this research. A general lack of confidence was identified from the student interviews when seeking guidance or clarification. This has been seen in other higher education settings so this corroborates their findings (Donovan & Erskine-Shaw, 2020). Improvements to the support given should be considered in the context of science within the Master of Pharmacy setting following these findings. Practicals can be a beneficial way of learning and understanding (Galloway et al., 2016) so refining these to scaffold and encourage more learning needs to be explored. Practicals should allow time to consider and create links between science and practice in addition to completing the specific experiment. Consideration should be given to the academic staff supporting teaching sessions who need to demonstrate an integrated understanding of both chemistry and practice that the students are expected to develop (Mawdsley & Willis, 2018). Development of pedagogical content knowledge within academics can support explanations of complex topics and improve student learning (Shulman, 1986).

5.4.8 Data triangulation with findings from phase one

This chapter's findings contributed to answering several of the overarching thesis research questions. Alongside the analysis of phase one, it also considered: 'What influences students' understanding and application of knowledge of chemistry within the MPharm degree?'. The findings from both phases were combined and compared to make inferences in relation to this research question (Tashakkori et al., 2021).

When reviewed alongside phase one, this phase two data analysis established some interesting findings with the qualitative data, potentially explaining some of the results seen from the phase one quantitative findings.

Students discussed the need to understand chemistry teaching and the theme of focusing on understanding was identified in the student participant group. They discussed that, for example, practising worksheets was helpful. Students were seen to engage well with the PeerWise tool to a significant extent above the suggested requirements. It may have been because it was very well suited to their preferred mode of study for chemistry.
Students also tended to prefer workshops when compared to other types of teaching sessions. Introducing PeerWise in an interactive workshop may have also encouraged them to engage with the tool as students had also explained they were more likely to ask questions and ask for clarification in a workshop setting.

Students and staff highlighted the transition to university was challenging and this was identified as a theme in both groups. There are different processes and procedures when taking summative assessments in higher education settings when compared to school or college. This could potentially have impacted on students summative midterm test score as this will have been students first summative assessment at university. However, this hypothesis would need further research to be conclusively established.

5.4.9 Informing the next phase of the study

This phase established the importance of relevance and contextualisation to maintain the interest and engagement of students. The emphasis students placed on their future careers was interesting. These aspirations seem to shape their attitude to learning, with application of knowledge being a key factor that was also identified as a theme. These views are clearly evident when teaching as academics easily recognised them as consistently important for students.

It is clear that the thinking integratively is a pivotal element to this thesis as opposed to focusing solely on the design of the programme. Although the concepts of using integration and contextualisation within pharmacy programmes are well documented (e.g. Husband et al., 2014; Pearson & Hubball, 2012), further research into how students study within an integrated curriculum is needed. Questions on this area will form the pivotal part of the next section, part 2 of phase 2 of this overarching thesis.

The experience of how well student participants were able to contribute to individual interviews was reflected on when considering the suitable research tool for the next phase. It was noted that some students were quite quiet in these interviews, even though they had volunteered to take part in the interviews so were engaged with the process. As some students sometimes struggled to articulate their thoughts and perceptions in one to one interviews within this phase, consideration will be given to using focus groups at the next phase to allow more meaningful interactive conversations about their shared experiences (Cresswell & Poth, 2018).

Chapter 6 Students' understanding and expectations of learning and integration on the MPharm degree programme

6.1 Introduction

This chapter presents the data for phase two (part two) of this study and its subsequent analysis.

There are several published innovative integrated teaching examples discussed in section 2.4.3 which often evaluated students' perceptions of these teaching methods but do not critically examine the underlying aims of integrated curriculum design or its success in meeting those aims. A study by Islam & Schweiger, (2015) implemented a more comprehensive approach by using a series of integrated modules over years 2 and 3 of their 4-year PharmD programme. A total of 169 students responded to the questionnaire and provided an overwhelmingly positive response to this approach. It also found that students in the higher years had a greater appreciation of this integrated approach when compared to the lower years. It was viewed as an effective way to learn but there was no data collected or analysed on any changes to understanding and application skills with this new approach.

How students experienced an integrated curriculum was explored at a School of Pharmacy in the UK (Mawdsley & Willis, 2019). Analysis from the focus groups of fifty-one MPharm students across all years identified a variety of themes. Students were able to identify pedagogic strategies of integration within their degree programme, but the integration needed to be clear to students for them to recognise it. They continued to find integrated assessments challenging and the authors highlight the need for further work on assessment formats and the need for explicit, relevant connections within integrated teaching.

What remains underexplored in the current published literature is students' perception and understanding of the skills they are (or should be) developing within an integrated curriculum approach (Husband et al., 2014). Higher order thinking skills are needed when problem solving, appraising the evidence base and clinical decision making (Persky et al., 2019). These skills are needed to be a competent pharmacist in today's healthcare system (NHS England, 2023).

In this chapter, students' expectations on the delivery and structure of the programme are explored alongside perceptions on their ability to integrate material. This more focused research on understanding and perceptions of the integrative nature of the curriculum will help inform the development of effective ways of learning, teaching and assessments to help ensure these skills are developed.

6.1.1 The research questions

Following consideration of the current knowledge base and the identified gap in published literature, the research questions were finalised as:

- Do MPharm students understand how to think and study 'integratively' within the context of the MPharm course at UH?
- What are undergraduate MPharm students' perceptions towards integration within the MPharm degree?
- Would using a case-based approach to teaching encourage MPharm students to think 'integratively' within their degree?

6.1.2 Integration as an approach to pharmacy curriculum design

The increased clinical nature of the pharmacist role in the UK (NHS, 2000; NHS England, 2019) required the initial education training standards to evolve and adapt to ensure that graduates are fit for this role (GPhC, 2011, 2021). These standards continued to highlight that a solid science foundation is still considered pivotal to achieve these newer, more clinical learning outcomes. In addition to new learning outcomes and standards, the curriculum approaches that could be used to deliver this new curriculum were also revised. The GPhC (GPhC, 2011) advised the use of Harden's ladder of integration (Harden, 2000) when designing a new programme to meet the new learning outcomes. This strategy, alongside using a spiral curriculum approach (Harden, 1999), where teaching and assessments increase in complexity in each year group, were adopted by Schools of pharmacy in the UK. These curriculum design approaches are also discussed in section 1.6 in the introduction chapter, with integration discussed and defined in chapter 2 (section 2.1.4). Discussion on the development and implementation of this approach in pharmacy programmes will be discussed here, focusing on countries where pharmacists have a similar clinical role to the UK.

The role of the pharmacist in the US and Canada has also developed with a more clinical focus, with corresponding updates and changes to their educational standards (ACPE, 2016, 2025; CCAPP, 2020). Their published literature provides useful insights into this curriculum approach. For example, Pearson & Hubball, (2012) discussed the concept of integration within pharmacy curricula as they began to evolve in response to educational reforms in Canada (CCAPP, 2020). They acknowledged that change was essential to meet the new demands of the clinical roles and described ways of evaluating them. They also called for further research and evaluation to ensure curricula design were fit for purpose. The strategy of using an integrated approach is also well established in the US Schools of Pharmacy.

Following the implementation of updated ACPE standards (ACPE, 2016) which required further integration within pharmacy programmes, Islam et al., (2016) investigated whether US pharmacy programmes would define their programmes as integrated. In total 70% of the 112 programmes who responded stated they were integrated but the level of this did vary from school to school; without a pre-set definition, it does not provide a detailed account of delivery.

Kerr et al., (2020) highlighted that there was no consistent description of integration, so its meaning is interpreted in multiple ways by different institutions. Although an integrated approach is widely respected as desirable and a requirement of many pharmacy regulators, consistent positive outcomes are yet to be proven with specific models used and levels of integration often not defined in published studies.

As integration does not have a universally recognised definition, this was discussed and defined in chapter 2 (section 2.1.4). The strategic definition written by Kerr et al., (2020) was deemed appropriate in the context of this thesis i.e. as a "multi-faceted term describing a curriculum design which may be defined by model (horizontal, vertical, spiral), theme (systems-based, stages of life, topic, cross-cutting theme) and integrative teaching and learning approach (problem-based, case-based, experiential, enquiry-based, team-based learning, inter-professional education) and level of integration" (Kerr et al., 2020 page 13).

An example of an integrated approach at a UK university has been widely cited and duplicated (Husband et al., 2014) which used a body-systems approach. The authors highlight the need for an integrated curricula to appropriately prepare pharmacy students. They emphasise it allows them to develop the skills needed to deal with complex clinical problems which need underpinning science as well as clinical knowledge, however they acknowledge it is currently hard to evidence whether this approach categorically improves the pharmacist's health care provision.

A thorough systematic review investigating integrated curricula (Nazar et al., 2019) considered the evidence of their impact on performance. Although there was evidence of a positive effect in terms of student experience as well as knowledge and skills development, clear data in terms of overall improved achievement with this type of curriculum is currently lacking. There is also little data regarding students' understanding of this design and its desired impact on their learning, understanding and application.

6.1.3 Consideration of the challenges to an integrated approach

Although there is literature on a range of integration models used in pharmacy and healthcare programmes (Nazar et al., 2019; Ryan et al., 2020; Zakeri et al., 2024), there is less discussion about specific chemistry content of the programmes (Faruk Khan et al., 2011). Core chemistry concepts have yet to be defined but are being researched (Angelo et al., 2022) with pharmacology-based core concepts recently published (Guilding et al., 2024).

DiVall et al., (2020), discussed the challenges faced when trying to implement this strategy of integrated curriculum in Schools of Pharmacy across the US. They argue there is not one single best model and finding a balance without marginalising the foundation sciences is important. However, whilst advocating against the loss of fundamental science from pharmacy curricula, they also warn against addressing this by simply doubling content. Recognising and acknowledging some content may need to be removed if it is now less relevant to clinical practice is an important factor for those who design curricula to reflect on.

With the expanding role of the pharmacist and increase in content brings the added challenge of curricular overload. Romanelli, (2020) discussed this issue, where educators tend to add new content in response to new scientific discoveries or new required competencies but do not remove material which may be outdated and less relevant. The potential consequences students adopting to a surface approach to learning to cope with the increased volume of work (Kelley et al., 2023). The challenges of integrated curricula and cognitive overload have been discussed in chapter 5 (section 5.1.3).

Despite the recognition of overloaded curricula within several healthcare programmes, there is often resistance to reducing the contents, including concerns about dumbing down complexity and reducing academic standards (Slavin & D'Eon, 2021). Following the growing concern regarding overloaded curricula within the pharmacy education community, a task group was set in the US (Kelley et al., 2023). They discussed possible solutions which included streamlining teaching with further integration and removing silos. They also suggested using pedagogical approaches rather than increasing content. A review and reduction of content and assessments in these overloaded curricula is essential to ensure that students learn with understanding rather than surface rote learning.

6.1.4 Thinking integratively

The paradigm shift from dispenser to medicines expert for pharmacists means they need to think more integratively to perform their new role competently. The role of the pharmacist is now more patient centred, so they are required to think holistically rather than in a discipline focused way.

Teaching using a case based and problem based approach is one way of preparing students for clinical practice providing authentic problems for them to solve (Schmidt et al., 2011). This approach recognises the importance of skills development and thinking strategies rather than solely basic knowledge recall (Hmelo-Silver, 2004) . Analysing a case study and evaluating how to deal with issues allows students to demonstrate and develop their higher order thinking skills (Forehand, 2010). This application of knowledge is recognised as higher level cognitive skill with Bloom's hierarchy (Krathwohl, 2002). It is noted that cases need particular attention to ensure the clinical questions have foundational science underpinning which require integrative thinking (Ratka, 2012). This helps ensure higher skills like analysis are needed (Krathwohl, 2002). A framework such as the one developed by Fergus et al., (2019) can be used to help ensure an integrated approach is used when using this teaching strategy. These metacognitive skills are meant to be one of the beneficial outcomes of an integrated curriculum (Husband et al., 2014). However currently there is not conclusive evidence this type of curriculum strategy achieves this (Nazar et al., 2019). Whilst there is a lot of published research on integrated curricula as well as examples of contextualised teaching, a research gap remains regarding the extent to which students understand the metacognitive skills they are intended to develop through this approach, and whether current curricula successfully cultivate these skills.

6.2 Methods

Focusing on the same Master of Pharmacy programme at the University of Hertfordshire as the earlier part of phase two, this study used a qualitative method of data collection to gain further insight into students' perceptions of their learning and understanding towards integration within their programme of study.

6.2.1 Selecting the research tool

Both focus groups and individual interviews were considered as a potential data collection method. In addition to learning from the experience of using interviews for part one in this phase, the advantages and limitations were closely considered between these two methods. This was discussed in Chapter 3 (section 3.11).

Having considered strengths and weaknesses of interviews and focus groups, it was concluded that focus groups would be most appropriate for this phase of the research. It was acknowledged that students may not be experienced in this topic area so the collaborative nature of a focus group where peers discuss the topics together would allow for more in-depth conversations and rich data to be collected (Morgan, 1996, 1997).

The size of each focus group was considered during the planning stages of this research. However, there is not a consensus on the number of participants or number of groups to conduct, due to the wide range of documented study purposes (Hennink et al., 2019). Morgan, (1996) also acknowledges the optimum number is dependent on the topic area and participant base. Tang & Davis, (1995) highlight that the aims of the research as well as question schedule should be considered when determining the size of the group.

Denscombe, (2017), references having between 6 and 10 participants but Morgan, (2016) defines focus groups as having from four participants upwards.

The composition of each focus group was also considered. There was concern that mixed - year focus groups may affect the dynamic of the conversation and therefore open discussion in the group in a negative manner (Cohen et al., 2018). There would potentially be a risk that students in the lower year groups felt less knowledgeable or intimidated by the later years (intentionally or otherwise). This could result in them remaining silent which would reduce the individual data contribution (Denscombe, 2017). It was important that all participating year groups realised their comments and perspectives were valid and welcomed, allowing rich data to be collected. Focus groups were therefore conducted in year groups rather than mixed.

6.2.2 Students as co-researchers

As with part one of this phase, the interviewer effect (Denscombe, 2017) was reviewed and reflected upon. As the researcher of this overarching thesis is both a PhD student and an academic teaching on the MPharm, there is clearly a power disparity in the relationship between an academic teaching on a programme and a student on the same course (Cohen et al., 2018). This type of relationship was considered when planning the running of the focus groups. Canning, (2017) highlights the possible flaws in gathering the student voice through a tutor-centred approach where they are facilitating the dialogue and conversations. Seale, (2010) argues that the student voice remains underdeveloped in Higher Education, due in part to the research methods that have been used historically.

Engaging with the principles of participatory research (Fielding, 2004), a group of fourth year MPharm students were involved in the design of this project and the conducting of the focus groups to gather data. A group of three students in the final year of the programme who were interested in pharmacy education volunteered to take part in this project as part of their own compulsory credit bearing research project module. To prepare and support them in this role, they attended theory lectures and workshops on relevant research methods, study design and interviewing techniques. Additionally, they participated in weekly tutorials with the academic to discuss this specific study. They were involved in designing the structure of the focus groups and conducting the focus groups.

To align with the theme of integration, these students were also involved in developing and designing some teaching material in the form of integrated case studies which will be discussed in more detail in the next chapter.

The research group discussed the organisation and design of the focus groups. An unstructured approach could have been taken, allowing students to converse freely around topic questions, the curriculum, teaching, learning and assessment preparation (Boulton & Hammersley, 2006). However, the possible risks associated with this in terms of not answering the research questions meant this approach was disregarded. A semi-structured approach was deemed most appropriate for this study (Jamshed, 2014).

6.2.3 Question development and justification

The student researchers provided input with the PhD researcher to develop the question schedule for the focus groups. The structure of this schedule was informed by the literature (Gillham, 2005) and the questions were written to align with the research questions. The rationale for each question was also justified with relevant published literature with the final schedule shown in table 24. The focus groups started with closed questions on individual factors followed by more open-ended discussion questions.

When planning questions relating to curriculum design, it was important to acknowledge terminology which may or may not be understood by the students. Although the terms 'integration' and 'contextualisation' are used frequently by educators, it should not be assumed that a student without a specific interest in education would fully understand them. The definition to operationally describe integration for the context of this thesis was "when connections are made across different modules or subject areas of the pharmacy course" (Mawdsley & Willis, 2019 page 452). The student co-researchers had input into deciding what phrase to use when discussing integration in the focus groups and agreed 'creating links' was a good phrase to use as a starting point for an explanation within the focus groups.

The questions were written then discussed and reviewed by a second researcher (the supervisor) who provided suggestions for amendments. The questions were piloted to ensure they were clear and there was no ambiguity. As the student co-researchers had no previous experience of conducting focus groups, simulated practices were conducted to build skills and confidence prior to running the actual research focus groups.

Table 25- Final question schedule for student focus groups

Introduction • Brief introduction of myself, thank them for participating in the research. • Remind and explain the purpose of this project (all participants have already consented and been sent a participation information leaflet). • Explain that as much detail as possible would be appreciated • Some short questions – age range, gender, year of study and prior study • Remind them they will remain anonymous and be allocated a letter rather than using their name when analysing the data
1. Could you tell me a little about the work experience within the pharmacy setting you have so far?
2. As pharmacy students, we are taught a range of subjects and topics. What are your expectations in teaching? Prompt for further discussion: taught in subjects like chemistry, pharmacology and clinical practice or taught in disease states with topics all mixed together?
3. Have your thoughts on this changed through the years on the MPharm course?
4. Do you feel certain topics are more relevant than others?
5. Do you feel you need to know and understand certain topics in practice?
6. Do you feel able to create links between science and practice when you are being taught?
7. Do you think it is important to create links? (Prompt: Creating links between modules and integration can be explained further if needed for clarification)
8. Do you feel your attitude to this has changed throughout the MPharm course? (For first years, the question was adapted slightly– do you feel your attitude has changed since starting the programme)
9. When studying for an exam, how do you approach revising?
10. Do you revise or approach learning differently each year/ module? {Prompt} Can you explain why you have different approaches?' (for first year, the question was adapted slightly – do you revise of approach learning differently since starting university

6.2.4 Consideration of the eligible participants

This study focussed on the student population within the University of Hertfordshire, a School of Pharmacy in the UK. All students registered from years 1 to 3 on the Master of Pharmacy programme at the University of Hertfordshire were considered eligible to participate.

The final year group (fourth year) of the MPharm programme were not included in the study population. The MPharm programme design is synoptic, and academics have found it common for the fourth-year students to have a realisation within this final year of study, recognising importance of the multiple elements of the programme and their integration.

This observation was agreed with and confirmed by the student co-researchers in this study. Also, with a group of fourth-year students acting as co- researchers and leading the focus groups, there was a discussion to consider conducting a focus group with their friends and colleagues from their own year group when compared to peers in different year groups. It is clearly a limitation to the participatory research method chosen, but it was felt the benefit of having students as co-researchers for this project outweighed this specific limitation. It was considered if the academic supervisor could have led a focus group with final year students but following reflection and discussion with PhD supervisors, it was agreed that this would deviate from the agreed methodology of this particular study. It would make the dataset for the fourth year arguably incomparable with the other year groups dataset so would be significantly less meaningful.

6.2.5 Ethics approval

Ethical approval was sought for the study; this was granted by the University of Hertfordshire ethics board with protocol number LMS/SF/UH/03939.

6.2.6 Participant recruitment and data collection

An invitation to take part in the focus groups was emailed to MPharm students via the university's virtual learning environment. All currently registered students from first to third year of the MPharm degree were invited. A reminder email was sent two weeks after the initial email.

Focus groups were then arranged per year group with one student co-researcher attending and leading. These focus groups were held face to face on the university campus in a private quiet room.

6.2.7 Data analysis

Davies, (2007) argues that analysis starts from the beginning of the focus group, with the researcher observing the dynamics and interactions within the group. With this in mind, the student and PhD researcher discussed each focus group afterwards to consider any observations and found that listening to the recordings multiple times also helped understand the dynamics within the group.

The qualitative data were analysed using thematic analysis (Braun & Clarke, 2006). The approach closely adhered to the six phases (see table 19). An iterative approach was taken for analysing qualitative data with familiarisation of the data first through listening and reviewing the transcripts. Codes were identified, then themes with multiple refinements taking place.

Rather than using computer software to support identification of codes and themes, a manual approach was again taken to analyse the data, using the same approach described in chapter 5 (see section 5.2.5). This approach has been utilised by other researchers (Basit, 2003; Mattimoe et al., 2021) and it was deemed appropriate because of the size of the dataset and the researcher's preference. It was found that a manual approach encouraged full engagement with the dataset with repeated reading and reviewing needed. It encouraged the researcher to be reflexive and aligned well with the iterative process required by the Braun and Clarke methodology (Braun & Clarke, 2006).

Although the co-researchers were involved in coding and identifying themes as part of their undergraduate project, the final presentation of the findings of this phase are intentionally the work of one researcher. This is in line with reflexive approach described by Braun & Clarke, (2006). The final themes presented were solely determined by the PhD researcher.

6.2.8 Assurance of research rigour for this chapter

The trustworthiness of this data analysis was assured by following a well-established method of data analysis (Braun & Clarke, 2006). This specific approach requires the researcher to be reflexive with iterative review, coding and refining of the analysis of the dataset. The manageable size of the dataset and use of manual coding added to the research rigour of this analysis. It encouraged a close engagement with the dataset and facilitated a deep immersion into the focus group transcripts. This deep engagement supported the interpretation needed during analysis.

The analysis of this data can be deemed credible due to multiple factors. A well-established method for qualitative data analysis (Braun & Clark, 2006) has been applied and adhered to. This analytic process has been done in a transparent way which assures the reader of the trustworthiness of the analysis (Lincoln & Guba, 1985).

It is important to acknowledge the social construction of reality, there are multiple realities as people see things differently due to their unique experiences and perceptions (Bodner, 1986; Denscombe, 2017). The absence of a single shared reality does impact on how transferable research finding can be. Lincoln & Guba, (1985) explain that results are transferable if the context and situation are the same and the reader takes the responsibility of this decision from their knowledge of their own relevant contexts.

6.3 Results

A total of fifteen Master of Pharmacy students volunteered and participated in this study. Five students were in the first-year cohort, six were in second year and four were in third year. Table 26 below shows further details on these participants.

For context regarding prior qualifications, a student may take a one-year initial science foundation programme (UH, 2025) and if this is successfully passed, they may gain entry to the programme via that route. This is often taken if the entry criteria were not met with A levels at a high enough UCAS tariff.

