Designing curricula to develop digitally capable professionals in engineering and management - the case in two UK universities

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This thesis results entirely from my own work and has not been offered previously for any other degree or diploma.

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Doctor of Philosophy, December 2018

Abstract

The development of digital capabilities has received significant attention in higher education (HE) in recent years, with numerous attempts made to develop digital frameworks to support curriculum design. However, few studies have articulated these generic capabilities in terms of specific disciplines. This thesis addresses the gap of disciplinary conceptualisations of digital capabilities by exploring how they are planned and experienced in HE curricula in two professional disciplines at two UK universities. Originality of the study is achieved in part through a conceptual framework that weaves together a theoretical perspective - Shulman's signature pedagogies, with JISC's Digital Capability Framework. Underpinned by a human capabilities approach, the study employed a multiple-case study methodology with each discipline as a case, and four undergraduate/postgraduate modules as the units of analysis, drawing on documentary sources, and academic, professional and student perspectives via interviews, focus groups and observation.

My findings indicate that the development of digital capabilities is aligned with the respective discipline's signature pedagogy. In engineering, digital problem-solving and collaboration/communication, followed by data and information literacy, appear to be most prominent. In management, data and information literacy overlap with problem-solving, and, together with digital content communication, form its signature digital capabilities. The thesis highlights similarities, differences and gaps in the way digital capabilities are developed in engineering and management curricula. In addition, the research process itself offers a major theoretical contribution, together with the identification of management's overarching signature pedagogy. Practical and theoretical implications of the study include the need to extend signature pedagogies to 'signature assessments', and articulating a link between signature digital capabilities and authentic assessments. Future research could explore potential solutions to a tension between mapping digital capabilities and constructive alignment. A methodological contribution of this study was using poems as a way of synthesising findings. Finally, using William Blake's art as illustration, it is suggested that harnessing a passion for creativity could be a starting point for supporting the digital capabilities of tomorrow's professionals.

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List of abbreviations

The six elements of the Digital Capabilities Framework

1-ICT	information and communication technology
2a-DL	data literacy
2b-IL	information literacy
2c-ML	media literacy
3-PS	digital problem-solving (scholarship, creative production)
4-CC	digital communication and collaboration
5-LD	digital learning and development
6-IW	digital identity and wellbeing

Other abbreviations

3D, 4D	3-dimensional, 4-dimensional
AR	Augmented reality
AT	Assessment task
BIM	Building Information Modelling
CAD	Computer-aided design
CAIC	Collect-Analyse-Interpret-Collaborate
CDIO	Conceive-Design-Implement-Operate
CEng	Chartered engineer
CPD	Continuing professional development
DigComp	Digital Competence Framework, EU
DigiCap	Digital Capabilities Framework, JISC
EC	European Commission
ENG	Engineering (for source IDs, see sub-section 4.7.7)
EU	European Union
HE	Higher education
HEA	Higher Education Academy (now part of Advance HE)
HEFCE	Higher Education Funding Council, England
HEI	Higher education institution
ICT	Information and communication technologies
ILO	Intended learning outcomes
IT	Information technology
JACS	Joint Academic Classification of Subjects (UK)
JISC	Joint Information Systems Committee (UK)
LLiDA	Learning Literacies in the Digital Age study

MAN	Management (for source IDs, see sub-section 4.7.7)
MOOC	Massive Open Online Course
NHS	National Health Service (UK)
NLS	New Literacy Studies
PBSR	Professional Body Standard Requirements
QAA	Quality Assurance Agency in Higher Education (UK)
SCONUL	Society of College, National and University Libraries
SEDA	Staff Educational Development Association
SOLO	Structured, Observed Learning Outcomes
TEF	Teaching Excellence Framework (UK)
TEL	Technology-enhanced learning
TLA	Teaching and learning activity
UCISA	Universities and Colleges Information Systems Association
UK	United Kingdom
UKPSF	UK Professional Standards Framework
UK-SPEC	UK Standard for Professional Engineering Competence
VLE	Virtual learning environment
VR	Virtual reality

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1 Chapter 1: Introduction

Universities have a dual role of research and education: advancing disciplinary knowledge as well as educating tomorrow's professionals. Digital capabilities are linked to economic competitiveness and disciplinary innovation (according to Orlik, 2018). In any role, professionals need to keep abreast of technological transformations in their field so that they can accomplish and enhance their practice (according to van Laar et al., 2017). To achieve this, how can educational institutions ensure that they prepare graduates with respect to their digital capabilities so that they can contribute effectively when joining their profession? As professionals lacking in digital capabilities may not be able to utilise advances in their field, and if graduates joining the workplace or attempting to achieve their own vision lack in digital know-how, they may fail to be competent in practising and progressing their own field. Whilst this study argues for the importance of digital capabilities, not much literature has discussed what this means in terms of its integration in specific disciplinary contexts in education.