Table 26- Summary of background information for the focus group participants

Year and code	GENDER	AGE	PRIOR QUALIFICATIONS
Year 1: 1A	Male	18-21	A levels including Biology, Chemistry
Year 1: 1B	Male	18-21	Access to higher education diploma
Year 1: 1C	Female	18-21	Initial year science foundation programme
Year 1: 1D	Male	18-21	A levels - Biology, Chemistry, Mathematics
Year 1: 1E	Female	18-21	Initial year science foundation programme
Year 2: 2A	Female	18-21	Initial year science foundation programme
Year 2: 2B	Female	22-30	Initial year science foundation programme (and A level chemistry)
Year 2: 2C	Female	18-21	1st year pharmaceutical science (level 4)
Year 2: 2D	Female	18-21	A levels : Biology, Chemistry, history
Year 2: 2E	Female	18-21	A levels including: Biology, Chemistry
Year 2: 2F	Female	18-21	Initial year science foundation programme
Year 3: 3A	Female	22-30	A levels : Biology, Chemistry, mathematics
Year 3: 3B	Female	18-21	Initial year science foundation programme
Year 3: 3C	Female	22-30	A levels :Biology, Chemistry, mathematics
Year 3: 3D	Male	22-30	A levels in Biology, Chemistry, mathematics

All students were asked what relevant work experience they had in relation to pharmacy and this information is summarised in table 27.

Table 27 -Summary of work experience information for the focus group participants

YEAR/ STUDENT CODE	WORK EXPERIENCE
Year 1: 1A	Community Pharmacy- 8 months.
Year 1: 1B	A few weeks of work experience- 4 weeks community pharmacy.
Year 1: 1C	Community Pharmacy- 7 months.
Year 1: 1D	Community Pharmacy – weekend work
Year 1: 1E	Not answered
Year 2: 2A	Community pharmacy -Weekend work.
Year 2: 2B	Hospital pharmacy-5 years full time.
Year 2: 2C	pharmacy & hospital work experience.
Year 2: 2D	Community pharmacy summer placement, industry placement
Year 2: 2E	2-month placement in community pharmacy
Year 2: 2F	Veterinary pharmacy overseas.
Year 3: 3A	Community pharmacy- part time role.
Year 3: 3B	None (only short university placements).
Year 3: 3C	Community pharmacy & hospital pharmacy Summer placements.
Year 3: 3D	Regular community pharmacy- weekend work

6.3.1 Themes

Four themes were identified following analysis of the focus groups transcripts.

These were: (i) strategic learning approaches, (ii) the importance of relevance to practice, (iii) benefits of work experience and (iv) creation of links within teaching and learning.

6.3.2 Illustrative quotes per theme

(i) Learning approaches

When discussing learning approaches, students across the year groups demonstrated a range of study strategies with some directly highlighting the importance of understanding.

> 1E: “I use the Cornell method, its effective for me”

1B "I make sure I understand [the material] …and try to figure out what they will ask us"

1C "I like writing notes and then reading textbooks…I try to answer questions…also working together with other people to try to understand it"

2E "I prefer doing extra reading, particularly with challenging topics, it helps me understand the subject deeper"

3B "I try my best [to revise] …so I understand what is going on [from lecture material]

However, some participants across the year groups linked their revision techniques and study approaches to the type of assessment that was used within a module.

2A "Sometimes, I don't like deep learning as it confuses me…surface learning for MCQs [is fine]"

2C "I differ my learning approach depending on the topic, if it is heavily weighted in lectures, I will spend more time applying a deeper learning approach..."

3B "so I'm not really a fan of integration cos the questions that come out on the exam really just make my head boil….it makes it hard for me to study"

Several students highlighted the importance of understanding taught material and showed an appreciation of how contextualised teaching supported this. Those taking a deeper approach appeared to appreciate the importance of integration.

1B: "It [integration] helps us to understand the knowledge…if we are told this is how we can link it back to practice and how you'll need it, it makes sense"

1C "I think case studies are really important for application. I think without the case studies I would struggle to put it...into practice"

More traditional additional reading seems to have been replaced with use of videos for revision which some students use to support learning and understanding.

1B "videos like YouTube…in A level, I used this as a revising tool which was quite good"

2B "I use the lecture notes as a baseline, I then use YouTube, video resources and books, which help enhance my understanding"

3D "I prefer videos to be honest; they would be better for me"

(ii) The importance of relevance to practice

Students often referred to their future careers, and the merit of a topic was frequently linked to how relevant they felt it was to their current chosen pharmacy sector.

> 1B “the minor ailments stuff [is important], we can use all that, if I am working in a pharmacy, I can figure out…the disease”

> 2A “I don’t feel like Pharmaceutical Chemical Analysis (PCA) is very relevant to pharmacy…”

Although this link to relevance was very individual depending on their own specific career plans.

> 2B “From working in a [hospital] QC, PCA is very relevant….”

> 3C “a lot of people kind of have an idea of what area they want to go into in the future….so for example, DMD. [drug development module] someone might be like fully set on community and wouldn’t want to do industry at all so that DMD is irrelevant for them”

(iii) Benefits of work experience

This theme was identified across the groups with students having a clear appreciation of how beneficial experiential learning is and discussing the desire for further placements to be embedded on the programme. (It should be noted that these focus groups were held prior to the implementation of the 2021 educational standards (GPhC, 2021) with extended placements).

> 1E “we need to take initiative to work in a pharmacy…. I was a little bit surprised that we only have one or two days this year because they could put in like so much more.”

> 2D “I do think it would be helpful to spend a longer time on placement in order to gain a stronger understanding between how pharmacists use science in their practice. How they operate and to be more hands on, rather than just shadowing a pharmacist”.

> 2F “we’re not applying our knowledge to practice as we’re there for such a short amount of time. So longer time on placement would be beneficial”

Students had a wide range of work experiences and reflected on it as a benefit at multiple points during the focus groups.

2B “Working in a hospital pharmacy already, [helps me] put the theoretical knowledge into practice a lot easier…”

2D “[Work] experience definitely exposes you to different ways of thinking and helps you to retain information better”

3A “I think for sure [work experience] helps cause I am more familiar with…drug names…. working helps me at uni and uni helps me with work. Before I was working, I didn’t really see how these things would apply [in practice].”

Time actively spent in a workplace setting helped students to consolidate their learning and embed their understanding.

(iv) Creation of links within teaching and learning

The expectation around integrated learning and teaching varied within focus groups with some students expecting staff to specifically highlight links whereas others took responsibility for this and the higher order thinking it requires.

1D – “I think that they should make it clear the connections between the topics and if its relevant to make connections”.

1C – “I’d rather it be in topics because otherwise you’d have to make the link yourself between modules and some people might not be able to do that and lose out”

2A “Creating links is so important and is something I didn’t realise the importance of in first year of the degree as there wasn’t much of it…. I find it difficult to make links between chemistry and practice”

3B “…it becomes your job to try to link everything yourself like oh that makes sense with this and that could be used in this and then in real life, this is how you would go about approaching it…”

3C- “I think it was really in second year you were able to make the link to 1st year [learning]

Students across the focus groups repeatedly showed a deep awareness of the importance of integration, often giving direct examples.

1C- we learnt about gout. Um, it was about how the salt forms …and it produces crystals and …how to treat the gout.

1A “we’re learning about isotopes and how effective that is in a drug formulation and how it can affect the body.

2C “[Integration is] very important. Otherwise, how would you understand what is happening to the patient in practice if you are not knowledgeable about the science behind the drugs you are giving out. You could potentially give the wrong drug, dose, interactions – which could potentially be fatal.”

> 3D [integration] is important cause as you said earlier, in real life when you've got out, you're not looking at different aspects of your course…its holistic… so it is important to put it together eventually.

> 3D "we have done a lot about diabetes in this semester, so you can see the clinical relevance to what we have been doing and the pharmacology of it, the pharmacodynamics and everything basically for the patient especially counselling the patient".

How teaching should be structured to embed integration was not fully agreed upon but the value of using case studies as a way of linking topics was unanimously agreed with.

> 1C "I think case studies are really important for application. I think without the case studies I would struggle to put it...into practice"

> 2 A "I think it would really be beneficial to learn in this way – particularly in disease states. It would help acknowledge the link between science and practice. Particularly with regards to how drugs are absorbed in the body".

> 2B "I think the case-study really breaks it down in a logical way, the questions integrate science and practice, explaining your rationale helps you enhance your understanding".

There were no themes identified that were specific to gender or age but it is acknowledged that the majority of participants were female and in the 18 to 21 years bracket, defined as 'young' in line with HESA definitions for university students. (HESA, 2019) .

6.3.3 Reflections on the differences between focus groups

Due to the variety of sizes of the focus groups and the comparatively small numbers, it was felt the individual focus groups were not large enough and did not generate enough data to compare results between the year groups. Themes were identified across the year groups rather than in individual years, but the direction of the discussions was noted to be slightly different in the different year groups. For example, as year group 2 had students with a lot of varied work experience, students' discussions did focus on this.

First year students were adjusting to the university setting and seemed to be struggling with adapting habitual study approaches to this new environment, so appeared less confident explaining how they would study at university. This year group were however confident in giving examples of integration from their recent teaching experiences. In contrast, the later year groups reflected that their ability to create links between science and practice came later in their educational experience. The later years appeared more definite in their specific chosen career path as they may have had more opportunity to experience different sectors of pharmacy by that point. This seemed to affect their perception of relevance in the curriculum but there was no clear consensus within this theme, possibly due to the range of sectors chosen for future careers.

6.4 Explanation of results

This study sought to explore students' expectations on the delivery and structure of the MPharm programme as well as delve into their perceptions and experience on integrating their learning. This deeper insight into their understanding of the integrative nature of the curriculum will help inform the development of effective teaching strategies.

The identified themes are first discussed in section 6.4.1 then the research questions will be addressed in section 6.4.2.

6.4.1 Discussion of themes

This research sought to establish a better understanding of students' perceptions towards integration and their lived experience of teaching on their degree programme. This section will discuss the identified themes in turn and then conclude with addressing the study's specific research questions.

Although there were no themes identified solely within one year group, there were nuances that merit acknowledgement and are discussed in section 6.4.3.

The relevant features identified within the four themes will be discussed in turn.

(i) Learning approaches

Quotes relating to this theme can be found in section 6.3.2

Students discussed their approaches to learning and some highlighted that these approaches had changed following the move to university. Considering the wider research, a systematic review of students' expectations of teaching and learning at university (Tomlinson et al., 2023) found that although some students had a realistic understanding, many perceptions did not fully align with accurate teaching practices at university. Lowe & Cook, (2003) highlight that self-directed study is expected at university level whereas secondary school education remains more guided by teachers with a strong focus on the final qualification and therefore the examinations. Their survey of first year undergraduate students at the University of Ulster found that some were unprepared for the more independent study expected at university and took time to adapt.

Although many students discussed the importance of understanding when revising, some clearly adapted a strategic approach depending on the type of assessment, admitting they assumed a multiple-choice question test would require less time to prepare (when compared to a test requiring application of knowledge). It did suggest they were assuming MCQs only needed basic recall to pass as opposed to deeper understanding. A longitudinal study of university students studying science found they adopted similar strategies in response to assessment expectations (Zeegers, 2001). How students learn is not an embedded personality trait, it is influenced by teaching and assessment (Entwistle, 2023). Designing assessments which requires demonstration of understanding rather than rote learning encourages a deeper learning approach (Entwistle, 2000).

A lack of time has also been identified as a significant factor when a student adapts to a surface and possibly less time-consuming learning approach (Biggs, 1987). With the increase of university fees and costs, there are an increasing number of students who take on paid work in addition to their full-time studies (HEPI, 2023). This has led to concerns that more students may automatically choose a surface learning approach due to time pressure. However, time commitments outside of university studies were not specifically explored in the focus groups so it is not possible to say if this was a contributing factor to their learning approaches in this study.

It was noted that students may not be aware of the important differences between deep and surface learning or other pedagogical concepts. Although students alluded to concepts like curriculum overload and a spiral curriculum, they did not know the specific words or terminology and on occasion seemed frustrated when trying to explain the issue. Explanation behind curriculum design and basic pedagogy each year in induction may be beneficial for students' overarching understanding of the programme. D'Souza & Broeseker, (2022) reviewed first year pharmacy students at their US university using an inventory questionnaire and found there were some inconsistent study habits. Research completed at a UK university investigated study habits across the first three years of the MPharm programme (Fergus, 2022). The author found that some students still focused on less effective study strategies, like passively re-reading notes as they have not learned about evidence-based strategies like active revision such as retrieval practice. It advised specifically teaching students about study strategies to promote deeper understanding.

When discussing additional reading, students often talked about not having enough time for this. Despite academics recommending reading as a common self-directed study activity, there is increasing evidence that students do not engage with this activity. Das et al., (2026) surveyed second and third year pharmacy students at their US university and found that a large majority did not rely on reading for extra studying. However, it is also noted that passive reading without self-testing is not considered an effective study strategy (Fergus, 2022).

Students often stated that they watched videos instead of reading. Didactic videos can be an ineffective learning tool with students likely to disengage and lose focus (Szpunar et al., 2013) as well as being an ineffective strategy to learn and understand (Fergus, 2022).

However, videos with opportunities to actively learn and problem solve have been shown to lead to learning gains and better metacognitive engagement than completion of background reading (Pulukuri & Abrams, 2021). Using this type of video resource should be considered instead of additional reading if students are more likely to engage with it and can promote metacognitive learning.

(ii) Relevance to practice

In a similar way to students in the earlier part of phase two, these students regularly discussed the perceived relevance of topics in the curriculum. Opinions differed as to what was relevant. It seemed it may be due to their lived experience, so not just their experience in learning on the MPharm programme but also their work experience as well as their own career aspirations.

A previous study on students' perspectives of chemistry within a UK pharmacy programme found they were enhanced when teaching materials and formative support were improved (Smith et al., 2017). In both this study and Prescott et al., (2014), students did sometimes appreciate why chemistry was relevant in terms of drugs and their mode of action, perhaps highlighting the need to focus on meaningful contextualisation when teaching chemistry to pharmacy students to emphasise relevance. Although chemistry is essential for pharmacy as a scientific foundation, students do seem to struggle to appreciate its relevance. Ensuring the teaching is appropriately contextualised to clinical problems helps students see why it is relevant (Fergus & Kostrzewski, 2011). Faruk Khan et al., (2011) also highlights the pivotal role medicinal chemistry has, providing the foundational knowledge for concepts such as drug to target interactions and structure activity relationships. Again, these authors remind us that teaching in a way that clearly connects chemical principles to pharmacy practice helps ensure that students recognise this relevance.

A perceived lack of relevance from participants in turn appeared to suggest a lack of engagement with learning of that topic, which was unsurprising as this was seen in previous studies exploring student perceptions on pharmacy programmes (Jesson et al., 2006; Prescott et al., 2014; Smith et al., 2017). However, relevance seemed subjective in these focus groups and there was no consensus on which topics they all felt were 'relevant'. Students often referred to their own career plans when reflecting what they felt was relevant. They may connect more when they feel it involves development of skills that are clearly linked to their future chosen employment. Evidence suggests that the financial impact of higher education study and a more challenging job market when compared to the previous generation may make students more self-aware of their future employability (Qenani et al., 2014).

(iii) Benefits of experiential learning

This positive theme recurred throughout the dataset in all three years. Students were specifically asked about working in a pharmacy setting. Some students had regular paid employment or summer placements and some mentioned university organised placements, the term 'work experience' in this chapter is used to incorporate them all. From the analysis of the focus groups, it is evident that students perceived working in a pharmacy setting helped their understanding and confidence as well as consolidated their learning. This perception may not correlate to improved performance though. Greene et al., (2010) reviewed students' results from a specific first year drug assessment at a US university and compared with their work experience prior to starting the programme. Although the lowest marks were associated with students who had little or no experience, the amount of work experience did not correlate with success. Mar et al., (2010) also looked at previous work experience at one US university and found that it did not have an overall impact on student performance however, it acknowledged that there were many other factors influencing attainment. The desire for more placements within the programme was a source of discussion in each focus group with queries around how many days each academic year had, as well as the range of settings that may be used. It is noted that there is a difference between structured planned experiential learning which is aligned to a programme of study and other types of pharmacy related work. This study took place before the implementation of the 2021 educational standards (GPhC, 2021) so students only had a very small amount of university allocated placement (approximately 4 weeks in total of observational placements across the four years of study). As a consequence, there were no further exploratory questions specifically on placement and experiential experiences.

Students valued the interaction they had with patients in practice, and they felt there were not sufficient opportunities to go on placement within their programme. They appreciated the opportunities to apply knowledge and skills during work experience. Learning in the workplace setting (both real or simulated) is an excellent example of 'learning by doing' and has been found to consolidate learning and build confidence and professionalism (Hope et al., 2021). Students often provided examples showing their application of knowledge when discussing interactions with patients in the focus group. Being able to translate complex information into a language that patients would engage with and understand was highly valued by the participants. Kerr et al., (2021) researched published literature on how communication skills can be developed and improved in pharmacy students and found repeated practice, feedback and reflection are effective strategies which can be achieved in the practice setting.

(iv) Creation of links

All focus groups appeared to understand and acknowledge the importance of a solid foundation in basic science and chemistry concepts within a pharmacy degree. Students were able to give examples of their experiences of integration, either specifically through teaching sessions or examples from practice settings where their previously acquired knowledge had been applied in practice. Integrative thinking was shown by these participants, but it was clearly more prominent when it was encouraged and scaffolded by educators directly teaching and signposting. This observation was also made in a study of 51 students which explored their perspectives of their integrated curriculum at a UK university (Mawdsley & Willis, 2019).

There were some negative comments from the participants about fully integrated assessments, which students felt were more challenging. Integrated assessments require application of knowledge (Mawdsley & Willis, 2019) and higher order thinking skills like synthesis of information, combining information from multiple disciplines and formulating an answer (Krathwohl, 2002) . From a student's point of view, this is likely to feel challenging. This suggests that the curriculum design intention is not fully aligned to the students' experiences, and a different level of integration and application has been required in the assessments when compared to teaching. Clearer alignment between teaching activities and assessment tasks will help support students further in this area (Biggs, 1996). Application of knowledge in an assessment is an appropriate way to prepare students for their future career (Gulikers et al., 2004). This authentic assessment approach requiring the application of knowledge helps to ensure that students achieve learning with understanding and can continue to improve with feedback and reflection on their efforts (Wiggins, 1993).

There was no consensus from the participants about how they thought they should be taught on the MPharm, however this is unsurprising given their lack of pedagogical knowledge. Students liked the range of different topics and could not envision how the contents could be taught in a different structure to the current modules. Students complimented the programme on being organised but that may suggest it is not truly integrated with a 'complementary' programme approach rather than a multi or trans disciplinary approach (Harden, 2000). The higher steps on Harden's integration ladder may, on the surface, look less ordered because all material is truly fused together with themes as the focus of learning rather than subjects or disciplines.

Using an integrated approach is clearly not sufficient. Kerr et al., (2020) highlighted that there was no consistent description of integration, so its meaning is interpreted in multiple ways by different institutions. Although an integrated approach is widely respected as desirable and a requirement of many pharmacy regulators, consistent positive outcomes are yet to be proven.

Hubball & Burt, (2007) discussed the programme level outcomes they developed and implemented on their pharmacy programme in Canada. This allowed them to focus on the development of skills including problem-solving and higher order thinking skills, needed for graduates to be ready for clinical tasks. Students reported feeling better prepared for post-graduation roles.

Sun et al., (2023) argues that programmes are often not designed with 'truly curricular integration' but rather 'sequenced integration'. With ever-increasing content needed, for example new drug classes and corresponding pharmacology and increased inter professional education requirements, these authors called for a more evidence-based model of integration with outcomes which is properly evaluated.

6.4.2 Discussion of the data analysis in relation to the research questions

This study aimed to specifically answer the following research questions:

i) Do MPharm students understand how to think and study 'integratively' within the context of the MPharm course at UH?

ii) What are undergraduate MPharm students' perceptions towards integration within the MPharm degree?

iii) Would using a case-based approach to teaching encourage MPharm students to think 'integratively' within their degree?

The results from the focus groups show that although some students do understand integrative thinking, they are not consistently able to do this. This understanding also varied from year to year.

In terms of perceptions of integration, they had differing opinions of how integrated the programme was. This may suggest that the level of integration in each year is inconsistent. Students in the later years thought integration may be too challenging in first year, but the first-year focus group participants were able to discuss examples of their contextualised and integrated learning.

The students seemed to appreciate the concept of a more case-based approach but all that can be gained from this research is their initial enthusiasm and nothing more.

Interestingly, their work experience tended to remind them of the importance of science, for example if a patient case they saw needed science as an explanation, then they believed science was therefore important for underpinning their pharmacy practice. Students did not mention that this understanding of the importance of underpinning of science came from academic staff. There needs to be some reflection from academics about whether this message is clearly communicated to students.

6.4.3 Reflective account of the researcher

Prior to this focus groups, I was interested what the results would be, and I was very interested to see how students would explain integration and how they felt it fitted into their programme. I did have some pre-conceived ideas on what answers they may provide and how the year groups may differ.

On reflection, at the point of this research, most of my interactions with students was in the final year of the Master of Pharmacy, as year lead and module lead of a large module. By fourth year, students seem to value the importance of integrated nature of the degree, and I had not appreciated this was a realisation that progressed slowly and steadily through the programme.

I was surprised with how confident the first year students were with giving integrated examples and how some of the older year groups thought that may be too complex for first year students. This led me to consider their full understanding of this concept and whether they had consciously or explicitly experienced integrative teaching early on in their degree.

I was expecting students to discuss what they felt was less relevant, but I was surprised at the inconsistency of their answers even within year groups. It was interesting to see how their experiences in practice shaped their viewpoint. It truly highlights that each experience is individual and supports the philosophy of constructivism.

I was pleasantly surprised at some of their examples from practice where they explained they needed their science underpinning to help solve a clinical problem.

I also reflected on the collaborative work with student researchers. In general, using this methodology was a rewarding and beneficial experience to both the students and staff members involved. Some discussions within the research group led to valuable insights and improved the richness of the data collected. It was felt that this honesty and depth would not have been directly achieved if only an academic had planned and facilitated the focus groups.

6.4.4 Limitations

There are several limitations with this study, the most important to highlight is the small sample size (n=15) and the use of only one School of Pharmacy. However, the detailed discussions within the focus groups allowed the researcher to capture a range of perspectives and identify relevant themes. The concepts of maintaining research rigour were adhered to as discussed in section 3.16 and section 6.2.8.

Because of the participatory research methodology used with students running the focus groups, there was potentially a missed opportunity to explain the design of an integrated curriculum in more detail to the participants by an experienced academic. However, this may have not been a suitable time. It would be more appropriate to use this as an approach to the cohort as a whole and embed it into induction teaching. This study also aimed to allow students to share how they experience the curriculum, which may not align with the intended design planned by academics. Capturing this individual lived experience (rather than explaining the intended experience), was pivotal to the study.

There is evidence regarding many factors that may affect engagement with academic study like financial and social factors (Tan, 2024), time available to study and caring responsibilities (Xue et al., 2023). This demographic data was not captured so any effects relating to these differences in this study could not be meaningfully explored.

The researcher reflected on the use of focus groups rather than one to one interviews. It was felt that individual voices were still heard and acknowledged through the thematic analysis, so the researcher was satisfied with the use of this research tool.

The size of the focus groups was smaller than hoped due to the number of volunteers. However, it is noted that Morgan, (2016) argued similar data was obtained when he compared interactions in a dyadic interviews and focus groups.

6.4.5 Summary of phase two

From the analysis, it is apparent that the current curriculum does not fully embed the independent skills of thinking and studying integratively consistently for all students from year one. Although students were able to understand the concept of integration, many still need to develop higher order thinking skills and take a more active approach with integrating their learning across disciplines. These findings support previous literature which suggest solely having an integrated curriculum does not necessarily lead to development of these higher order skills (Nazar et al., 2019; Mawdsley et al., 2019).

From these students' perspectives, experience within the pharmacy workplace setting appears to be supporting them to become more integrative thinkers, with 'benefits of work experience' identified as a common theme. However, previous studies have not found a substantive link between work experience and attainment (Mer et al., 2010; Greene et al., 2010) although they did not explicitly look at integration. Karimi et al., (2010) designed an innovative approach to science integration and placements which was well received. This area merits further research as the expansion of placements in the MPharm 2021 standards could potentially help to further improve these problem solving skills (GPhC, 2021).

The pharmacy programme is a time intensive and challenging programme. Students admitted to adapting their learning approach depending on the specific assessment they were preparing for, with 'learning approaches' an identified theme in this study. This strategic approach to learning when under time pressure is well documented (Entwistle & Ramsden, 2015). To encourage deeper learning, previous literature has suggested assessments should be designed in a more truly integrated fashion to allow them to demonstrate their integrative higher order thinking (Mawdsley & Willis, 2019).

6.4.6 Data triangulation with findings from phase one and phase two

Together with part one of this phase in chapter 5, this chapter's findings contribute to answering one of the overarching thesis questions: "What are MPharm students' attitudes towards the relevance of chemistry within the MPharm degree as well their motivation and most effective ways to learn and understand chemistry?".

A student theme in part one was 'focus on understanding', with students showing a clear appreciation for the need to understand chemistry. 'Learning approaches' was identified as a theme in part two. Students explained their strategic approach to learning, where they would tend to rote learn when they felt this would be enough to pass the test. They did also emphasise their engagement with deeper learning when they have assessments which require them to demonstrate understanding. These deeper discussions and meaningful conversations within the focus groups have helped to deepen the interpretations of this phase's data analysis. Despite advocating their strategic approach, students still demonstrated an appreciation for understanding complex chemistry concepts. Students discussed their mechanisms for understanding new material i.e. using videos to help their review of lecture notes as well as the use of case studies to help with application.

Students from both phases did explore the importance of relevance and future careers and it was a recurring theme for both datasets. However, there were no consistent topics or areas identified in terms of relevance. Students were interested in a range of pharmacy sectors, and this seemed to influence the ideas on what was relevant.

6.4.7 Informing the final phase of the study

The findings from both phase one and two also contribute to the planning of the final phase of the thesis. Combining these findings from both quantitative and qualitative data analysis helps to provide a deeper understanding of the research questions (Tashakkori et al., 2021). It also helps to strengthen the credibility of the overall research (Bazeley, 2018). Any divergence between findings has been explored and supports richer interpretations of the data analysis (Cresswell & Plano Clark, 2018).

Like many students on intensive degree programmes, these pharmacy students use a strategic approach to progress through their degree (Dunn et al., 2003; Fergus, 2023). It can be hypothesised that students took a strategic approach to the midterm test in phase one, using recall multiple choice questions rather than questions which require understanding and complexity. This could potentially explain high engagement with the PeerWise tool without a corresponding high result in the summative midterm test. However, to be fully confident in this hypothesis, further analysis on types of PeerWise questions written would need to be carried out (like Galloway & Burns, (2015); Fergus et al., (2023)).

Students demonstrated an interest in learning with understanding but appear to need additional scaffolding to support this. The data from phase one suggests that there is no one specific demographic influencing learning so targeted support should be directed towards whole cohorts. These students appear consistently career focused. With this in mind, using a patient centred approach for case study teaching may be beneficial as the patient is likely to be a main starting point whichever career path the students choose.

The findings from this study suggest that students would benefit from a more directly scaffolded approach to integration with the links being highlighted at the beginning of the programme more clearly. Students were very positive regarding the use of case studies in teaching. A case-based approach with fully integrated cases and a multidisciplinary approach to preparation would be beneficial and support students in developing the necessary integrative skills (Schmidt et al., 2011). This approach will be investigated further in the next chapter. There is evidence that critical thinking skills can be developed (Persky et al., 2019) using active learning like case studies and these skills are a critical attribute needed for pharmacists.

Chapter 7 – Development, delivery and evaluation of integrated case-based workshops

7.1 Introduction

This chapter presents phase three of this research; the development and delivery of a teaching intervention tool to support pharmacy students' learning. As well as discussing and justifying the teaching design, this chapter also presents the data analysis from the evaluation questionnaire completed by students after the final teaching session.

Previous published literature has demonstrated the use and evaluation of integrated chemistry teaching interventions within pharmacy undergraduate programmes (e.g. Alsharif, 2007; Fergus et al., 2019; Roche, 2009). This was discussed and critiqued in chapters 2.4.3 and 2.5.3. These often prioritised the specific chemistry elements prior to focusing on the application to the patient, with the teaching developed by the chemistry academic staff as opposed to a multi-disciplinary team. They also often focused on narrowly defined topic areas within chemistry, rather than addressing the broader range of foundational sciences which all underpin the clinical pharmacy practice knowledge. This intervention intends to be distinct from previous published literature and the rationale for each element of this approach will be explained and justified.

7.1.1 Presentation of the research questions

Following analysis and consideration of the previous phases, a teaching intervention was designed to help support students' development of integrative thinking and their understanding of curriculum integration. This intervention draws on previous published findings but offers a different approach so provides a new contribution to the literature.

The research questions are:

- Does the use of science concept driven teaching have an impact on a 1st year MPharm student's ability to recognise the importance of chemistry to clinical pharmacy practice?'
- Does the use of science concept driven teaching have an impact on a 1st year MPharm student's ability to create links between and apply their knowledge across the programme?

7.1.2 The importance of conceptual understanding

Understanding concepts rather than solely memorising facts within chemistry and pharmacy is important to ensure students are suitably prepared for practice. This learning can then be applied to a variety of situations in a workplace setting, where a diverse range of complex cases may be seen.

Ensuring the underpinning chemistry is understood rather than rote learned is important for pharmacy students to support them in developing their reasoning and decision-making skills. Holme et al., (2015) investigated and defined key characteristics for conceptual understanding in the context of general chemistry, but these principles can be related to pharmacy due to its need for underpinning chemistry. Following a survey involving 1,519 chemistry academics, the authors used the consensus found to define important skills that are demonstrated by students who have gained conceptual understanding. These included the ability to transfer their knowledge to a novel situation and translate it, so that they could apply it in different circumstances. They would also be expected to demonstrate a depth of reasoning which goes beyond basic recall and hence be able to problem solve and predict what may happen in a given setting or situation.

Cheung et al., (2019) discussed the importance of both knowledge and skills when planning teaching in healthcare education. In addition to teaching how something should be done, i.e. providing an explanation of 'how', it is also important to develop an understanding of 'why', meaning the underlying concept is also explained. This conceptual understanding allows the student to transfer this knowledge and apply it to new and different situations. This supports the development of clinical reasoning which can be used to justify clinical decisions. Angelo et al., (2022) also argues that core concept knowledge and understanding should be prioritised above basic factual content in pharmacy education for several reasons. Due to the increasing scope of pharmacy with new classes of drugs and therefore new pharmacology, solely factual content is no longer possible due to this extensive content. If teaching also focuses on essential concepts rather than just key facts, it will encourage learning with understanding rather than rote learning.

In addition to conceptual understanding, there are important theories to consider when structuring teaching in healthcare education. Building on the work of both Vygotsky (Vygotsky, 1978) and Dewey (Dewey, 1938) who highlighted the importance of social interaction in building new knowledge and understanding, Lave & Wenger, (1991) proposed "situated learning theory". These authors emphasise that when learning, the context (i.e. the situation or area where students learn) and action taken whilst learning is also influential. Although this theory is more directly related to placement and experiential learning, it is useful to consider within the classroom workshop setting. O'Brien & Battista, (2020) conducted a review looking at the use of this theory within educational research in healthcare professional programmes. They found that it was beneficial for understanding how students learn and interact with each other in authentic situations. Consideration of this theory encouraged academics to think beyond building knowledge in individuals when learning but also to reflect on the learning in relation to social interaction as well as the context and setting. This is relevant when considering how students may interact when working together in a workshop.

7.1.3 The foundational science clinical gap

This issue is highlighted in the educational context of multiple healthcare professions including pharmacy. This gap refers to the timing of students' scientific knowledge acquisition and their subsequent ability to apply this knowledge in clinical practice. There are multiple reasons why this gap exists in pharmacy education. Traditionally, the separate disciplines have been taught in siloes, with the pharmaceutical sciences teams and pharmacy practice teams teaching separately (Sun et al., 2023). Whilst clinical teaching has increased following changes to pharmacists' roles and subsequent educational regulatory changes, the importance of the underpinning science was not always considered and included (Waterfield, 2010). The development of clinical reasoning skills tends to be organised by pharmacy practice teams and focuses on clinical, legal and ethical knowledge and skills (Cooper et al., 2008; Wright et al., 2019) as opposed to underpinning science. However, several researchers have sought to integrate this teaching by specifically tailoring it to include chemistry when students are developing these skills. Krol & Albon, (2025) argues that with their detailed knowledge of medicinal chemistry, pharmacists have a unique place within the healthcare setting. Integrating their knowledge from medicinal chemistry with their clinical skills to solve clinical problems can be seen as a key competency.

It is also important to note that critical thinking skills are fundamental to develop in relation to clinical reasoning skills and these can be taught within science teaching. Choo et al., (2022) used a problem-based learning approach in their pharmaceutical chemistry workshops to develop critical thinking. Students reported that they were able to apply concepts to solve new unseen problems following this teaching. This principle can be built on when developing clinical reasoning skills.

The overarching structure of pharmacy training in the UK with a 4 plus 1 model (Guile & Ahamed, 2011) has meant the separation of theory and practice, with a four-year university degree programme followed by one year in practice to allow application of knowledge (RPS, 2019). This structure assumed that students would easily transfer their knowledge to practice but this has been questioned with some students reporting that they could not see the connection between their university learning and the work setting (Guile & Ahamed, 2011). Within busy healthcare settings in the UK, there may be limited time for detailed teaching so the 'how' to do something can be taught but perhaps there is not sufficient time to revisit previous theory and explain the 'why'.

With the updated standards for initial education and training (GPhC, 2011, 2021), the move away from an indicative syllabus to meeting specific outcomes helped education providers focus more on developing the skills for the future workforce. To assess in line with these standards, assessments need to show that students achieved "ability-based outcomes" rather than only specific knowledge. This approach encourages the use of an integrated curriculum, although from previous research, it is acknowledged that it is not enough to provide assurance that all students can routinely think integratively (Mawdsley & Willis, 2019).

Waterfield, (2011) highlights the importance of ensuring an experiential learning curriculum is well designed and there is clear integration in the undergraduate degree. With the most recent changes to the standards for initial education and training (GPhC, 2021), the foundation year education providers are being accredited so there should be a much more integrated approach to experiential learning and the degree programme.

The historic curriculum design of medical degrees also highlights the challenge of linking their scientific learning to application in practice settings. Watmough et al., (2009) interviewed 46 graduates from two cohorts who studied on the University of Liverpool medical degree programme. They stated that although their programme gave them a solid grounding in science to help understand disease physiology, it was not integrated enough with practice, so they did not feel it directly prepared them for clinical work. They would have appreciated greater integration of the theory with clinical practice. Thoughtful integration of underpinning science taught with clear intent within a healthcare education programme has the potential to narrow this science practice gap. Schmidt & Rikers, (2007) highlight the need to teach science in a clinical context to help ensure the knowledge is 'encapsulated' so students may automatically use this science knowledge when trying to solve a clinical problem.

Santana et al., (2025) considered the foundational science teaching in their medical degree in the US and how to improve students' connections to the clinical setting. Following a questionnaire to first-year medical students, they were able to identify which areas they found most difficult to connect their science knowledge to its clinical application. They have planned patient focused teaching in this area to help improve understanding where students struggled to bridge the gap with subsequent evaluation of the impact planned.

A patient centred approach to linking foundational sciences and clinical application will be used in the teaching intervention presented in this chapter.

7.1.4 Effective teaching approaches for integrated learning

Like other healthcare professions, integrative thinking is central to practice and therefore needs to be considered within pharmacy education. It draws together information from the different disciplines to help ensure that high quality holistic patient care is delivered (Rosch, 1998). An overarching integrative curriculum approach within the pharmacy degree can support students in applying their knowledge across the different disciplines (Husband et al., 2014). However, Mawdsley & Willis, (2019) found that students tended to be more able to think in this manner when the teaching was designed to clearly demonstrate integration between disciplines. With this in mind, teaching needs to make the integration explicit. A teaching approach which actively encourages integrative learning is needed to improve the students' ability to routinely do this.

There are a range of active learning strategies that have been discussed in the literature and implemented across a number of pharmacy programmes to help improve integrative learning. Ofstad & Brunner, (2013) discusses the use of team-based learning within pharmacy education. They found this strategy encourages learners to actively participate and develop critical thinking, with published literature discussing the use of this approach across a range of healthcare programmes. Tweddell et al., (2016) implemented this approach across the MPharm programme at the University of Bradford. They found that it led to better participation within the classroom, with students taking greater accountability for their learning. They did note that although academics found it rewarding, it was initially a challenge to adapt to a different way of teaching. This approach is popular across other pharmacy programmes, with Silberman et al.,(2021) also finding it improved students' critical thinking skills in their US School of Pharmacy.

Tsekhmister, (2023) investigated the benefits of case based approaches when compared to traditional teaching in both pharmacy and medical education. The evaluations conducted varied across the studies reviewed but overall students' higher order thinking and analytical skills were shown to improve with this approach.

Learning with understanding goes beyond knowing facts and requires students to be able to solve issues in novel scenarios. Problem-based learning is well established in healthcare education which can allow students to apply their learning to solve issues in a scenario which encompasses multiple disciplines. Yew & Goh, (2016) provide an overview of this teaching strategy and explain that this approach can lead to longer term retention of knowledge, with some studies appraised showing the ability to apply and integrate knowledge was well developed in students participating in this approach.

Another type of approach known as POGIL is thought to be an effective active learning strategy. The abbreviation POGIL stands for process orientated guided inquiry learning. This method of teaching encourages students to work as a team and supports the development of critical thinking and problem-solving skills (Simonson, 2023). This approach is considered in the methods section for use in this teaching intervention.

In addition to being taught in an integrated manner with multi discipline scenarios, students also benefit from reflecting on their own learning experiences. Tsingos et al., (2014) explains that reflection can support development of critical thinking and problem-solving skills.

Integrative learning will be a new skill to learn at university which is not likely to have been practised in school or college. There is evidence that students should be supported in multiple ways during their transition from secondary education to university to successfully progress through their degrees including learning how to learn (Briggs et al., 2012). In addition to the specific design of any case study or scenario, consideration needs to be given on how students will be supported during this teaching. Wingate, (2007) argues that students need to be specifically taught how to learn in the higher education setting when they join in first year and rather than providing separate study skills teaching, this teaching can be embedded into their subject specific teaching.

This teaching intervention will combine several approaches which support active learning and will also aim to provide contextualisation for several chemistry concepts with suitable scaffolding to support them in their learning to think integratively.

7.2 Methods

From the research findings in previous chapters, it is acknowledged that integration should be explained and embedded from the start of the programme, so this teaching intervention was designed to be implemented in year one of the MPharm programme.

7.2.1 Student involvement

Three fourth year pharmacy students were involved in the initial planning of the case studies. Although they did attempt to draft the case studies themselves, they found the higher order thinking skills needed to appropriately integrate and create new material challenging, so the final case studies were written by the PhD researcher. The students were also involved in designing and reviewing the evaluation questionnaire.

7.2.2 The teaching intervention design and delivery

A workshop approach, centred around patient case studies was chosen as opposed to a didactic lecture structure to encourage application of knowledge to develop students' critical thinking skills (Tsekhmister, 2023).

Discussion within the student research group helped determine the most suitable module to deliver the teaching. Although all the first year modules aim to integrate material, they are seen by students as having a specific subject focus. An academic and professional study skills module is also in first year (named Transition to Higher Education) and it was deemed the most appropriate module for the intentions of this teaching.

The group discussed the types of scenarios to write in terms of conditions and the relevant drugs associated with them. It was felt that it was important to use commonly used drugs in the UK (Hitchings et al., 2023) that students would see frequently in practice. The PhD researcher liaised with the first-year module leads to ensure drug structures and other concepts included in the cases were in line with the other teaching delivered at level 4 (first year). The design framework developed and presented by Fergus et al., (2019) was utilised when designing the case studies.

Clinical reasoning and critical thinking skills were also developed within the case study scenarios as students were required to choose appropriate drug treatment for the patient at each stage. Students were also required to justify 'why' this decision was made by using the underpinning science they had learnt (Wall et al., 2022).

Reflecting on the findings of the earlier research in this doctoral study, several features were also incorporated in the case study design. Explaining clearly what integration was before working on the case studies was deemed very important (Mawdsley & Willis, 2019). The cases were intentionally written to ensure they were authentic and relevant to current pharmacy practice and links to potential future careers were explained. There was discussion on the importance of learning with understanding rather than rote learning (Angelo et al., 2022).

In addition to including chemistry concepts, other foundational science topics (like pharmacology and pharmaceutics) were also included. It is recognised that although chemistry was the core of this thesis, there is evidence that all the foundational sciences should be included in teaching and have a place in underpinning clinical knowledge (DiVall et al., 2020).

In line with recommendations from Kerr et al., (2020), the level of integration and approach for these workshops are clearly defined. These are horizontally integrated case-based workshops at a trans-disciplinary level (Harden, 2000).

The style of teaching was considered. There are several examples of the POGIL teaching method being used in higher education settings. For example Soltis et al., (2015) found a significant improvement in academic performance with students' results on questions requiring higher order thinking skills improving by 7% points (75.8% to 82.8%) after the POGIL intervention was used. This POGIL method was reviewed and incorporated in the structure when designing these workshops.

For the cohorts that were taught during the COVID pandemic with the need for online teaching; students were taught in smaller groups and Zoom break out rooms were used for each team with the staff member visiting each room regularly to facilitate learning.

7.2.3 Structure of the teaching sessions

Students attended three case-based workshops which each lasted 2 hours. These workshops were scheduled throughout the two 12-week semesters as they aimed to align with the relevant teaching in the corresponding modules so that teaching could be readily recalled by the students.

Earlier research has shown that it is beneficial for integration to be made explicit for pharmacy (Mawdsley & Wallis, 2019). Because of this, the whole cohort was introduced to the terms integration and contextualisation in a lecture prior to the first workshop and it was again discussed in the introduction to each workshop.

The description of the POGIL method of teaching (Simonson, 2023) was utilised when designing this case study teaching, to help the students to develop important transferable skills. Students discussed and explored relevant concepts then applied these concepts to the scenario, working as part of a team. This helped to develop their critical thinking and problem-solving skills as well as practising communication skills and team working skills (Brown, 2010)

Students were allowed to choose their own small groups to work in at the beginning of each workshop. Expectations were set, with students being given an authentic case to work on. Students then needed identify the prominent issues and what further data they may need to suitably treat and care for the patient. The small groups worked together to explore concepts, then interpret and apply these to the case. At several scaffolded stages in the workshops, each group shares their findings and clinical reasoning to the whole group before the next stage of the case was revealed. At the end of each workshop, students was asked to reflect on what they had learnt and the featured concepts were summarised to help support knowledge and understanding development. As the facilitator, the researcher guided discussions and asked probing questions rather than providing answers without debate.

Students were encouraged to engage with the cases as a pharmacist providing and justifying advice to their prescribing colleagues. Following the introduction of the 2021 educational standards (GPhC, 2020), the workshops were adapted with a focus on evidence based decision making as a future prescriber. It was explained to students that it is important to be able to explain prescribing decisions with the underpinning science.

Each case aimed to increase in complexity across the series of workshops. The scenarios and concepts are summarised in table 28. There is also an example lesson plan in appendix 6.

Table 28- Summary of contextualised workshops

Workshop scenario	Areas covered
Treatment of headache in community pharmacy setting	The effect of chemical structure on absorption, function and onset of action. The influence of pharmacology on drug effect and side effects Practice of patient questioning technique and patient counselling
Chest infection in primary care setting with relevant antibiotic prescribing	Appropriate use of antibiotics, challenge of AMR Respiratory infection guidelines Penicillin allergy and structurally related allergies Drug structure in relation to action, interactions and warnings
Review of asthma inhaler medication	Importance of formulation The influence on pharmacology and disease physiology Inhaler use, chemical structure and onset of action The importance of reflection on learning and practice

There were several factors which helped support the engagement of the students. The case studies were specifically written as common, clinically relevant topics. The scenarios also allowed students to link them directly to their future careers. These have been two recurring themes identified through the qualitative data analysis in this thesis. The workshops were planned to ensure they were interactive, with all students being required to participate. Learning with peers to actively learn and understand material has been discussed as an effective way of achieving meaningful learning (Bryce & Blown, 2024; Kozulin, 2003). The summative assessment linked to the workshops was also highlighted at beginning of the workshops as students tend to adapt their learning approach in relation to the corresponding assessment (Biggs & Tang, 2011).

Each workshop was run three to four times to ensure there were small numbers of students. This was to encourage engagement and interaction, as phase two had identified a lack of confidence in asking questions in larger group settings.

The intended learning outcomes for students to achieve by the series of workshops were:

- Integrate knowledge of science and practice when supporting patient care
- Appreciate the relevance of science to pharmacy practice
- Understand the relevance of functional groups in relation to drug absorption, onset of action and side effects
- Provide a scientific rationale to explain and justify when making medication recommendations

An aim of this overarching thesis was to produce pharmacy students who can apply their scientific knowledge to problem solve clinical cases. These workshops and their intended aims allowed the students to practise these skills with significant scaffolding in place, They also had the opportunity to independently keep developing these skills, creating links between their science and practice learning in the rest of the programme

7.2.4 Discussion and justification of evaluation methods chosen

How to evaluate this teaching intervention was carefully considered. Analysing the module's summative test was seriously considered as a possible measure. However, this was rejected for multiple reasons. The test covered all aspects of the module, with these workshops compromising of only a small proportion of them. This would make the analysis of the whole test less meaningful for this specific intervention. In addition, although supporting the students to apply knowledge in this series of workshops, some of the teaching material had already been taught. A measure of achievement could have been linked to other teaching, so it would not have been possible to objectively say it was linked solely to this intervention. Finally, an additional summative test following the series of workshops was considered. However, there is a clear assessment strategy across the programme which is carefully planned in a chronological landscape to avoid bunching and overload. Adding in an additional assessment would have disrupted the organisation of the year's assessments. It may have caused overload and encouraged surface as opposed to deep learning approaches (Biggs & Tang, 2011).

Consideration was given to the specific research questions this evaluation sought to measure. Achievement in a test would not have provided any information on the students' individual experiences, specifically their thoughts on the importance of underpinning science or their ability to automatically create links in their multi-disciplinary studies.

The process of learning and students' individual perceptions around chemistry within their pharmacy degree is a major element of this thesis. Questions which clearly linked to the research questions were used in the evaluation tool. In addition, they were asked to reflect on any learning gains they felt they had. Learning gains can be linked to a student's increase in confidence, understanding (Evans et al., 2018) as well as indication of their level of motivation. Reflecting on learning is a valuable exercise and can encourage metacognition (Tanner, 2012). Students can be more aware of their learning, their progress and actively identify weaker areas (Livingston, 2003).

It is acknowledged that there are several limitations to the chosen evaluation. Measurement of perceived learning gains cannot be considered a substitute for academic attainment evaluation. Students may incorrectly estimate their learning ability and gains (Kruger & Dunning, 1999). There is no consistent evidence that their perceptions correlate correctly with their knowledge levels.

7.2.5 Selection of the research instrument

The type of research instrument to gather students' feedback was considered. To gather data from as large a sample as possible in each cohort, questionnaires were used. This would achieve a larger sample response, when compared to interviews and would allow a larger number of questions to be asked. Questionnaires were also considered suitable because there were standardised straightforward questions to be answered (Cohen et al., 2018) which would be suitable for statistical analysis to help describe and scrutinise the results.

7.2.6 Question development and justification

The questionnaire aimed to gain an understanding of students' learning gains rather than their perceptions and enjoyment on the teaching. Previous research has shown that what students perceive as interesting and effective as a study technique may not actually positively impact learning gain (Fergus, 2022).

Although previous research suggests that an integrated curriculum should encourage students to think integratively (Husband et al., 2014, Mawdsley et al., 2019), it was deemed beneficial to understand directly from students how they felt about the development of this skill and which types of teaching would encourage this further. The questions used in the final questionnaire are listed in table 29.

Ethical approval was sought for the study; this was granted by the University of Hertfordshire ethics board with protocol number LMS/PGR/UH/04581.

Table 29-Summary of the questions in the workshop evaluation questionnaire

Demographic questions - data, gender and age
Learning gains questions- answer options using 5-point Likert scale (Very good improvement, good improvement, moderate improvement, a little improvement, no improvement) -What improvement do you think that you have made in your understanding of each of the following: -Correctly identifying functional groups -The role of functional groups in relation to drug absorption -The relevance of drug absorption in relation to patient counselling -The role of functional groups in relation to drug side effects -The role of functional groups in relation to the speed of drug action What improvement did you make in the following skills: -Connecting the concepts discussed at the workshops with other knowledge learnt on the MPharm -Applying what you have learned in other teaching sessions on the MPharm
Creating links- thinking integratively questions - Answer options were a 5-point Likert scale (Strongly agree, agree, unsure, disagree, strongly disagree) I have used some of the knowledge gained from these workshops in other teaching sessions on the MPharm programme. I have used some of the skills gained from the workshops in other teaching sessions on the MPharm programme. I now automatically create links between the modules that you have been taught and consider in a patient context My attitude regarding the relevance towards science and chemistry and patients has changed following these workshops
Future approaches to help with integrative thinking - Answer options were a 5-point Likert scale (A lot, some, a little, not at all, unsure) Regarding the following, what would further encourage you to create links between the science and practice teaching on the MPharm programme? -Co -teaching sessions with science and practice lecturers -Case based workshops with relevant science and practice information -Assessments which require you to use both science and practice learning
Free text questions Are there any barriers that prevent you from creating the links between science and practice teaching? Is there anything else you would like to add about your learning from these workshops?

Five-point Likert scale questions was used to gather the feedback. This allowed students to give a range of responses rather than being restricted to a definitive agreement or disagreement. Likert is also a well-recognised and commonly understood scale (Cohen et al., 2018) which facilitates meaningful feedback from those completing the questionnaires. It is acknowledged that this data will be ordinal rather than interval data so should be analysed appropriately (Jamieson, 2004) in respect of the data type. Although the Likert scale provides more nuanced data, it does not allow students to provide further comments on their thoughts towards this type of learning and integrative thinking. Because of this, several free text questions were also included to give participants the opportunity to provide richer written responses on this topic area if they wished to.

7.3 Results from evaluation questionnaire

As part of a longitudinal study, three cohorts of first-year pharmacy students were invited to provide feedback on the case-based intervention over three consecutive years. A total of 70 responses were received across all three cohorts. Three of these responses were removed during the cleaning of the data due to significant unanswered questions in their individual dataset so the total number of analysed responses was 67.

Table 30- Participant number and response rate for post workshop questionnaire

Cohort	Number of responses	Workshop attendees	Percentage response rate
1 - 2021	24	88	27%
2 - 2022	15	75	20%
3 - 2023	28	91	31%

To provide a more accurate representation of the data, students who attended the workshops rather than the cohort as a whole have been used to calculate the percentage response rate. This is because the university data at that time included students that were dormant or planning on withdrawing from the programme. It is noted that the programme did have an enforceable 100% attendance policy (although some students who do not attend or attend infrequently struggle to pass the summative assessments).

7.3.1 Section A - Demographic data

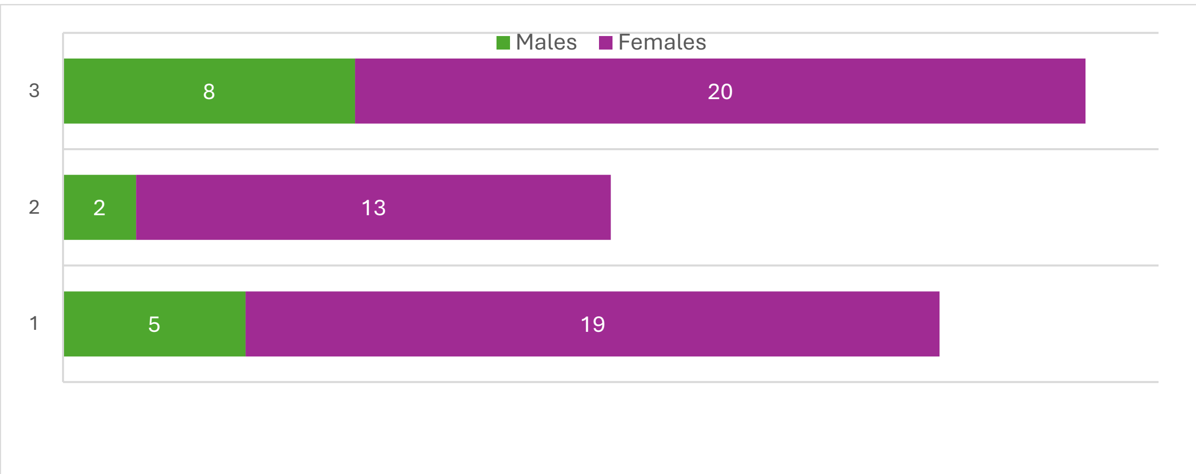

Figure 13-Self identified gender for participants in each cohort

Figure 13 shows the numbers of students who participated in the questionnaire from each cohort. In comparison to overall cohorts over last five years, females have represented 70 to 80% of the cohort, with males representing 20 to 30%.

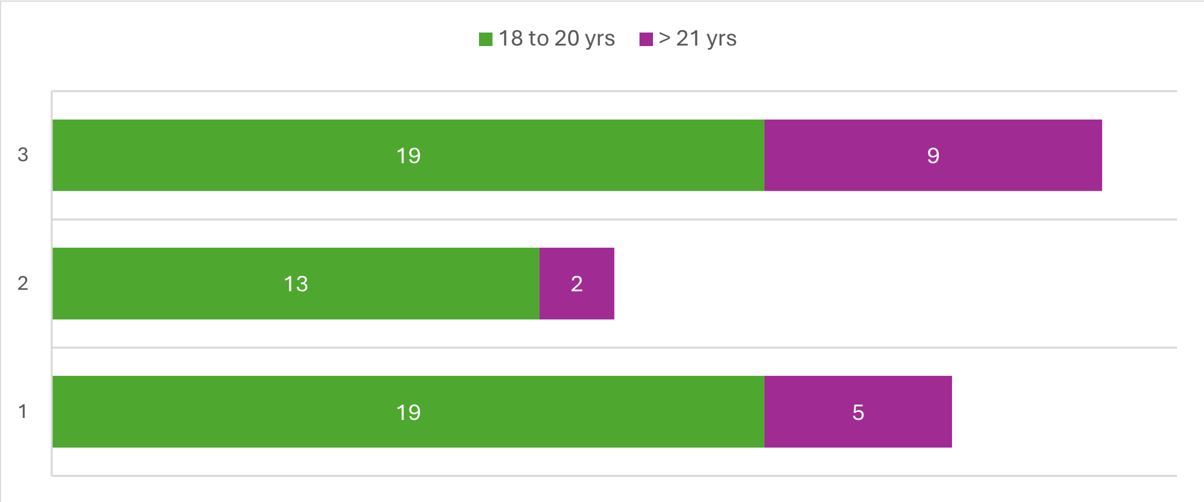

Figure 14- Self identified age range upon commencing studies for participants in each cohort

In terms of the overall cohorts over last five years and using the HESA definitions for age of students (HESA, 2019), young students have represented 80 to 85% of the cohort, with mature representing 15 to 20%.

Answers to the questions in the next sections of the questionnaire are first displayed in bar charts. Options with zero responses do not have a bar within the chart but these data are subsequently clearly shown in the summary tables at the end of each section.

7.3.2 Section B – Student perceptions of their individual learning gains

The 5 point Likert scale answers to questions 3a to 3e are presented below

Question 3a What improvement do you think that you have made in your understanding of correctly identifying functional groups?

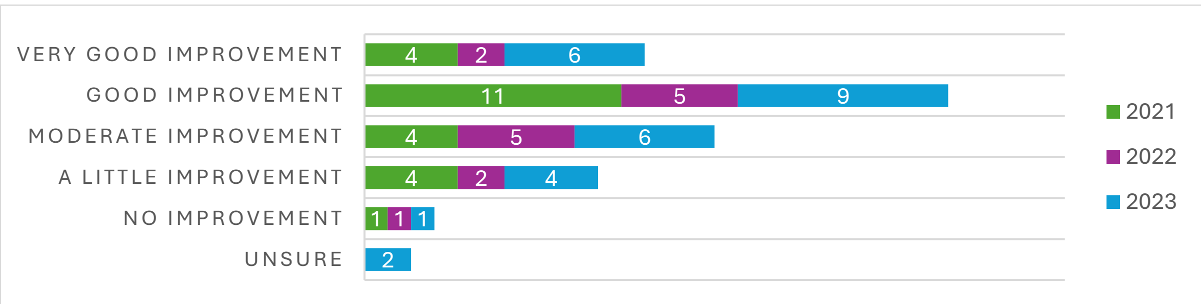

Figure 15- Question 3a answer summary for all cohorts

Question 3b - What improvement do you think that you have made in your understanding of the role of functional groups in relation to drug absorption?

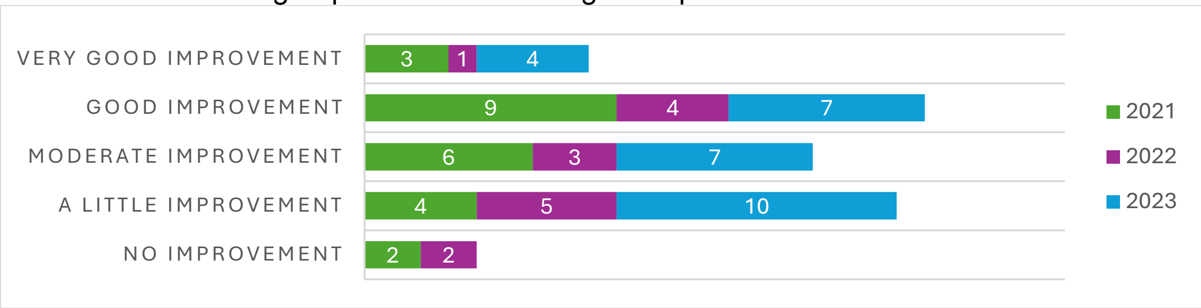

Figure 16- Question 3b answer summary for all cohorts

Question 3c - What improvement do you think that you have made in your understanding of the relevance of drug absorption in relation to patient counselling?

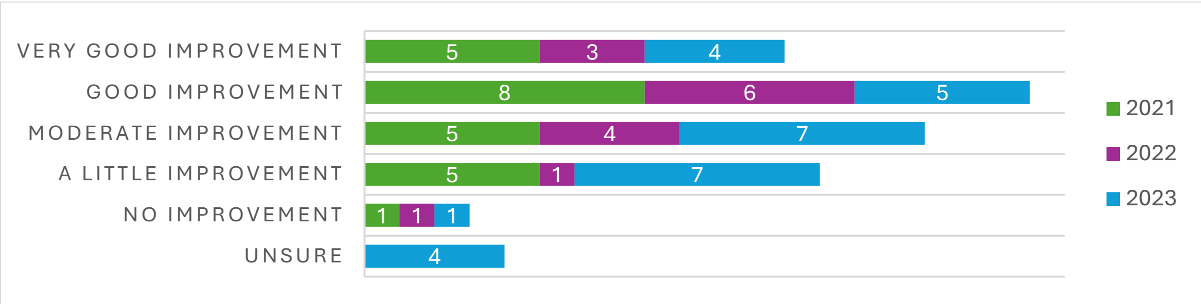

Figure 17- Question 3c answer summary for all cohorts

Question 3d What improvement do you think that you have made in your understanding of the role of functional groups in relation to drug side effects?

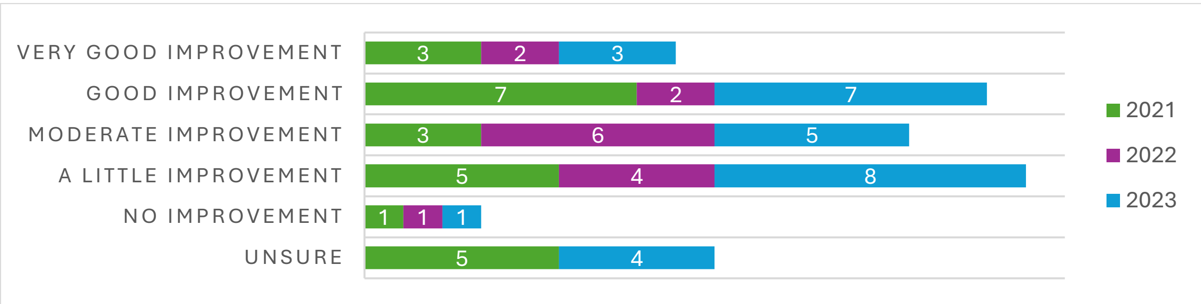

Figure 18-Question 3d answer summary for all cohorts

Question 3e What improvement do you think that you have made in your understanding of the role of functional groups in relation to the speed of drug action?

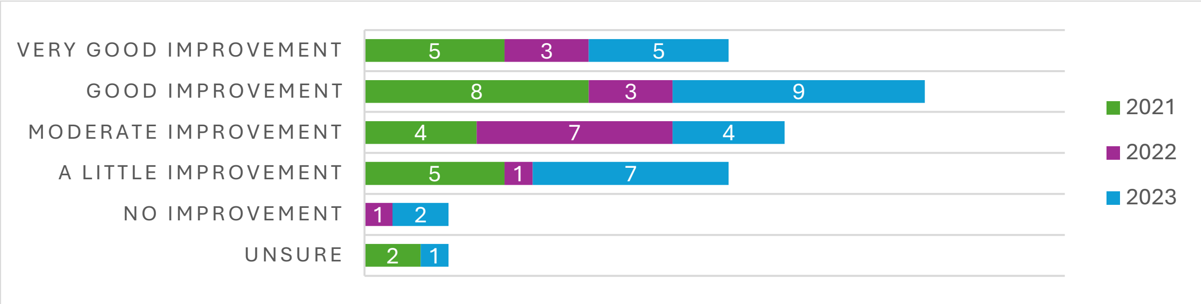

Figure 19- Question 3e answer summary for all cohorts

Table 31 - A summary of the data for question 3 across the cohorts

Question	Answer options	**2021** No. of students answering/No. of students in cohort (%)	**2022** No. of students answering/No. of students in cohort (%)	**2023** No. of students answering/No. of students in cohort (%)
Question 3				
3.a. Correctly identifying functional groups	Very Good Improvement	4/24 (16.7)	2/15 (13.3)	6/28 (21.4)
	Good Improvement	11/24 (45.8)	5/15 (33.3)	9/28 (32.1)
	Moderate Improvement	4/24 (16.7)	5/15 (33.3)	6/28 (21.4)
	A Litte Improvement	4/24 (16.7)	2/15 (13.3)	4/28 (14.3)
	No Improvement	1/24 (4.2)	1/15 (6.7)	1/28 (3.6)
	Unsure	0 (0)	0 (0)	2/28 (7.1)
3.b. The role of functional groups in relation to drug absorption	Very Good Improvement	3/24 (12.5)	1/15 (6.7)	4/28 (14.3)
	Good Improvement	9/24 (37.5)	4/15 (26.7)	7/28 (25.0)
	Moderate Improvement	6/24 (25.0)	3/15 (20.0)	7/28 (25.0)
	A Litte Improvement	4/24 (16.7)	5/15 (33.3)	10/28 (35.7)
	No Improvement	2/24 (8.3)	2/15 (13.3)	0 (0)
	Unsure	0 (0)	0 (0)	0 (0)
3.c. The relevance of drug absorption in relation to patient counselling	Very Good Improvement	5/24 (20.8)	3/15 (20.0)	4/28 (14.3)
	Good Improvement	8/24 (33.3)	6/15 (40.0)	5/28 (17.9)
	Moderate Improvement	5/24 (20.8)	4/15 (26.7)	7/28 (25.0)
	A Litte Improvement	5/24 (20.8)	1/15 (6.7)	7/28 (25.0)
	No Improvement	1/24 (4.2)	1/15 (6.7)	1/28 (3.6)
	Unsure	0 (0)	0 (0)	4/28 (14.3)
3.d. The role of functional groups in relation to drug side effects	Very Good Improvement	3/24 (12.5)	2/15 (13.3)	3/28 (10.7)
	Good Improvement	7/24 (29.2)	2/15 (13.3)	7/28 (25.0)
	Moderate Improvement	3/24 (12.5)	6/15 (40.0)	5/28 (17.9)
	A Litte Improvement	5/24 (20.8)	4/15 (26.7)	8/28 (28.6)
	No Improvement	1/24 (4.2)	1/15 (6.7)	1/28 (3.6)
	Unsure	5/24 (20.8)	0 (0)	4/28 (14.3)
3.e. the role of functional groups in relation to the speed of drug action	Very Good Improvement	5/24 (20.8)	3/15 (20.0)	5/28 (17.9)
	Good Improvement	8/24 (33.3)	3/15 (20.0)	9/28 (32.1)
	Moderate Improvement	4/24 (16.7)	7/15 (46.7)	4/28 (14.3)
	A Litte Improvement	5/24 (20.8)	1/15 (6.7)	7/28 (25.0)
	No Improvement	0 (0)	1/15 (6.7)	2/28 (7.1)
	Unsure	2/24 (8.3)	0 (0)	1/28 (3.6)

7.3.3 Section C – integrative thinking

The 5-point Likert scale answers to questions 4 to 8 are presented below

Question 4- What improvement do you think that you have made in your understanding of connecting the concepts discussed at the workshops with other knowledge learnt on the MPharm?

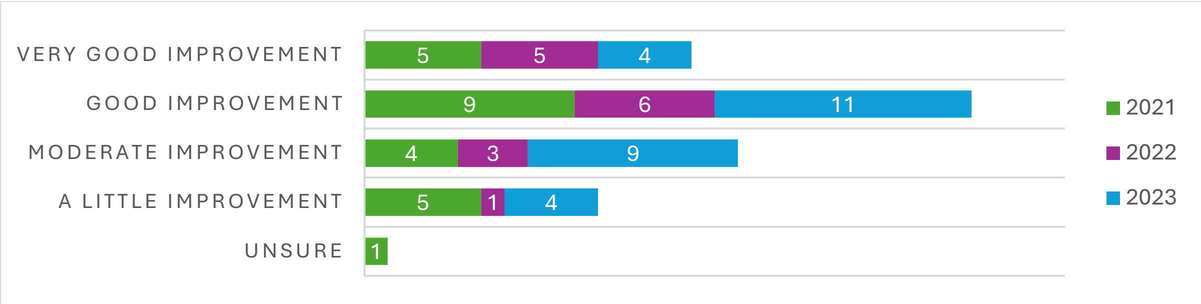

Figure 20- Question 4 answer summary for all cohorts

Question 5- What improvement do you think that you have made in your understanding of applying what you have learned in other teaching sessions on the MPharm?

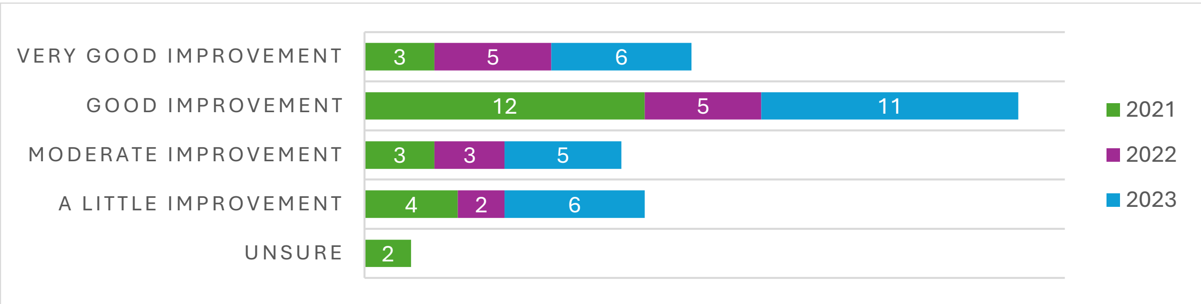

Figure 21- Question 5 answer summary for all cohorts

Question 6- I have used some of the knowledge gained from these workshops in other teaching sessions on the MPharm programme

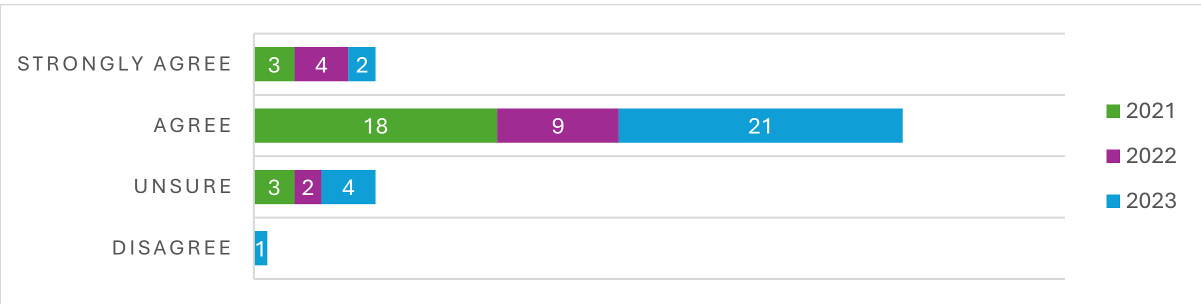

Figure 22- Question 6 answer summary for all cohorts

Question 7 I have used some of the skills gained from the workshops in other teaching sessions on the MPharm programme

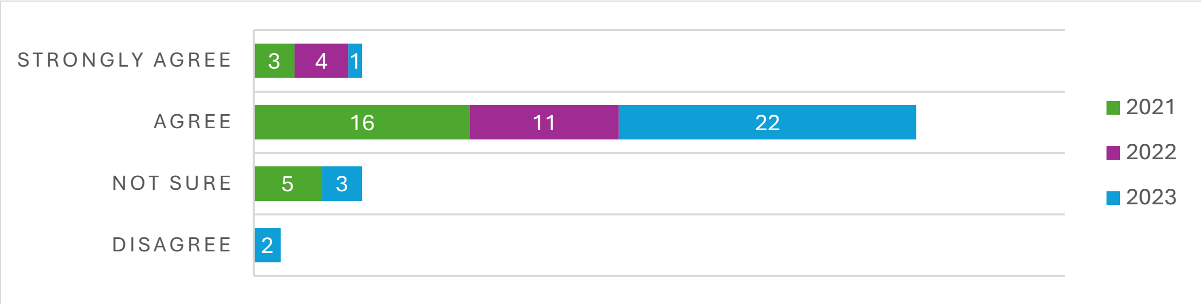

Figure 23- Question 7 answer summary for all cohorts

Question 8 I now automatically create links between the modules that you have been taught and consider in a patient context

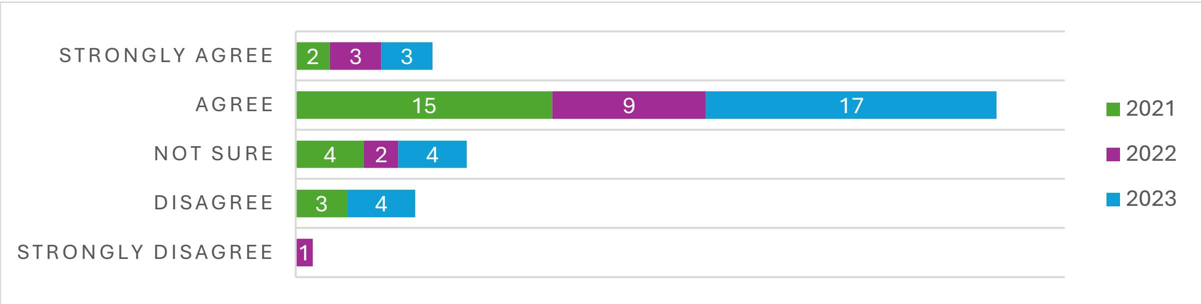

Figure 24- Question 8 answer summary for all cohorts

Table 32- A summary of the data for questions 4 to 8 across the cohorts

Question	Answer options	**2021** No. of students answering/No. of students in cohort (%)	**2022** No. of students answering/No. of students in cohort (%)	**2023** No. of students answering/No. of students in cohort (%)
Question 4	Very Good Improvement	5/24 (20.8)	5/15 (33.3)	4/28 (14.3)
	Good Improvement	9/24 (37.5)	6/15 (40.0)	11/28 (39.3)
	Moderate Improvement	4/24 (16.7)	3/15 (20.0)	9/28 (32.1)
	A Litte Improvement	5/24 (20.8)	1/15 (6.7)	4/28 (14.3)
	No Improvement	0 (0)	0 (0)	0 (0)
	Unsure	1/24 (4.2)	0 (0)	0 (0)
Question 5	Very Good Improvement	3/24 (12.5	5/15 (33.3)	6/28 (21.4)
	Good Improvement	12/24 (50.0)	5/15 (33.3)	11/28 (39.3)
	Moderate Improvement	3/24 (12.5)	3/15 (20.0)	5/28 (17.9)
	A Litte Improvement	4/24 (16.7)	2/15 (13.3)	6/28 (21.4)
	No Improvement	0 (0)	0 (0)	0 (0)
	Unsure	2/24 (8.3)	0 (0)	0 (0)
Question 6	Strongly Agree	3/24 (12.5)	4/15 (26.7)	2/28 (7.1)
	Agree	18/24 (75.0)	9/15 (60.0)	21/28 (75.0)
	Unsure	3/24 (12.5)	2/15 (13.3)	4/28 (14,3)
	Disagree	0 (0)	0 (0)	1/28 (3.6)
	Strongly Disagree	0 (0)	0 (0)	0 (0)
Question 7	Strongly Agree	3/24 (12.5)	4/15 (26.7)	1/28 (3.6)
	Agree	16/24 (66.7)	11/15 (73.3)	22/28 (78.6)
	Unsure	5/24 (20.8)	0 (0)	3/28 (10.7)
	Disagree	0 (0)	0 (0)	2/28 (7.1)
	Strongly Disagree	0 (0)	0 (0)	0 (0)
Question 8	Strongly Agree	2/24 (8.3)	3/15 (20.0)	3/28 (10.7)
	Agree	15/24 (62.5)	9/15 (60.0)	17/28 (60.7)
	Unsure	4/24 (16.7)	2/13 (13.3)	4/28 (14.3)
	Disagree	3/24 (12.5)	0 (0)	4/28 (14.3)
	Strongly Disagree	0 (0)	1/15 (6.7)	0 (0)

Future approaches for developing integrative thinking questions

The 5-point Likert scale answers to questions 9 to 11 and 14 are presented below

Regarding the following, what would further encourage you to create links between the science and practice teaching on the MPharm programme?

Question 9 … more case based workshops with relevant science and practice information?

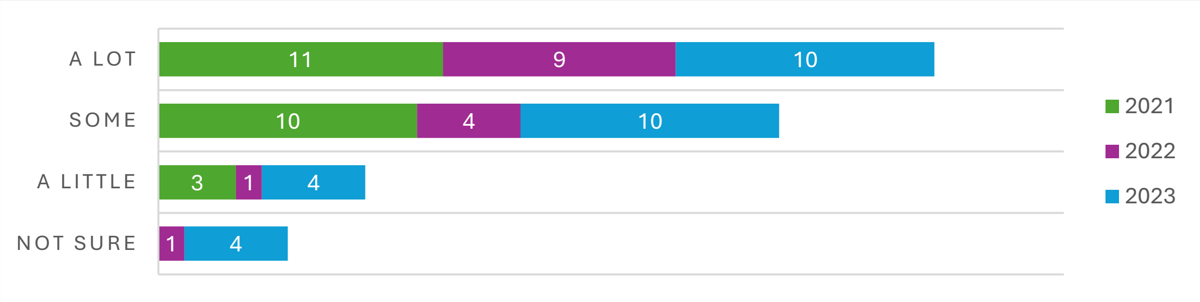

Figure 25- Question 9 answer summary for all cohorts

Question 10 …co -teaching sessions with science and practice lecturers?

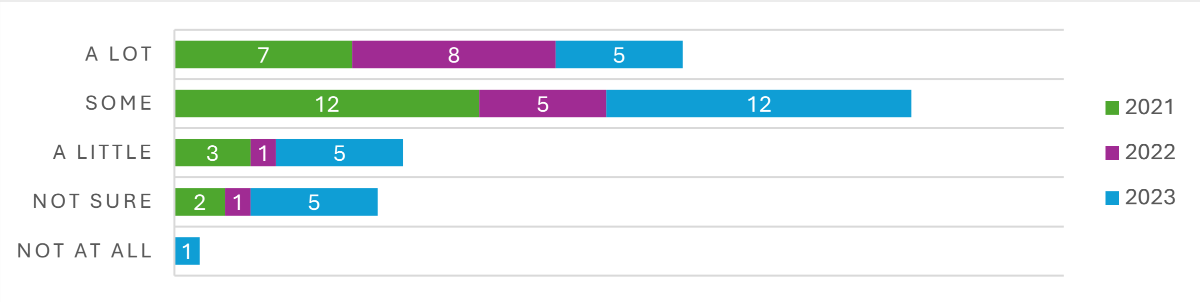

Figure 26 - Question 10 answer summary for all cohorts

Question 11 …assessments which require you to use both science and practice learning?

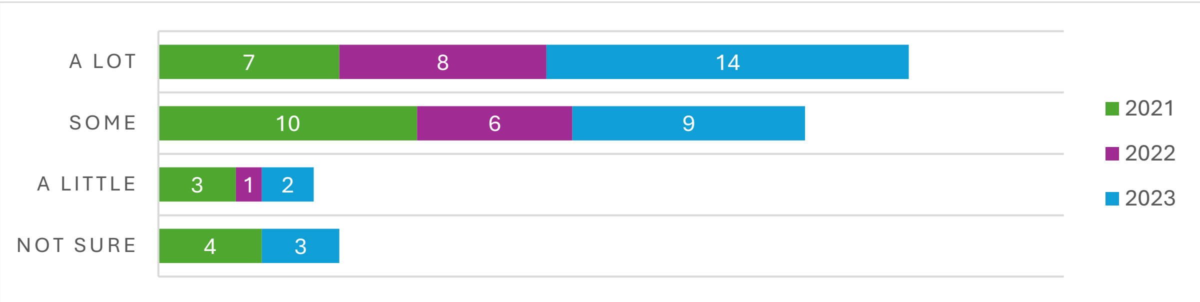

Figure 27- Question 11 answer summary for all cohorts

Question 14 My attitude regarding the relevance towards science and chemistry and patients has changed following these workshops

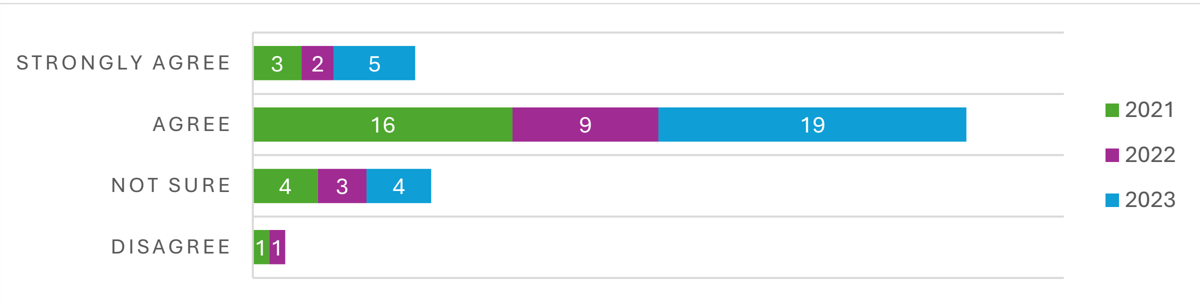

Figure 28- Question 14 answer summary for all cohorts

Table 33- A summary of the data for questions 9- 11 and 14 across the cohorts

Question	Answer options	**2021** No. of students answering/No. of students in cohort (%)	**2022** No. of students answering/No. of students in cohort (%)	**2023** No. of students answering/No. of students in cohort (%)
Question 9	A lot	11/24 (45.8)	9/15 (60.0)	10/28 (35.7)
	Some	10/24 (41.7)	4/15 (26.7)	10/28 (35.7)
	A little	3/24 (12.5)	1/15 (6.7)	4/28 (14.3)
	Not sure	0 (0)	1/15 (6.7)	4/28 (14.3)
	None at all	0 (0)	0 (0)	0 (0)
Question 10	A lot	7/24 (29.2)	8/15 (53.3)	5/28 (17.9)
	Some	12/24 (50.0)	5/15 (33.3)	12/28 (42.9)
	A little	3/24 (12.5)	1/15 (6.7)	5/28 (17.9)
	Not sure	2/24 (8.3)	1/15 (6.7)	5/28 (17.9)
	None at all	0 (0)	0 (0)	1/28 (3.6)
Question 11	A lot	7/24 (29.2)	8/15 (53.3)	14/28 (50.0)
	Some	10/24 (41.7)	6/15 (40.0)	9/28 (32.1)
	A little	3/24 (12.5)	1/15 (6.7)	2/28 (7.1)
	Not sure	4/24 (16.7)	0 (0)	3/28 (10.7)
	Not at all	0 (0)	0 (0)	0 (0)
Question 14	Strongly Agree	3/24 (12.5)	2/15 (13.3)	5/28 (17.9)
	Agree	16/24 (66.7)	9/15 (60.0)	19/28 (67.9)
	Unsure	4/24 (16.7)	3/15 (20.0)	4/28 (14.3)
	Disagree	1/24 (4.2)	1/15 (6.7)	0 (0)
	Strongly Disagree	0 (0)	0 (0)	0 (0)

7.3.4 Qualitative comments from questions 12, 13 and 15

Table 34- Questionnaire comments on students' thoughts on the workshops

Cohort	Free text comments from questions 12 and 15
2021	"I was able to link content in these workshops to other modules" "I can apply my knowledge in identifying interactions, how drugs work at different sites and how they are designed to fit its purpose" "I would like more Practice sessions to link both science and practical knowledge" "I would have preferred to have a session face to face and have social interaction with others instead of breakout rooms" "[The workshops] help creating the links between the science and the reality of medicine. I personally view each module individually and struggle creating links." "They were great, I wish there were more so we could cover more topics and cover more links between modules."
2022	"Very interactive and helpful sessions which help breakdown lectures and help us better understand some topics" "My learning has definitely improved with the sessions and being able to go back and watch the recorded workshops in order to fully understand what it is we went through" "More practical scenarios and real-life situations in a pharmacy setting which we can apply our knowledge to [would be helpful]"
2023	"Love your sessions they are very interesting and extremely informative! Thank you so much for being so clear in the way you articulate information, it really helps me understand on the spot rather than rethinking about this at home" "I like the drugs we discus in the workshop, it helps in the other module when we talk about diseases and symptoms. From there I can relate the drug with the diseases and helps in revising" "I learn a lot in workshops in terms of how the drug works and the how we should educate the patient" "Its good it is [taught] in smaller groups"

Table 35- Questionnaire comments on barriers to integrative learning

Cohort	Free text comments from questions 13
2021	"Not being in the lecture hall can be seen as a barrier because we cannot approach them directly and using email can be ineffective for asking some questions" "It would be nice if other modules could refer to other modules when relevant links come up in the actual lectures."
2022	"I don't particularly enjoy organic chemistry"
2023	"Some content taught in workshops such as The Patient module consist of lots of complex information not learnt in the lectures. This can be confusing." "It is a lot of information"

7. 4 Explanation of results

7.4.1 Discussion of finalised teaching intervention

The final design of the workshops aimed to encourage students to think in an integrative manner rather than thinking in modular silos through an integrated case-based design. Working in groups, they aimed to facilitate student engagement and understanding across all the modules. These integrated workshops were structured differently to those already published in the literature. They were designed to be very much patient focused, written and facilitated by a registered pharmacist but with input from chemistry and pharmaceutics academic staff. The tasks were designed for students to answer as though they were already practising pharmacists. Each workshop started with the patient at the core of the discussion and concepts were discussed in terms of the impact they would have on the patient. Explanations and justification were always linked to the patient. It was also tailored to one university's specific MPharm curriculum and cohort (i.e. the University of Hertfordshire), with clear links to corresponding teaching on other modules which were referred to by module and specific lecturer by name. This gave the students confidence that the curriculum was intentionally planned with effective co-ordination and integrated topics. The distinction was also clearly made when relevant co-ordinating teaching had already been delivered, and for any content that would be addressed further in future teaching.

There was a focus on practising communication too with the importance of how students could use their underpinning science in their explanation to the patient. The importance of explaining 'why?' was emphasised. Although relating to nursing rather than pharmacy, there is evidence that patients have more confidence in their healthcare practitioners when they can explain their treatment technically (Abdel Maqsood et al., 2012). A qualitative study involving qualified nurses (Montayre et al., 2021) also found the nurses felt more confident in themselves when they understood underpinning science knowledge and its relevance, using it in their explanations to patients.

There is a considerable amount of published literature examining how science should be taught and incorporated into a range of healthcare degrees. For example, Bandiera et al., (2013) considered the place of science with the medical curriculum. They concluded that although science needs to be introduced early in the degree, it needs to be appropriately linked to clinical knowledge and its role in supporting clinical reasoning should be emphasised. They advised using appropriate and effective teaching strategies (like case based and problem-based learning) and advocated for intentional repeated integration, utilising the principles of the spiral curriculum (Harden, 1999). Although there has been research into integration and how this may be modelled successfully in pharmacy programmes (Husband et al., 2014; Kerr, 2000), there is less literature regarding specific chemistry and science content. Topics within chemistry related to drug structure and activity are clearly relevant to pharmacy. Contextualising chemistry highlights the importance and relevance of science which has been found to have a positive impact on students' experience (Fergus et al., 2019). Using contextualised cases allows the emphasis of the application of science in clinical practice and structuring the teaching of chemistry in this way can also allow students to practise these skills (Fergus & Kostrzewski, 2011). The understanding of medicinal chemistry allows students to develop an understanding of drug action which can be utilised when making clinical decisions for patient care (Wall et al., 2022). Although there are currently no published chemistry concepts for pharmacy, several articles were reviewed when planning the workshops and considering the concepts to include (for example Alsharif et al., 1999; Faruk Khan et al., 2011; Trippier, 2018). It is hoped that future work will create a consensus for core chemistry concepts for pharmacy, like this concept list for nursing students which highlighted topics most relevant to clinical practice (Brown et al., 2012).

7.4.2 Discussion of the questionnaire data analysis in relation to research questions

Two research questions were investigated as part of this study and analysis of the student questionnaire helped to ascertain the answers. The first research question was:

- Does the use of science concept driven teaching have an impact on a 1st year MPharm student's ability to recognise the importance of chemistry to clinical pharmacy practice?'

The results from the questionnaire across all three cohorts surveyed demonstrate that this teaching did encourage students to realise the importance of the chemistry that underpins their practice knowledge.

Rather than asking about their enjoyment and engagement with the teaching which has been done with previous case study evaluations, the questions in section B asked students to reflect on their own skills development and improvement using a Likert scale. The majority of students found their understanding of the relevance of functional groups and drug absorption had increased. Question 3d which asked about the connection between functional groups and side effects showed the lowest level of improvement, but the majority of the students still felt they had improved in this area with 82% across the three cohorts stating they had at least a little improvement. Students were invited to explain their answers to these questions or give examples but very few students did this. It is therefore not possible to objectively state what improvements they had in understanding, but it is important to note that from their own reflections, understanding of side effects and drug absorption was rated the lowest out this set of questions.

Question 14 asked the students to reflect on their attitude with 81% of students (across all cohorts) agreeing or strongly agreeing that their attitude towards the relevance of chemistry had changed since the teaching sessions. Previous research on chemistry teaching approaches has also shown improved perception of relevance when the links between chemistry and clinical practice are explicitly demonstrated (Roche et al., 2004). Appreciating the relevance of a subject has been shown to be a key factor in motivating students (Kember et al., 2008) although it is acknowledged that solely increasing motivation does not equate to increased attainment.

Two free text questions gave the students the opportunity to provide any further relevant thoughts on the teaching. Although there were few free text comments written by participants, these were all reviewed and analysed with the comments being overwhelmingly positive. The students stated that they found the teaching beneficial and it improved their understanding. These case studies were often examining material and concepts these students had already been taught and allowed them to apply it to a clinical situation. This can be considered self-testing or retrieval practice which can support longer retention of study material as well as consolidating learning and improving understanding (Roediger & Butler, 2011).

The second research question was:

- Does the use of science concept driven teaching have an impact on a 1st year MPharm students' ability to create links between and apply their knowledge across the programme?

Section C of the questionnaire asked participants about the development of their integrative thinking skills. Although students did feel the skills had improved, their responses do not suggest that they can confidently create links independently throughout teaching without sufficient scaffolding. With questions 4 to 7, the majority of students did positively reflect on improvements. Participants felt they had improved in terms of applying some of the knowledge and understanding developed from the workshops across their other modules as well as connecting concepts across other modules.

However, question 8 asked if they now automatically create links between modules. Students were less confident with this statement, with 73% agreeing or strongly agreeing with this statement and 12% disagreeing or strongly disagreeing (across the cohorts). (15% of participants were still unsure on their ability to do this). This question has a lower percentage of participants agreeing or strongly agreeing with the statement compared to earlier questions in this section.

The students were also asked to consider which other teaching and learning strategies would be helpful. They were positive about all three options given, which were more specifically integrated teaching in the style of case studies, co-teaching and integrated assessments. The perceived usefulness of more case-based teaching was also mentioned in the free text comments. It is noted that requesting more scaffolded teaching to highlight integration could suggest that students struggle with the concept of independently creating links between science and practice teaching. There may not be an appreciation that the skill of application is meant to be performed independently once mastered. However, it is noted that these students are only in the first year of the programme so this awareness may develop later in the course. This does though, support the case for specifically teaching students about cognitive theories and how knowledge and skills are developed and assessed throughout the degree.

The free text questions were reviewed in relation to this research question. Question 13 gave students the opportunity to highlight any barriers they perceived in relation to thinking integratively. There were few responses, but it was noted that the 2023 cohort comments seem to indicate an issue with cognitive overload in individual sessions on other modules. Acknowledging the limits on the working memory (Cowan, 2012) when teaching is pivotal and should be considered when designing teaching sessions including the complexity of tasks and new material (Kirschner, 2002). Whilst the importance of students taking responsibility for their own learning was acknowledged with this teaching intervention, the tutor still provided scaffolding and guided support to successfully develop their critical thinking skills (Greening, 1998). This acknowledged they were in their first year of study and aimed to encourage and support them to help prevent cognitive overload.

There was a comment regarding online teaching. In terms of context, the first-year students during the COVID pandemic did not have a 'typical' university experience and the frustration about the lack of social interaction has been reported elsewhere in the literature (Leal Filho et al., 2021). One student did say they would be less likely to contact the lecturer online. However, previous literature suggests that students do not feel confident in asking questions in lectures (Donovan & Erskine-Shaw, 2020). It is noted that during this part of the data collection, the COVID-19 pandemic had a significant and sustained impact on how teaching and assessment were delivered in higher education settings. A delay to data collection was considered and discussed with supervisors. As it was unclear how long restrictions and adaptions would be in place as well as what the post COVID-19 educational landscape may look like, it was decided that it would be sensible to carry on. How best to teach these case studies in the COVID-19 era was planned in detail. For one cohort of this data, students were taught online. This could potentially have an impact on their engagement and interaction. The way it would be taught was discussed with supervisors who had significant experience in teaching and adaption during COVID-19 (Fergus et al., 2020). The researcher also discussed with her first year personal tutees, to informally gain an insight into their lived experience from being taught online during a pandemic with no other experience in higher education. The students had found the lack of social interaction which made making new friends the most frustrating part of first year. They stated breakout rooms during online teaching did encourage engagement with teaching but did not help them make friends, which was a continued source of concern for some of them.

7.4.3 Student involvement with the development of the case studies

The rationale for this approach was that student involvement would be valuable but in reality, they found it difficult to write case studies at the correct level and they also tended to write questions which were in silos rather than fully integrated. It is acknowledged that this was perhaps an unrealistic task given their experience. Synthesising new information, like writing a new case study, is considered a complex higher order cognitive task (Anderson et al., 2001). In addition to this, integrative thinking without scaffolding is not automatically achieved by pharmacy students even though they may study an integrated pharmacy programme (Mawdsley et al., 2019). In addition, the students had not undergone any sort of teacher training. Academic staff are required to study towards a specific post graduate teaching qualification if they have a teaching contract, which supports them in learning how to prepare teaching material. In order to prepare high quality teaching, pedagogical knowledge is beneficial (Shulman, 1986) as well as subject and concept knowledge, so it is not unexpected that this was a difficult task for untrained students.

An alternative could have been to use ‘real’ case studies from the literature and adapt these to integrated inter-disciplinary cases following the approach taken by Fernandes, (2018). However, that would have also been a complex task to ensure these highlighted appropriate concepts and were appropriate disease states and drug structures.

Some of the academic staff across the disciplines provided feedback on the written case studies and they admitted to finding it challenging to review due to their integrated nature. It needs to be acknowledged that integration can be complex and a sensible approach to preparing high standard integrated teaching is to work together as a multi-disciplinary team. There is evidence that qualified practitioners find it difficult to effectively use their underpinning science. Some qualitative research from qualified nurses identified they found it challenging to explain the underpinning science concepts in relation to clinical scenarios to their students (Clancy et al., 2000). It is noted that if their previous education has not prepared these academics and practitioners to think integratively, then it will be challenging for them to teach their own students at university or on placement with the underpinning science.

7.4.4 Limitations

The questionnaire response rate was disappointing although not wholly unexpected and like other educational surveys, acknowledges there are a range of reasons for not responding (Porter & Whitcomb, 2005). As the module spanned two semesters, the teaching was spread throughout the year. Scheduling the workshops perhaps weekly or fortnightly followed by a questionnaire may have resulted in a larger collection of data. However, the scheduling was intentional, with one of the reasons being to allow students to have time to reflect and create links on their own, which would not have been possible if the teaching had been scheduled together.

A further limitation is the lack of an objective measure to evaluate the students' ability to integrate material. Although the module was assessed as part of the end of module test, the workshop material formed a very small part of this test, so its analysis was intentionally not included in the ethics application. There is also other integrated teaching in first year so any improvement in integrative skills could not be solely attributed to this teaching alone. A type of chemistry concept inventory test (similar to (Barbera, 2013) could be designed specifically for pharmacy students to provide a more objective measure. This could form part of the future work after completion of this doctoral thesis building on research already completed by the supervisory team (Fergus & Hitch, 2014).

Although the researcher is satisfied that analysis carried out is detailed and self-contained, there could be further work done. To determine any statistically different outcomes according to cohort and potentially the impact of COVID-19 on teaching and learning, a statistical test like the Kruskal- Wallis H test could be used.

7.4.5 Reflective account from the researcher

Working with the student researchers to plan the workshops was very useful to consider the presentation from a student's perspective and it was interesting to see they focused on relevance and future career goals (like the identified theme in an earlier chapter).

The response rate to the questionnaires was disappointing, but there are potential reasons for that. Students were given many questionnaires to complete and it is possible that they had 'questionnaire fatigue' (Ghafourifard, 2024). They were happy to chat at the end of the sessions to explain how useful they found them but did not take time to complete the questionnaire at the end of the final session. On reflection, collecting at the end of each session as well as the final session may have been helpful but again no guarantee there would have been an improved response rate. I had also only taught them for those three workshops in first year so had less time to build up a rapport with them when compared to leading a module for the whole cohort.

The comments from other staff when reviewing made me realise that writing integrated cases within one discipline is less effective and we need to use the strengths across the disciplines more effectively. It should be standard practice to ask for support, and it will make the cases better and more integrated rather than feeling as though as an academic you already have all the sufficient knowledge.

7.4.6 Summary of phase three

This teaching intervention was evaluated by considering the students' own perceptions of their learning gains. Their responses highlighted the importance of integrating chemistry and formulation science in pharmacy practice and its relevance as part of the curriculum. Many students felt they were now able to think integratively without the direct scaffolding following the workshop series. This was not consistent across the participants however, and so it is not yet an instinctive way of thinking and performing tasks despite the short intervention. The transfer of science knowledge to clinical reasoning is acknowledged as a crucial element of many healthcare professions education structure (Castillo et al., 2018). Without contextualised teaching, students do struggle to apply their science knowledge into clinical contexts (Norman, 2009) and teaching needs to be appropriately adapted to facilitate this transfer.

The evolution of this teaching interventions explored the students' own experiences but cannot demonstrate an objective improvement in application skills. Further research needs to be carried out to determine whether specific teaching methods are able to categorically improve these abilities needed for future practice.

Chapter 8 – Conclusions, reflections, recommendations and future work

8.1 Introduction

This chapter provides a summary of the key findings from this research in relation to the overarching research questions introduced in chapter one and highlights the contribution to the existing literature. It reflects on the methods used, the study's limitations and presents key recommendations. It also discusses future work that may be carried out following this PhD study.

This doctoral study explored staff and students' perceptions of chemistry in the context of the pharmacy degree as well as analysing possible factors affecting engagement and attainment in a first-year chemistry module. Finally, it considered what teaching approaches could be developed to further support and foster pharmacy students' understanding and application of chemistry within the pharmacy context. Although chemistry education research is well established, there has been much less research in the context of non-chemistry degrees especially pharmacy. This paucity of research, alongside the novel research approaches utilised in this thesis, results in a meaningful contribution to the literature in this area.

8.2 Summary of the background to this doctoral study

As a profession, pharmacy has a traditional foundation in scientific principles, but its identity now has an increasingly significant clinical component. There have often been differing opinions over the years within the profession regarding the emphasis, teaching and assessment of these elements (Faruk Khan et al., 2011; Smith & Darracott, 2011). Although historically chemistry has been at the core of pharmacy undergraduate education across the globe, more recently, it has become more patient focused in its curriculum whilst aiming to maintain the underpinning fundamental chemistry and science (Skau, 2007). Pharmacy regulatory bodies across the globe continue to prioritise the importance of science within the curriculum in their educational standards (ACPE, 2025; CCAPP, 2020; GPhC, 2021). With the continued clinical expansion of the pharmacist role, there has been a change in emphasis of pharmacy curricula to include both new clinical content as well as traditional science elements. Including chemistry in the right context within the degree ensures that its role and its importance in underpinning clinical knowledge is clearly acknowledged.

Chemistry is a complex and wide-ranging subject which has logical, intricate rules to follow and multiple concepts, but when understood, will allow the student to problem solve unseen cases and issues (Johnstone, 1991). When taught in the relevant context, this understanding can be used to critically evaluate and justify clinical decisions (Wall et al., 2022). A better understanding of chemistry's fundamental principles is needed for deeper learning to develop both problem solving and application skills. Focusing on teaching methods which incorporate relevance, contextualisation and active learning may help the development of these skills.

8.3 Summary of the research approaches in this study

A mixed methods approach was selected to utilise both qualitative and quantitative data collection and analysis. This methodology (described in chapter 3) allowed the research questions to be addressed fully and provided a greater breadth and depth to the study that may not have been achieved with only one approach (Bazeley, 2018). It recognised the lived experiences of both staff and students as well as statistically analysing relevant assessment results are important in elucidating a rich picture which can provide insight into the nature of how students learn integratively. This mixed methods research allowed more precise and detailed identification of the issues than in previous research, and these findings were then used to inform the planning of a teaching intervention (Cresswell & Plano Clark, 2018).

A sequential model was selected as most appropriate and realistic for this study with multiple phases needed to allow for a full exploration of the research questions as well as a suitable evaluation process for the impact of a teaching support intervention (Cresswell & Plano Clark, 2018; Tashakkori et al., 2021).

Having students as partners (Bohnacker-Bruce, 2019) in some of the data collection was also a key component of this doctoral study. Although this required careful planning and time management, their involvement was found to be very valuable. Even though the researcher was a previous pharmacy undergraduate student, it was acknowledged that lived experience in Higher Education now is very different to the 1990's, so these students provided helpful awareness of current issues. They provided thoughtful insights into the question development of the research tools and their engagement and enthusiasm were greatly appreciated. On reflection, the students enhanced the richness of the data collection and the authenticity of the approach.

This study approach has many strengths but there are weaknesses and limitations linked to each study phase. The strategies for maintaining the quality and rigour of the research as well as limitations were discussed in Chapter 3 (section 3.16 and section 3.17) and in each individual results chapter. Reflections on any weakness of the data collection are also considered here.

Like most research, this doctoral study does have some limitations. This study was conducted at only one site (University of Hertfordshire) and in its entirety for only one programme of study (MPharm). Although there was only one programme, studies were conducted in several year groups and multiple cohorts were involved in the research over several years which granted a deeper exploration of perceptions across students registered on the programme over a longer time period. In addition, the number of universities offering an accredited pharmacy programme has increased significantly since the 1990s and the University of Hertfordshire does represent one of these newer universities with a higher level of support for widening participation students. This is one of the reasons that this represents a novel contribution to the literature as these universities have been less involved in education research previously.

Throughout all phases of this study, there were a high ratio of female to male participants, but this does reflect the gender distribution of the pharmacy programme at the University of Hertfordshire and is reflective of the gender profile within the profession (GPhC, 2025b) so was a representative sample of the population being researched. Although a small sample size when compared to the total pharmacy student population, the results do offer useful insights in this specific population and can be used to improve the pharmacy education approach. This can be applicable to this specific university and its curriculum design.

8.4 Summary of findings for each research question

The literature review followed by the research from phase one and two informed phase three of this study, the design and development of a teaching intervention for students to support their learning of chemistry with both application and understanding. The findings from all phases are summarised in relation to each of the overarching doctoral study research questions and are presented below.

8.4.1 Research Question 1

What influences students' understanding and application of knowledge of chemistry within the MPharm degree?

This question was answered via both qualitative and quantitative data collection and analysis. Several interesting findings and themes were identified from these studies.

Teaching which has a clear relevance and is taught in a pharmacy context were themes identified in both staff and student interviews. In terms of application and understanding, students repeatedly highlighted the importance of relevant context in teaching and how this facilitated learning from their perspective. The pharmacy students felt more interested when they believed the teaching to be relevant, however, their perceptions on what was relevant was found to be subjective. Staff also noticed a positive change in their interest when topics were clearly contextualised and relevant to specific pharmacy sectors. In addition, students seemed to demonstrate understanding when they discussed seeing a chemistry concept applied in practice during a range of their own experiences in the workplace. With this insight, ensuring the chemistry taught is clearly contextualised to practice examples is likely to have an impact on understanding of this knowledge.

The importance and impact of prior knowledge was an identified theme within the staff interviews that were conducted. Although this was not discussed in student interviews, the statistical analysis from the PeerWise and midterm test also linked to this theme. Students on the Master of Pharmacy programme performed better on the midterm test as well as gaining higher scores in the PeerWise tool when compared to students on the Bachelor of Pharmaceutical Science programmes. (The MPharm programme has higher entry requirements, so students arguably have a higher level of prior knowledge). The PeerWise task required students to understand chemistry concepts and apply this knowledge; this understanding and application was then also required when completing the test so makes the analysis well aligned to addressing this research question.

There were no single demographic factors identified which demonstrated a marked difference in contribution to the tasks. Mature females did appear to engage more with the PeerWise tool, but this did not translate to a higher score in the test. Differences within some ethnicities were also seen when looking at further subsets of age and gender. Some of these students were clearly contributing well to the formative task but this contribution did not translate to a better performance in the summative test.

These distinctions did not reflect national data with reference to differences in degree outcomes (OfS, 2024). Reflecting on these findings, it needs to be considered whether some students are being disadvantaged by the type of tests being used when the homework task suggests they have knowledge and understanding but this is not reflected in their summative test. One further explanation could be the complexity of questions written and answered in the PeerWise tool when compared to the midterm test. Previous research has shown that writing and answering only recall questions was not beneficial in summative assessments, but writing higher level questions showed a positive correlation in academic performance (Hudson et al., 2018).

It is also important to consider the impact assessment marks have on students. Harlen & Deakin Crick, (2002) reviewed the impact of assessment looking at 183 studies (at a school level rather than university level) and found that low test results lowered self-esteem and re-enforced low self-image in these students. A lack of understanding of an assessment, rather than a lack of understanding of the subject matter can have a negative impact on performance. Rust et al., (2003) conducted an intervention to improve student understanding of assessment criteria. This project found that the intervention improved the students' understanding of the assessment process and its corresponding criteria which resulted in an improved assessment performance.

The theme of learning approaches is also important in answering this research question. Students discussed the importance of understanding, which was also an identified theme, however students explained that they adapted their learning approach depending on the assessment. With the MPharm degree, ensuring chemistry is assessed in a way that requires application and also actively engaging students with assessment criteria may have a positive impact on performance and learning. It is important that the teaching and assessment are clearly aligned so expectations are clear when problem solving skills rather than basic recall are required to be successful in assessments.

8.4.2 Research question 2

What are MPharm students' attitudes towards the relevance of chemistry within the MPharm degree as well their motivation and most effective ways to learn and understand chemistry?

Students consistently highlighted the importance of relevance in both individual interviews and in the focus groups. However, students' specific perceptions of what topics were relevant were highly individualised and appeared to be influenced by external factors as well as their degree course and how it was taught. When describing relevance, students often linked it to their own circumstances and experiences. This variety of perceptions was seen even within the same year of study and was influenced by their work placements and their own current future career choices. Students appreciated clear contextualisation within the curriculum and explicit links to how and why material was relevant.

Students' motivation was clearly linked to their perceptions of relevance to practice and how teaching could be beneficial to them in future careers. Although through interactions in the focus groups, they acknowledged that relevance could be interpreted in different ways, depending on which pharmacy sector a student wished to work in.

Students talked about changing the way they studied at university compared to secondary education and described what they thought was effective for them. They did seem to use retrieval practice less at university, possibly having been used to the abundance of past papers during preparation for national examinations. The teaching of evidence-based and effective strategies is important for the development of understanding, so how to study effectively is now taught in the programme (due to separate research distinct from this doctoral study).

The overarching concepts of integration and contextualisation and how a curriculum may be designed to support developing understanding in this area was explored. Students continued to highlight relevance as a motivating factor for them as well as any assessment requirements influencing the depth of their learning approach. The results showed that students did not fully understand thinking in an integrative manner and indicated they would benefit from more scaffolding earlier on in the programme (as well as focused assessments to potentially encourage deep learning approaches).

This research suggests that the structure of the curriculum does not appear to encourage students to identify relevance themselves. Like previous research, students seem to need more scaffolding to understand the relevance as well as how to create the links between disciplines from the beginning of the programme and as a conscious continuous approach throughout their studies (Bandiera et al., 2018). Assessments should be integrated to allow students to demonstrate these skills and learn how to continue to develop and improve them (Mawdsley & Willis, 2019). It is important to acknowledge that not everything can be taught but conceptual understanding and the development of problem-solving skills and critical thinking skills is imperative (Angelo et al., 2022).

One way of ensuring relevance is clearly highlighted through a programme can be through the integrative approach to curriculum design. Whilst integration has been a requirement for pharmacy degrees in line with educational standards (GPhC, 2011, 2021), there are numerous perspectives on how it should be carried out effectively (Harden, 2000; Husband et al., 2014) but there is no nationally accepted definition for best practice (Kerr et al., 2020) or evidence to show it objectively improves educational outcomes (Nazar et al., 2019). There is a risk that with the additional pressure of independent prescribing requirements, integration takes a lower priority on the degree programme. However, it is important that this is avoided, as integration is a key factor in building critical thinking skills and demonstrating understanding so prescribers can justify their decisions (Abuzour et al., 2018). Rather than focusing on the design of integration, developing the integrative thinking skills needs to remain a priority.

Development of integrative thinking skills was explored further and is discussed when addressing support strategies in research question 4. However, the potential integrative nature of chemistry practicals were not explored in that phase, so it warrants further discussion here following analysis of student interviews and focus groups. It is clear that a student's own interpretation of relevance motivates them in their studies. Ensuring the perspective of relevance is considered when planning chemistry teaching may have an impact on overall motivation. For example, the skills learned and mastered within a laboratory like manual dexterity and record keeping are transferable and relevant in clinical pharmacy practice. If this is explicitly highlighted to students, arguably they are more likely to appreciate this important link.

Students specifically highlighted two practicals in the programme that they found effective in developing their understanding. These were aspirin synthesis (Olmsted, 1998) and pH absorption practicals (Hickman & Neill, 1997) and students highlighted how this supported their understanding of important concepts. The design and delivery of practicals within the MPharm could be reviewed with this in mind. Dube, (2018) designed a set of laboratory classes which linked concepts to the theme of drug action and drug discovery. The structure ensured that the relevance was clear and meaningful to her students studying on non- major degrees, which would be transferable to the MPharm students. Consideration of how to ensure learning within the laboratory is effective is important with acknowledgement of the relevant pedagogy. Seery et al., (2024) have reviewed this evidence and presented ten principles to support learning and assessing in a laboratory environment.

8.4.3 Research question 3

What do University of Hertfordshire staff understand to be the student perceptions regarding chemistry on the MPharm programme?

Following the literature review, it was clear that there was very little in the current published literature that addressed academic staff perceptions and none were found specifically on this topic. Six staff members were interviewed, and several themes were identified from the discussions. Within the themes identified, four were common to both staff and students interviews with an additional three identified solely in the staff group.

Staff (and students) recognised the importance of relevance, with pharmacy students' continuing to emphasise their future careers when compared to their counterparts on non-vocational programmes. Staff noticed that the perceived relevance of the teaching material has a significant impact on student engagement in teaching sessions.

Staff also recognised the challenges created by a linear approach in secondary education due primarily to the pressures of national examinations. Without a spiral curriculum approach or similar to encourage revisiting of previous material and checking understanding, concept knowledge was found to be variable within the same cohorts which made teaching large groups challenging due to the very clear mixed abilities. Academic staff felt that students' prior knowledge and experience influenced their perceptions and expectations of chemistry at university.

The lack of confidence due to fear of being incorrect when in chemistry practical sessions was a prominent theme in this study which had not been identified in previous comparable literature. Staff differentiated this from any lack of motivation. Other chemistry academics have considered how to support students in developing laboratory skills and understanding in a risk-free environment. Blackburn et al., (2019) used a series of computer simulations with specific activities to be completed before the face-to-face laboratory practical which helped to improve confidence and attainment in their student population. The use of these types of simulations need to be more seriously considered for the MPharm programme.

Staff appeared to be discouraged by their perceptions of student attitudes towards chemistry. Teaching chemistry on a vocational programme may require a different teaching approach and understanding of the profession so more emphasis should be placed on supporting chemistry academic staff when moving from teaching on chemistry major programmes. Interestingly, teaching approaches were not specifically discussed by academic staff in the interviews. The development of pedagogical content knowledge will form part of the final recommendations from this study (Shulman, 1986).

Although not interviewed, academic staff were involved in reviewing and providing written feedback on some examples of the integrative case studies in phase three of this thesis. It was clear that some staff were more prone to thinking in silos of chemistry and practice. It is important that staff as well as students appreciate the importance of thinking integratively and work together more frequently to develop and deliver relevant and appropriately contextualised integrated teaching and assessments.

8.4.4 Research question 4

What strategies can support students' application of chemistry and integration with practice learning within the MPharm degree?

Firstly, the qualitative data collection and analysis explored themes which included discussion of support strategies. Staff felt that engagement and motivation was very much linked to relevance and students emphasised how important they perceived relevance alongside how it would support them in future pharmacy practice. Teaching which specifically uses relevant practice examples may be a helpful support strategy for students and was investigated further with the teaching intervention.

Although an integrated curriculum approach is a widely acknowledged strategy; it is still open to interpretation with is no agreed definition (Kerr et al., 2020). Topics can still be taught in silos at times with students needing to make the connections between science and practice themselves. This study suggests that some students may struggle to make these links themselves. There is clearly a need for a more nuanced strategy to support integrative learning than solely using a type of integrated curriculum as students did not appear to automatically create links, they may need to be specifically taught how to integrate.

During focus groups, students supported the concept of further case-based teaching to support them in developing and improving their integrative thinking skills. A series of patient-focused case-based workshops were designed with appropriate scaffolding and clear links to the specific relevant teaching across both science and practice.

Following the implementation of the integrated case-based workshops, a survey gathered perceptions on how the students felt the teaching had supported their ability to think integratively. It also asked them to consider what other approaches or strategies may continue to improve this skill. The students did perceive their ability to create links had improved and also stated they found the teaching improved their understanding, but they also would appreciate more scaffolding and support with this development.

The research conducted provided a valuable insight into their perceptions of integrative thinking although it did not objectively measure if there was any improvement. It is noted that this research question considered strategies that can *support* application rather than *improve* application. Investigating how to evaluate any objective improvement will form part of the future work following this doctoral study.

8.5 Recommendations

Based on the findings of all three phases of this study, some key recommendations are summarised below. These can be implemented at the University of Hertfordshire to support their pharmacy students' development of integrative thinking.

The underpinning science and chemistry should be incorporated into clinical teaching to help ensure that information is understood rather than rote learnt. For example, whilst teaching about clinical guidelines is imperative, this can be done without any understanding and requiring students to recall these without any underpinning knowledge as the sole reason behind clinical decision making is not a rational approach. The chemistry content of the programme should also be reviewed to ensure it is appropriately contextualised for relevant sectors of the profession, including industry, acknowledging that the pharmacy degree allows entry into all sectors of the profession and once qualified, staff do routinely switch between sectors. As discussed in the response research questions 2 and 3 (section 8.4.2 and 8.4.3), reviewing how laboratory practicals can support the development of this underpinning science knowledge and understanding is important. Staff reported a lack in confidence in practicals, with students noting the type of practicals they most engaged with were those with a clear pharmacy context.

Continued contextualised teaching and learning with clearly aligned assessments to test students' ability to integrate is a key recommendation. Students were clear that their learning approaches adapt depending on assessments. To encourage higher order thinking skills, students need to be taught and assessed in this manner. There is understandably a new focus on independent prescribing. It can be argued that this science underpinning provides some level of assurance and safety for potential patients. Students can be taught to problem solve and justify their prescribing decisions with their understanding of underpinning science.

It is important to acknowledge that it is not solely integration and contextualisation but the development of the higher order skills of integrative thinking, with the skills of analysing and solving new issues being a priority. Students need to be encouraged to think integratively and not compartmentalise their learning, using it all to solve clinical problems in a holistic manner. This skill is needed when qualified as a pharmacist. Discipline teams need to work together to develop patient focused integrated teaching to allow students to develop and practise these skills.

Direct evaluation of integrative assessments would be beneficial to ascertain if students do demonstrate understanding of underpinning science in relation to clinical practice. This evaluation could assess if they are able to use this knowledge to effectively problem solve and make clinical decisions.

In addition to using an overarching integrative curriculum design, the design of teaching within the programme should directly consider evidence- based educational theories to help support and improve learning outcomes (Tweddell & Purvis, 2025). With this in mind, staff development should focus on both pedagogical approaches as well as learning about new subject specific initiatives and advances.

8.6 Future work

In terms of future work, further integrated teaching interventions should be developed to continue to foster integrative thinking through each year of the MPharm in line with the increasing complexity of teaching in each year of study. This could be evaluated with pre and post testing to ascertain any impact on attainment. Although students responded positively to the teaching intervention in this study, their perceived learning gains need to be investigated further to see if there is any direct evidence of improved understanding.

8.7 Final Conclusion

This research highlights the importance of relevance and context in order to teach chemistry with understanding and application in the Master of Pharmacy programme. With the evolving healthcare system including more complex medication and technology and with the added responsibility of prescribing, pharmacists have more autonomy that ever before. This means they need to be confident with their own decision making, and with clear understanding of the underpinning science, this can help justify their prescribing choices. The importance of application and relevant context of chemistry for pharmacy students' needs to be emphasised. This understanding of the fundamental science supporting clinical practice is their unique selling point and an important contribution to the multidisciplinary team. This thesis adds to the literature base in this area, but further research is needed. It is required to establish the most effective teaching and assessment strategies to ensure pharmacy students can confidently and consistently apply this science knowledge in practice.

9. References

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Appendices

Appendix 1 – Further detail on chemistry within the modular MPharm structure

The figure below shows the current MPharm module structure at the University of Hertfordshire following the introduction of the 2021 GPhC educational standards (GPhC, 2020)

Figure 29- Modules within current MPharm programme at the University of Hertfordshire

This appendix aims to provide some additional context on the structure of the MPharm programme. It will help the reader understand where chemistry is taught, assessed and integrated within the programme. It is noted that significant levels of details could be potentially commercially sensitive, so some information is provided in broader terms where most appropriate. Information about admissions and the general course content is publicly available and can be found on this link:
https://www.herts.ac.uk/courses/undergraduate/pharmacy

Chemistry is a mandatory pre-requisite within the admissions criteria for the degree, with either a chemistry A level (or international equivalent) or a widening participation qualification like an Access course containing appropriate chemistry modules.

The programme contains modules adding up to total of 480 credits (as required for an integrated Masters degree (QAA, 2021). Each academic year contains four 30 credit modules in addition to one zero credit module which contains professional elements including placement attendance hours. All modules are compulsory and there are no optional modules. (Students may rank disciplines when being allocated projects in the third year). The descriptions of relevant teaching and assessments will be addressed in chronological order for each academic year from year one.

Year one

Level 4 has modules with a chemistry focus (Drugs and Medicines), a biology focus (The Patient) and a pharmacy practice and legal focus (The Pharmacist). The final credit bearing module is Transition to Higher Education, a module designed with a range of academic skills teaching as well as reflective writing skills in support of the students' professional development.

Drugs and Medicines was previously a chemistry focused module which co-taught with BSc Pharmaceutical Science. It has now been separated to allow a more pharmacy contextualised approach following student feedback from both programmes. It covers the fundamentals of pharmaceutical chemistry and pharmaceutics in relation to drug development, design and delivery. Assessment takes the form of a laboratory report (on an aspirin analysis experiment), and tests to check knowledge and understanding of the module. PeerWise continues to be used successfully in this module as formative support prior to the midterm test.

Although the majority of the chemistry is found within Drugs and Medicines, students do consider the science behind medicines in The Pharmacist, through consideration of formulations, side effects and interactions. The Patient module also has a focus on biochemistry in some laboratory practicals like glucose tolerance testing.

Year two

At level 5, the first three credit bearing modules contain pharmacology, pharmaceutics and chemistry teaching taught in a relevant contextualised manner. They consider drug action in relation to their chemical structure/activity relationships with their targets, their pharmacology in relation to mode of action and side effects as well as concentration and dilution calculations. Each module covers different disease states. Assessments include a QSAR assignment and an aseptics practical where sterile eye drops need to be prepared for a simulated patient with the associated paperwork and calculations. Knowledge and understanding is also assessed in mid-term and end of year exams. Support is provided in the form of workshops, voluntary drop ins and formative laboratory practicals. Additional support is provided for calculations.

The final credit bearing module ,Pharmacy Practice and Medicines, focuses on medicines management, considering the medical, legal and clinical aspects of prescriptions. Formulations and pharmacology matters are considered within this module too, so students do need to demonstrate their underpinning science reinforcing their pharmacy practice knowledge.

Year three

The two most relevant modules to consider at level 5 are Applied Therapeutic Interventions 1 and 2. These study different disease states with a focus on pharmacology, drug design and pharmaceutics as well as relevant evidence based guidelines. Students are required to demonstrate their science knowledge and understanding in clinical context with the end of module examinations.

Year four

Year four has a range of clinically focused modules which build in complexity from the earlier years, focusing on even more complex patients with multiple morbidities and polypharmacy issues. Following the introduction of the GPhC 2021 standards, modules discussing diseases have placed more focus on clinical decision making and prescribing. Additional placements and clinical simulations have been added to allow more practice of and development of clinical skills needed as a prescriber. Although still relevant when thinking of drug actions, side effects and formulations, it is evident that chemistry and science is less visible on the final year with the focus elsewhere.

Appendix 2 – Full data analysis from Chapter 4

Unadjusted odds ratios at 95% confidence interval

	Age						
	mature		young			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	20	9	39	49	2.79	1.1	6.8
author score	19	10	47	41	1.66	0.7	4.0
question answering score	19	10	40	48	2.28	1.0	5.5
total answer score	17	12	44	44	1.42	0.6	3.3
question rating score	18	11	42	46	1.79	0.8	4.2
progress test score	14	15	45	43	0.89	0.4	2.1
progress MCQ score	14	15	46	42	0.85	0.4	2.0
progress SAQ score	14	15	47	41	0.81	0.4	1.9

	gender						
	male		female			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	9	23	56	29	0.20	0.1	0.5
author score	14	18	52	33	0.49	0.2	1.1
question answering score	10	22	49	36	0.33	0.1	0.8
total answer score	11	21	50	35	0.37	0.2	0.9
question rating score	11	21	49	36	0.38	0.2	0.9
progress test score	14	18	45	50	0.86	0.4	1.9
progress MCQ score	17	15	43	42	1.11	0.5	2.5
progress SAQ score	16	16	45	40	0.89	0.4	2.0

	Females and age						
	mature females		young females			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	19	5	37	24	2.46	0.8	7.5
author score	16	8	36	25	1.39	0.5	3.7
question answering score	18	6	31	30	2.90	1.0	8.3
total answer score	16	8	34	27	1.59	0.6	4.3
question rating score	16	8	33	28	1.70	0.6	4.6
progress test score	11	13	34	27	0.67	0.3	1.7
progress MCQ score	11	13	32	29	0.77	0.3	2.0
progress SAQ score	11	13	34	27	0.67	0.3	1.7

	males and age						
	mature males		young males			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	1	4	8	19	0.59	0.1	6.2
author score	3	2	11	16	2.18	0.3	15.3
question answering score	1	4	9	18	0.50	0.0	5.2
total answer score	1	4	10	17	0.43	0.0	4.4
question rating score	2	3	9	18	1.33	0.2	9.5
progress test score	3	2	11	16	2.18	0.3	15.3
progress MCQ score	3	2	14	13	1.39	0.2	9.7
progress SAQ score	3	2	13	14	1.62	0.2	11.3

	Age and gender						
	mature females		mature males			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	19	5	1	4	15.20	1.4	168.0
author score	16	8	3	2	1.33	0.2	9.7
question answering score	18	6	1	4	12.00	1.1	129.4
total answer score	16	8	1	4	8.00	0.8	83.9
question rating score	16	8	2	3	3.00	0.4	21.7
progress test score	11	13	3	2	0.56	0.1	4.0
progress MCQ score	11	13	3	2	0.56	0.1	4.0
progress SAQ score	11	13	3	2	0.56	0.1	4.0

	Age and gender						
	younger females		younger males			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	37	24	8	19	3.66	1.4	9.7
author score	36	25	11	16	2.09	0.8	5.3
question answering score	31	30	9	18	2.07	0.8	5.3
total answer score	34	27	10	17	2.14	0.8	5.4
question rating score	33	28	9	18	2.36	0.9	6.1
progress test score	34	27	11	16	1.83	0.7	4.6
progress MCQ score	32	29	14	13	1.02	0.4	2.5
progress SAQ score	34	27	13	14	1.36	0.5	3.4

	ethnicity						
	all white students		all BAME students			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	8	8	49	48	0.98	0.3	2.8
author score	7	9	57	40	0.55	0.2	1.6
question answering score	7	9	50	47	0.73	0.3	2.1
total answer score	12	4	53	44	2.49	0.8	8.3
question rating score	9	7	49	48	1.26	0.4	3.7
progress test score	8	8	48	49	1.02	0.4	2.9
progress MCQ score	8	8	50	47	0.94	0.3	2.7
progress SAQ score	7	9	50	47	0.73	0.3	2.1

	ethnicity						
	Black Africian/carr		white			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	12	17	8	8	0.71	0.2	2.4
author score	14	15	7	9	1.20	0.4	4.1
question answering score	13	16	7	9	1.04	0.3	3.6
total answer score	13	16	12	4	0.27	0.1	1.0
question rating score	14	15	9	7	0.73	0.2	2.5
progress test score	13	16	8	8	0.81	0.2	2.8
progress MCQ score	16	13	8	8	1.23	0.4	4.2
progress SAQ score	15	14	7	9	1.38	0.4	4.7

	ethnicity						
	all Asian		all white			Confidence Interval	
	269ositive	negative	positive	negative	Odds Ratio	From	To
reputation score	24	24	8	8	1.00	0.3	3.1
author score	29	19	7	9	1.96	0.6	6.2
question answering score	24	24	7	9	1.29	0.4	4.0
total answer score	25	23	12	4	0.36	0.1	1.3
question rating score	22	26	9	7	0.66	0.2	2.1
progress test score	27	21	8	8	1.29	0.4	4.0
progress MCQ score	25	23	8	8	1.09	0.4	3.4
progress SAQ score	25	23	7	9	1.40	0.4	4.4

	ethnicity						
	all arab		all white			Confidence Interval	
	269ositive	negative	positive	negative	Odds Ratio	From	To
reputation score	9	4	8	8	2.25	0.5	10.4
author score	10	3	7	9	4.29	0.8	21.8
question answering score	9	4	7	9	2.89	0.6	13.5
total answer score	10	3	12	4	1.11	0.2	6.2
question rating score	7	6	9	7	0.91	0.2	4.0
progress test score	6	7	8	8	0.86	0.2	3.7
progress MCQ score	7	6	8	8	1.17	0.3	5.1
progress SAQ score	5	8	7	9	0.80	0.2	3.6

	ethnicity						
	all black		all asian			Confidence Interval	
	270ositive	negative	positive	negative	Odds Ratio	From	To
reputation score	12	17	24	24	0.71	0.3	1.8
author score	14	15	29	19	0.61	0.2	1.6
question answering score	13	16	24	24	0.81	0.3	2.0
total answer score	13	16	25	23	0.75	0.3	1.9
question rating score	14	15	22	26	1.10	0.4	2.8
progress test score	13	16	27	21	0.63	0.2	1.6
progress MCQ score	16	13	25	23	1.13	0.4	2.9
progress SAQ score	15	14	25	23	0.99	0.4	2.5

	ethnicity						
	all Black		all Arab			Confidence Interval	
	270ositive	negative	positive	negative	Odds Ratio	From	To
reputation score	12	17	9	4	0.31	0.1	1.3
author score	14	15	10	3	0.28	0.1	1.2
question answering score	13	16	9	4	0.36	0.1	1.4
total answer score	13	16	10	3	0.24	0.1	1.1
question rating score	14	15	7	6	0.80	0.2	3.0
progress test score	13	16	6	7	0.95	0.3	3.5
progress MCQ score	16	13	7	6	1.05	0.3	3.9
progress SAQ score	15	14	5	8	1.71	0.5	6.5

	ethnicity						
	all arab		all asian			Confidence Interval	
	271ositive	negative	positive	negative	Odds Ratio	From	To
reputation score	9	4	24	24	2.25	0.6	8.3
author score	10	3	29	19	2.18	0.5	9.0
question answering score	9	4	24	24	2.25	0.6	8.3
total answer score	10	3	25	23	3.07	0.7	12.5
question rating score	7	6	22	26	1.38	0.4	4.7
progress test score	6	7	27	21	0.67	0.2	2.3
progress MCQ score	7	6	25	23	1.07	0.3	3.7
progress SAQ score	5	8	25	23	0.58	0.2	2.0

	ethnicity/gender/age						
	white younger females		BAME younger females			Confidence Interval	
	271ositive	negative	positive	negative	Odds Ratio	From	To
reputation score	6	4	30	19	0.95	0.2	3.8
author score	4	6	31	18	0.39	0.1	1.6
question answering score	3	7	27	22	0.35	0.1	1.5
total answer score	2	8	31	18	0.15	0.0	0.8
question rating score	6	4	26	23	1.33	0.3	5.3
progress test score	3	7	29	20	0.30	0.1	1.3
progress MCQ score	3	7	28	21	0.32	0.1	1.4
progress SAQ score	3	7	29	20	0.30	0.1	1.3

	ethnicity/gender/age						
	white younger female		Black younger female			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	6	4	2	6	4.50	0.6	34.6
author score	4	6	4	4	0.67	0.1	4.4
question answering score	3	7	2	6	1.29	0.2	10.5
total answer score	2	8	3	5	0.42	0.1	3.4
question rating score	6	4	2	6	4.50	0.6	34.6
progress test score	3	7	4	4	0.43	0.1	3.0
progress MCQ score	3	7	4	4	0.43	0.1	3.0
progress SAQ score	3	7	6	2	0.14	0.0	1.2

	Programme specific cohort						
	MPharm		Pharm sci			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	47	41	12	17	1.62	0.7	3.8
author score	55	33	11	18	2.73	1.1	6.5
question answering score	44	44	15	14	0.93	0.4	2.2
total answer score	47	41	14	15	1.23	0.5	2.8
question rating score	44	44	16	13	0.81	0.3	1.9
progress test score	51	37	8	21	3.62	1.4	9.1
progress MCQ score	52	36	8	21	3.79	1.5	9.5
progress SAQ score	50	38	11	18	2.15	0.9	5.1

Unadjusted odds ratios at 90% confidence interval

	Age						
	mature		young			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	20	9	39	49	2.79	1.3	5.9
author score	19	10	47	41	1.66	0.8	3.4
question answering score	19	10	40	48	2.28	1.1	4.7
total answer score	17	12	44	44	1.42	0.7	2.9
question rating score	18	11	42	46	1.79	0.9	3.7
progress test score	14	15	45	43	0.89	0.4	1.8
progress MCQ score	14	15	46	42	0.85	0.4	1.7
progress SAQ score	14	15	47	41	0.81	0.4	1.6

	Education						
	A levels		widening participation			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	26	24	28	28	1.08	0.6	2.1
author score	30	20	31	25	1.21	0.6	2.3
question answering score	27	23	26	30	1.35	0.7	2.6
total answer score	25	25	32	24	0.75	0.4	1.4
question rating score	26	24	29	27	1.01	0.5	1.9
progress test score	27	23	28	28	1.17	0.6	2.2
progress MCQ score	28	22	26	30	1.47	0.8	2.8
progress SAQ score	28	22	27	29	1.37	0.7	2.6

	gender						
	male		female			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	9	23	56	29	0.20	0.1	0.4
author score	14	18	52	33	0.49	0.2	1.0
question answering score	10	22	49	36	0.33	0.2	0.7
total answer score	11	21	50	35	0.37	0.2	0.7
question rating score	11	21	49	36	0.38	0.2	0.8
progress test score	14	18	45	50	0.86	0.4	1.7
progress MCQ score	17	15	43	42	1.11	0.6	2.2
progress SAQ score	16	16	45	40	0.89	0.4	1.8

	Females and age						
	mature females		young females			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	19	5	37	24	2.46	1.0	6.3
author score	16	8	36	25	1.39	0.6	3.2
question answering score	18	6	31	30	2.90	1.2	7.0
total answer score	16	8	34	27	1.59	0.7	3.6
question rating score	16	8	33	28	1.70	0.7	3.9
progress test score	11	13	34	27	0.67	0.3	1.5
progress MCQ score	11	13	32	29	0.77	0.3	1.7
progress SAQ score	11	13	34	27	0.67	0.3	1.5

	males and age						
	mature males		young males			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	1	4	8	19	0.59	0.1	4.2
author score	3	2	11	16	2.18	0.4	11.2
question answering score	1	4	9	18	0.50	0.1	3.5
total answer score	1	4	10	17	0.43	0.1	3.0
question rating score	2	3	9	18	1.33	0.3	6.9
progress test score	3	2	11	16	2.18	0.4	11.2
progress MCQ score	3	2	14	13	1.39	0.3	7.1
progress SAQ score	3	2	13	14	1.62	0.3	8.2

	Age and gender						
	mature females		mature males			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	19	5	1	4	15.20	2.0	114.2
author score	16	8	3	2	1.33	0.3	7.0
question answering score	18	6	1	4	12.00	1.6	88.3
total answer score	16	8	1	4	8.00	1.1	57.5
question rating score	16	8	2	3	3.00	0.6	15.8
progress test score	11	13	3	2	0.56	0.1	2.9
progress MCQ score	11	13	3	2	0.56	0.1	2.9
progress SAQ score	11	13	3	2	0.56	0.1	2.9

	Age and gender						
	younger females		younger males			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	37	24	8	19	3.66	1.6	8.3
author score	36	25	11	16	2.09	1.0	4.5
question answering score	31	30	9	18	2.07	0.9	4.6
total answer score	34	27	10	17	2.14	1.0	4.7
question rating score	33	28	9	18	2.36	1.1	5.2
progress test score	34	27	11	16	1.83	0.8	4.0
progress MCQ score	32	29	14	13	1.02	0.5	2.2
progress SAQ score	34	27	13	14	1.36	0.6	2.9

	ethnicity						
	all white students		all BAME students			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	8	8	49	48	0.98	0.4	2.4
author score	7	9	57	40	0.55	0.2	1.3
question answering score	7	9	50	47	0.73	0.3	1.8
total answer score	12	4	53	44	2.49	0.9	6.8
question rating score	9	7	49	48	1.26	0.5	3.1
progress test score	8	8	48	49	1.02	0.4	2.5
progress MCQ score	8	8	50	47	0.94	0.4	2.3
progress SAQ score	7	9	50	47	0.73	0.3	1.8

	ethnicity						
	Black African/carr		white			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	12	17	8	8	0.71	0.3	2.0
author score	14	15	7	9	1.20	0.4	3.4
question answering score	13	16	7	9	1.04	0.4	2.9
total answer score	13	16	12	4	0.27	0.1	0.8
question rating score	14	15	9	7	0.73	0.3	2.0
progress test score	13	16	8	8	0.81	0.3	2.3
progress MCQ score	16	13	8	8	1.23	0.4	3.4
progress SAQ score	15	14	7	9	1.38	0.5	3.9

	ethnicity						
	all Asian		all white			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	24	24	8	8	1.00	0.4	2.6
author score	29	19	7	9	1.96	0.8	5.1
question answering score	24	24	7	9	1.29	0.5	3.3
total answer score	25	23	12	4	0.36	0.1	1.0
question rating score	22	26	9	7	0.66	0.3	1.7
progress test score	27	21	8	8	1.29	0.5	3.3
progress MCQ score	25	23	8	8	1.09	0.4	2.8
progress SAQ score	25	23	7	9	1.40	0.5	3.6

	ethnicity						
	all arab		all white			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	9	4	8	8	2.25	0.6	8.1
author score	10	3	7	9	4.29	1.1	16.8
question answering score	9	4	7	9	2.89	0.8	10.5
total answer score	10	3	12	4	1.11	0.3	4.7
question rating score	7	6	9	7	0.91	0.3	3.1
progress test score	6	7	8	8	0.86	0.3	2.9
progress MCQ score	7	6	8	8	1.17	0.3	4.0
progress SAQ score	5	8	7	9	0.80	0.2	2.8

	ethnicity						
	all black		all asian			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	12	17	24	24	0.71	0.3	1.5
author score	14	15	29	19	0.61	0.3	1.3
question answering score	13	16	24	24	0.81	0.4	1.8
total answer score	13	16	25	23	0.75	0.3	1.6
question rating score	14	15	22	26	1.10	0.5	2.4
progress test score	13	16	27	21	0.63	0.3	1.4
progress MCQ score	16	13	25	23	1.13	0.5	2.5
progress SAQ score	15	14	25	23	0.99	0.5	2.1

	ethnicity						
	all Black		all Arab			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	12	17	9	4	0.31	0.1	1.0
author score	14	15	10	3	0.28	0.1	1.0
question answering score	13	16	9	4	0.36	0.1	1.2
total answer score	13	16	10	3	0.24	0.1	0.8
question rating score	14	15	7	6	0.80	0.3	2.4
progress test score	13	16	6	7	0.95	0.3	2.9
progress MCQ score	16	13	7	6	1.05	0.4	3.2
progress SAQ score	15	14	5	8	1.71	0.6	5.3

	ethnicity						
	all arab		all asian			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	9	4	24	24	2.25	0.8	6.7
author score	10	3	29	19	2.18	0.7	7.2
question answering score	9	4	24	24	2.25	0.8	6.7
total answer score	10	3	25	23	3.07	0.9	10.0
question rating score	7	6	22	26	1.38	0.5	3.9
progress test score	6	7	27	21	0.67	0.2	1.9
progress MCQ score	7	6	25	23	1.07	0.4	3.0
progress SAQ score	5	8	25	23	0.58	0.2	1.6

	ethnicity/gender/age						
	white younger females		BAME younger females			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	6	4	30	19	0.95	0.3	3.0
author score	4	6	31	18	0.39	0.1	1.2
question answering score	3	7	27	22	0.35	0.1	1.2
total answer score	2	8	31	18	0.15	0.0	0.6
question rating score	6	4	26	23	1.33	0.4	4.2
progress test score	3	7	29	20	0.30	0.1	1.0
progress MCQ score	3	7	28	21	0.32	0.1	1.1
progress SAQ score	3	7	29	20	0.30	0.1	1.0

	ethnicity/gender/age						
	white younger female		Black younger female			Confidence Interval	
	postive	negative	positive	negative	Odds Ratio	From	To
reputation score	6	4	2	6	4.50	0.8	24.9
author score	4	6	4	4	0.67	0.1	3.2
question answering score	3	7	2	6	1.29	0.2	7.5
total answer score	2	8	3	5	0.42	0.1	2.4
question rating score	6	4	2	6	4.50	0.8	24.9
progress test score	3	7	4	4	0.43	0.1	2.2
progress MCQ score	3	7	4	4	0.43	0.1	2.2

Adjusted odds ratios

Confounding Variable Age

Contingency Table X (HESA young Age)	Education			
	A-Levels		Widening Participation	
	Positive	Negative	Positive	Negative
reputation score	23	23	15	22
author score	27	19	18	19
question answering score	24	22	13	24
total answer score	23	23	19	18
question rating score	24	22	17	20
progress test score	24	22	19	18
progress MCQ score	25	21	20	17
progress SAQ score	25	21	19	18

Total Number of Respondents Table X	83

Contingency Table Y (HESA mature Age)	Education			
	A-Levels		Widening Participation	
	Positive	Negative	Positive	Negative
reputation score	3	1	13	6
author score	3	1	13	6
question answering score	3	1	13	6
total answer score	2	2	13	6
question rating score	2	2	12	7
progress test score	3	1	9	10
progress MCQ score	3	1	10	9
progress SAQ score	3	1	8	11

Adjusted Odds Ratios	Confidence Interval	
	From	To
1.46	0.51	2.32
1.49	0.56	2.62
1.93	0.63	2.91
0.86	0.35	1.61
1.15	0.47	2.16
1.20	0.55	2.52
1.15	0.68	3.16
1.33	0.64	2.94

Total Number of Respondents Table Y	23

Confounding variable age

Contingency Table X (for young students)	gender			
	male		female	
	Postive	Negative	Positve	Negative
reputation score	8	19	37	24
author score	11	16	36	25
question answering score	9	18	31	30
total answer score	10	17	34	27
question rating score	9	18	33	28
progress test score	11	16	34	27
progress MCQ score	14	13	32	29
progress SAQ score	13	14	34	17

Contingency Table Y (for mature students)	*gender*			
	male		*female*	
	Positive	Negative	Positive	Negative
reputation score	1	4	19	5
author score	3	2	16	8
question answering score	1	4	18	6
total answer score	1	4	16	8
question rating score	2	3	16	8
progress test score	3	2	11	13
progress MCQ score	3	2	11	13
progress SAQ score	3	2	11	13

Adjusted Odds Ratios	Confidence Interval	
	From	To
0.21	0.08	0.49
0.52	0.22	1.12
0.36	0.14	0.79
0.37	0.16	0.86
0.40	0.16	0.90
0.70	0.39	1.94
1.10	0.49	2.50
0.65	0.39	2.00

Total Number of Respondents Table Y	29

Confounding variable age

	ethnicity			
	white		*BAME*	
Contingency Table X (for young students)	Positive	Negative	Positive	Negative
reputation score	6	8	31	40
author score	5	9	41	30
question answering score	5	9	33	38
total answer score	10	4	38	33
question rating score	7	7	33	38
progress test score	6	8	36	35
progress MCQ score	6	8	38	33
progress SAQ score	5	9	39	32

Total Number of Respondents Table X	85

Contingency Table Y (for mature students)	ethnicity			
	white		BAME	
	Positive	Negative	Positive	Negative
reputation score	2	0	18	8
author score	2	0	16	10
question answering score	2	0	17	9
total answer score	2	0	15	11
question rating score	2	0	33	38
progress test score	2	0	36	35
progress MCQ score	2	0	38	33
progress SAQ score	2	0	39	32

Adjusted Odds Ratios	Confidence Interval	
	From	To
1.20	0.34	2.82
0.60	0.19	1.59
0.86	0.25	2.12
2.69	0.75	8.27
2.34	0.43	3.65
1.61	0.35	2.94
1.43	0.33	2.71
1.11	0.25	2.12

Total Number of Respondents Table Y	28

Confounding variable gender

	age			
	mature		*young*	
Contingency Table X (for male students)	Positive	Negative	Positive	Negative
reputation score	1	4	8	19
author score	3	2	11	16
question answering score	1	4	9	18
total answer score	1	4	10	17
question rating score	2	3	9	18
progress test score	3	2	11	16
progress MCQ score	3	2	14	13
progress SAQ score	3	2	13	14

Total Number of Respondents Table X	32

Contingency Table Y (for female students)	age			
	mature		young	
	Positive	Negative	Positive	Negative
reputation score	19	5	31	30
author score	16	8	36	25
question answering score	18	6	31	30
total answer score	16	8	34	27
question rating score	16	8	33	28
progress test score	11	13	34	27
progress MCQ score	11	13	32	29
progress SAQ score	11	13	34	27

Adjusted Odds Ratios	Confidence Interval	
	From	To
3.51	1.14	6.81
1.41	0.69	3.97
2.78	0.95	5.46
1.54	0.61	3.31
1.69	0.76	4.23
0.69	0.39	2.07
0.78	0.37	1.97
0.69	0.35	1.89

Total Number of Respondents Table Y	85

Confounding variable gender

Contingency Table X (for male students)	education			
	A level		widening participation	
	Positive	Negative	Positive	Negative
reputation score	6	10	3	12
author score	7	9	6	9
question answering score	8	8	2	13
total answer score	7	9	4	11
question rating score	7	9	4	11
progress test score	7	9	7	8
progress MCQ score	10	6	7	8
progress SAQ score	7	9	9	6

Total Number of Respondents Table X	31

Contingency Table Y (for female students)	education				Adjusted Odds Ratios	Confidence Interval	
	A level		widening participation			From	To
	Positive	Negative	Positive	Negative			
reputation score	20	14	25	16	0.95	0.51	2.32
author score	23	11	25	16	1.33	0.56	2.62
question answering score	19	15	24	17	0.97	0.63	2.91
total answer score	18	16	28	13	0.56	0.35	1.61
question rating score	19	15	25	16	0.85	0.47	2.16

progress test score	20	14	21	20	1.33	0.55	2.52
progress MCQ score	18	16	23	18	0.91	0.68	3.16
progress SAQ score	21	13	18	23	1.93	0.64	2.94

Total Number of Respondents Table Y	75

Confounding variable gender

	ethnicity			
	white		*BAME*	
Contingency Table X (for male students)	Positive	Negative	Positive	Negative
reputation score	1	3	7	19
author score	1	3	12	14
question answering score	2	2	7	18
total answer score	4	0	8	18
question rating score	1	3	9	17
progress test score	3	1	10	16
progress MCQ score	3	1	13	13
progress SAQ score	2	2	12	14

Total Number of Respondents Table X	30

Contingency Table Y (for female students)	ethnicity			
	white		BAME	
	Positive	Negative	Positive	Negative
reputation score	7	5	42	29
author score	6	6	45	26
question answering score	5	7	43	28
total answer score	7	5	45	26
question rating score	8	4	40	31
progress test score	5	7	38	33
progress MCQ score	5	7	37	34
progress SAQ score	5	7	38	33

Adjusted Odds Ratios	Confidence Interval	
	From	To
0.96	0.34	2.82
0.57	0.19	1.59
0.49	0.25	2.12
0.90	0.75	8.27
1.51	0.43	3.65
0.66	0.35	2.94
0.69	0.33	2.71
0.63	0.25	2.12

Total Number of Respondents Table Y	83

Appendix 3 – Summary of codes and final themes for staff interviews

Initial codes	Example quotes	Final theme
Passengers within practicals - not involved Students seem fearful Less confident when compared to students on other programmes Not understanding the relevance of practicals Less practicals now	" SChemEs would ensure that you don't have " passengers" ...they're always paired [in lab classes] so unless you keep a close eye on them, there will be passenger, that's a shame" [Staff A] I can imagine for some students who are not confident with their chemistry, [they see] the session as an exposing environment and it can be quite intimidating, quite daunting [Staff D] The Bioscience students are less afraid to experiment ....and they're less afraid to be wrong [Staff D] ."..but a lot of pharmacy students learn very little in the practicals because they work in pairs and they try to let their partner do the work" [Staff F]	Lack of confidence towards chemistry
Students not understanding the requirements on a pharmacy course Students expecting more pharmacy practice and less science Engagement in science changes over the years of the programme Disengagement with the science content Degree structure implies chemistry is not important Students not expecting chemistry or only in first year	" Everything else is new and exciting...and chemistry is just old hat ad there's always the philosophy of we've done it all before..." [Staff A] "I think my main concern is they get quite a big chemistry module early on in the first year and then it just sort of peters out..." [Staff B] "...they've chosen a science-based degree and so they are anticipating that [the degree] will contain lots of lab classes, whereas perhaps pharmacy students aren't thinking that they're going to be doing lots of lab classes" [Staff C] " I think first year, they are more accepting that they're getting some chemistry content" [Staff D] " I think in the early stages, students aren't aware of how significant it {ie chemistry} really is for pharmacy [Staff F]	Expectations regarding chemistry on degree programme
Decrease in skills Changes in attitude Impact of A level structure - less practicals Understanding of basic concepts Prior knowledge quite variable	" [I think things have changed] quite markedly....in terms of specifically the teaching of chemistry that they have had, they do not have the manipulative skills the used to have" [Staff A] " ...the ones that tend to come from Access and BTECs, I think tend to be more practically minded....maybe the A level ones aren't quite so...yeah, definitely less hands on" [Staff B] "....so we are concerned that they don't have the concepts, that they learn facts and reproduction of those facts...maybe because it is very prescriptive {i.e. A level}, taught to a	Prior learning and assessment experiences

BTEC students	test". [Staff C] "...they don't come in understanding molecular shape, how bonds are formed... that sort of thing...I mean they can reel off what type of bonds you've got but it's very surface level [Staff D]	
Goal focused rather than focused on education Very patient safety focused Chemistry not a new career-focused topic like others Motivated by end point/future career	" One of the problems with teaching chemistry to pharmacy students is trying to get across the relevance...you couldn't do it in year one..." [Staff A] I think with the pharmacy students, they are sort of more focused on the end goal of becoming a good pharmacist [Staff B]. " I think if you can relate it to drug examples, you know, I think that suddenly, they're more interested" [Staff E] When the fourth years and first years meet up...the fourth years would have to explain how relevant it {chemistry} becomes at a later stage [Staff F]	Perception of relevance of chemistry to their vocation
challenge to integrate challenge to contextualise Motivation linked to context Engagement changes when link to future career	" ...it can be difficult to contextualise that {the chemistry} and that's what they {ie the students} want; to see it in the greater scheme of things [Staff A] I enjoy the second year better because that's about teaching the drug structure and how it works and how it fits in with the clinical stuff so I, to me, that's the bit I really like because I'm hoping that the students can see why the chemistry is there [Staff C]	Contextualised learning
Less support at university Less accessible staff Larger number of students taught together Lack of specialist teachers at school New different unfamiliar environment Change in teaching delivery	"They're not used to independent study, they're not used to the idea that the lecture is not the lesson, it's not the end of everything they need to know so I think they find that tough" [Staff C] "It is an issue...because they're wanting the access to tutors that they had at previous study, at school study and you can do what you want, especially in the first semester, you can do whatever you want as a lecturer to try and manage that expectation, but ultimately they will become frustrated by a lack of direct access" [Staff D] I think that they find it {the teaching methods at university} really hard... I think mature students can handle it better. [Staff E]	Transition to new learning environment
Staff student ratio Large class sizes influences learning Good ways to re-enforcing concepts Incorporating application tasks in large lectures Workshop tasks improve understanding	"I like to use lectures that {....} that every couple of lecture slides, I'll stop, and I'll ask a question and then I'll try and encourage a group discussion and just try to understand, get them to understand I have taught you this concept, now let's try and apply it." [Staff B] "I think it's important to present them with the scientific information, so introduce it to them and explain it to them and then I think that you then need to get them to try and apply that in terms of a question." [Staff D]	Application of learning

Appendix 4 – Summary of codes and themes for student interviews

Initial codes	Example quotes	Final theme
Responsibility for own learning More independent learning Time management New people to get to know Easier chatting to known teachers at school	" Coming from school I found chemistry a bit more difficult...um, maybe, because you had to do further reading yourself" S3Y2 " " I think [A levels] have more of a structure, so you knew what you had to know- whereas in uni, it's a bit, like, vague. You don't really know what you need to know for the exam".S4Y2 " Lectures? It does make sense...but y'know, they don't really expand on it as much, so its down to you whether you explore it in your own time" S1Y3	Transition to new environment
Prioritising links to future role Linking work experience to learning Focus on own individual career goals Identify possible patient queries in teaching examples	" I think chemistry is a very core subject in pharmacy and basically everything we do with drugs comes back to the core which is chemistry " S1Y2 " I think it depends what kind of pharmacist you want to be, but I think for community and hospital - not at all completely relevant?" S5Y2 "I think it's very relevant, because you have to understand...for example, one change in part of the molecule can actually change...side effects or therapeutic effects" S3Y4	Perception of relevance to future chosen career
Appreciate context teaching See science context in practice	"One of the things that helps us learn is when they relate it back to real life circumstances" S1Y1 " I think it's a good idea, because it will help you ultimately when you go into practice" S5Y2 " We did...antibiotic resistance and looking at, y'know, the penicillin structures and it really made sense" S1Y3	Contextualised learning
Thinking of ways for authentic learning Appreciation of application practice Link application to future work	" I like pharmacy as you are actually applying your knowledge - you're not just studying about it" S1Y2 " You can learn theory, but if you can't apply it...then it's not very beneficial, is it?" S1Y4 "... in lectures, obviously you go over information but don't apply it, but in workshops you apply it" S7Y4	Application of learning
Find it hard to learn in large group Cannot clarify understanding Nervous about asking questions Appreciate clear explanations (so don't need to ask questions)	"I learn more in workshops as it's more easy to ask questions on topics of concern" S1Y1 " I ask...questions...it might sound silly when I ask obvious questions..." S2Y3. "I prefer the workshops and labs ...because its more one to one with the lecturers" S6Y3 "I like workshops, they are teaching in small groups, so you can ask questions...this is the main reasons why" S2Y4 "I prefer workshops definitely... in lectures, you can't really ask questions." S6Y4	Academic confidence

Different ways of revising Aiming to make sense of it Need for high achievement Using videos to understand topics	"I think to try to interlink everything together...rather than just memorising. I like explaining to my friends...because I learn most from explaining" S1Y2 " I think for chemistry... I had to actually understand every lecture...for other topics you can just memorise but for chemistry, its different, you have to understand" S2Y3 " ...for chemistry, you have to give it more time...there is a lot more content you need to go through ..and understand" S3Y3 "...but for chemistry, because it's like, a challenging topic, so you obviously have to put more effort into it...it has to be explained well" S5Y4	Focus on understanding

Appendix 5 – Summary of code and themes for student focus groups

Initial codes	Example quotes	Final themes
Importance of understanding not appreciated by all students Adaption of study techniques Videos as additional learning Deep learning by some students Cognitive load	" You learn the information right, you will find out later how it relates" 1A "I make sure I understand the notes ...try to figure out what people will ask us" 1B "Sometimes, I don't like deep learning...it confuses me...surface learning for MCQs [is fine]" 2A " The way some questions are based in the exam...you don't feel the need to think integratively to answer the questions" 2B "Sometimes when I'm revising...one of them [i.e. lectures] is seventy slides, so I might not be able to do more than one in a day" 3A	Strategic learning approaches
Preparing for practice Motivated by relevance Disengaged when no relevance perceived Perception of importance is very individual	"We're learning OTC medications... its good to know because we can then use it in practice" 1C "Why would a patient have an adverse drug effect... I feel we should know that" 1D "I believe that whatever we're learning we need to know...why...that is the foundation" 1B " the reliability is less [in some modules]...for those that want to go into industry, it does help" 2D "There are some [topics] that are more important than others...it would help more if there would be a link back to how this would help us in practice" 3A	Importance of relevance to practice
Putting theory into practice Appreciating experiential learning Work has positive impact on study	"We need to take the initiative to work in a pharmacy..." 1A "Working in a hospital pharmacy already, [helps me] put the theoretical knowledge into practice a lot easier" 2B " "You're able to apply theory and put it into practice...[work] definitely puts you at an advantage" 3D	Benefits of work experience
Difficulty in creating links Seeing modules in silos Some trying to integrate Expectation that links are highlighted by academic	"We currently doing chemistry, biology and The Pharmacist module" 1B "I like to do independent work cos I think it works for me...I like to try and make connections" 1D " I do think more is needed in certain modules to help us create links" 2A "A lot of students don't know how to think integratively, I think...mostly due to a lack of experience" 2B "in real life you are not going to sort of look at one aspect, you look at things together, so it's important to create links" 3D	creation of links within teaching

Appendix 6 – Example lesson plan from teaching intervention

Example Lesson Plan for MPharm Year 1 contextualised workshops

Workshop 1   Week number - 19

Timing 2 hours

Pre-session work: Introductory lecture to understand terms (integration contextualisation) and discussion of the given examples in lecture

Resources required: BNF, Access to SmPC website and Canvas pre session PP slides

Learning outcomes for series of workshops:

- Integrate knowledge of science and practice when supporting patient care
- Appreciate the relevance of science to pharmacy practice
- Understand the relevance of functional groups in relation to drug absorption, onset of action and side effects
- Provide a scientific rationale to explain and justify when making medication recommendations

Task Description	**Other details**
Reminder of terms – contextualisation and integration. Discussion of structure of these workshops- students to work in small groups as a team to explore a concept then use this knowledge to help the patient. Answers to each problem to be discussed as whole student group, students are responsible for solving the problem. Problem solving skills and being able to explain 'why' clinical decisions are made are skills being developed in the workshops.	Make sure all students are working within a group. Check they have access to required materials.
The patient map – what do we consider important when planning treatment? Purpose: Highlighting importance of holistic care for patient and underpinning science impact on rational decision making	Encourage full group participation
The patient in this case – visit to community pharmacy – what communication technique to use?	Remind students where this is taught
Students to practise WHAMM technique (taught previously by SJHO) Patient mentions one drug has been tried but did not help – chemical structure to look at for next task	Student to work in pairs and provide feedback on interaction

Chemical structure- students to identify drug and work out chemical name. Calculate molecular mass. Purpose: Correct identification of functional groups, calculation practice	
Students to discuss 3 other drug options for patient issue (headache). Chemical structures provided. Students to identify functional groups and consider their solubility (ie polarity) – (taught previously by SF and MC) Concept: functional groups and their role in solubility	
Students to counsel patient on use of chosen drug – ibuprofen. Student to work in pairs and provide feedback on interaction	Make sure students swap patient/pharmacist role
Students discuss the concepts in ADME then relate this to ibuprofen considering the chemical structure (refer to The Patient module also MC teaching) Concepts: Pharmacokinetics, solubility of drugs and acid-base properties in relation to structure	
Students to consider the effect of the drug on the body Students to consider pharmacology terms – receptor, agonist, antagonist, enzyme (refer to JS teaching) Concept – drug target interaction	Remind students when they have been taught these terms.
Mode of action of ibuprofen as a member of NSAID class New teaching but some previous physiology knowledge Concepts: Impact of enzyme inhibitors, importance of selectivity and specificity of a drug	
Students to consider what side effects may occur following mode of action explanation Concept: type A adverse drug reactions	
Students asked to consider why an antacid could be used for indigestion, write chemical equation Concept: Introduction to structure reactivity relationships	
Advert for Ibuprofen Express – students to consider will this work 'better' than ibuprofen? Concept: functional group impact on drug action	
Students to explain their answer in a patient friendly way to a 'patient' -working in pairs Purpose: continue to practise communication skills	Make sure students swap patient/pharmacist role
Student to reflect on what they have learnt and how they could 'create links' in other topics	
Summary of concepts taught about in the session from facilitator	