Consequently, this thesis focuses on the notion of digital capabilities in the context of two applied higher education (HE) disciplines in the United Kingdom (UK), namely engineering and management. More specifically, it explores what it means to be a digitally-capable engineering or management professional and how university educators can contribute to their development in the curriculum. As such, and building on the complex literature on digital capabilities, my thesis is intended to advance effective curriculum design in HE professional programmes. An original aspect of this study is its contextualisation of an existing general digital capability framework in two disciplines. Furthermore, this study's findings are relevant not just to engineering and management educators and professionals, but also more generally, to educators from any discipline and to those who occupy central roles such as educational developers, learning technologists, senior managers, researchers, policy-makers professional bodies and associations.

In this thesis, I draw on the Joint Information Systems Committee's (JISC) definition of digital capabilities which recognise:

> …capabilities which fit someone for living, learning and working in a digital society (JISC, 2017c).

This is a deliberately broad definition that can accommodate many contexts, fields and sectors (see section 2.2). Although this thesis focuses on the development of engineers and managers, I use these two groups as examples of professionals, namely individuals following a set curriculum to meet the requirements of the relevant professional body, with requirements usually expressed through particular standards of practice (QAA, 2018). Thereby, this study is interested in how to design effective curricula for university students undertaking study in a professional discipline in order to enable them to thrive as professionals “in an age when digital forms of information and communication predominate” (Littlejohn, Beetham, & McGill, 2012, p.547).

In the UK context, I use the term ‘module’ to denote a unit of study, usually across one or two semesters, and a ‘course’ or ‘programme’ to mean an undergraduate study usually lasting three years at university. The terms used for organisational units within a university are: ‘programme teams’, ‘departments’, ‘schools’ (a collection of departments) and ‘faculties’ (a collection of schools). I use ‘staff’, ‘academic’, 'lecturer' and 'tutor' interchangeably.

1.1 Preamble: Daniel Blake, or a human capabilities approach

My stance on digital capabilities and the role of university is in the spirit of the human capabilities approach (Nussbaum, 2011; Sen, 1999). To illustrate this, I call on themes from a recent social realist film directed by Ken Loach, *I, Daniel Blake* (O’Brien & Loach, 2016). In this film, a 59-year-old joiner, convalescing after a heart attack, has to seek employment in order to obtain a support allowance in the UK, despite being too unwell to work. He has never used a computer. All the processes involved in finding employment, such as searching for a job, filling out forms and handing in curriculum vitae (CV), are digital. Daniel seeks help learning to use a computer in the local library. He conscientiously fulfils all the requirements but decides to conduct job searches in the traditional way by handing out his CV in person across the city. At a subsequent job centre appointment, the administrator asks him to provide evidence that he has actually handed out his CV. Daniel cannot, as there is no digital trace. On an everyday level, the fact that Daniel lacks digital skills has negative consequences for his job seeking and his attempt to obtain benefits. However, and in a much wider sense, Daniel’s digital incapability impacts on him as a person. His truthfulness and identity are called into question; he is becoming more and more isolated. Although the film’s primary message is more to do with humanity and social justice, Daniel’s story is also an example of the link between economic growth and human wellbeing (Sen, 1999); Daniel’s lack of digital capabilities adversely impact on his wellbeing.

1.2 Context and rationale

I will use Daniel Blake's character to illustrate, in the following sub-sections (1.2.1-1.2.4), the importance of digital capabilities in educating professionals in a HE context. Although Daniel is at the end of his career and his lack of digital skills is less than typical for UK HE, his example is useful for considering capabilities from a human capability perspective, which, as mentioned above, can also encapsulate economic aspects.

1.2.1 Policy context

Daniel Blake is an example where, in order for someone to thrive, digital competence is both a human right and necessity (Ferrari, Punie, & Redecker, 2012). The UK government's most recent 'Digital skills and inclusion' policy (Department for Digital Culture, Media and Sport [DCMS] and Bradley, 2017a/b) mainly concerns citizens' basic digital skills. As one of the 30% of UK people aged between 16-74 years with no basic digital skills (Ashworth, 2017; Vuorikari et al., 2016), Daniel Blake is a typical target of UK and European Union (EU) digital policies. Such digital skills generate economic benefits, e.g. accessing services, training and workplace practices, as well as promoting civic engagement and wellbeing, e.g. participation in democracy or access to public services (Biggins, Holley, Evangelinos, & Zezulkova, 2017; McDougall, Readman, & Wilkinson, 2018). The UK's Quality Assurance Agency for Higher Education (QAA, 2014) as well as a recent Nesta (formerly National Endowment for Science, Technology and the Arts) report (Orlik, 2018a) cite various positive economic benefits derived from using digital tools in the workplace, such as increased productivity, catalysation of innovation and improvements in the lives of workers. The other main governmental concern is the sustainability of a highly-skilled computing workforce to maintain Britain's economic position (Warren, 2011).

Out of various digital learning policy frameworks collated (Beetham, McGill, & Littlejohn, 2009), one influential European policy within a lifelong learning context seems to be the Digital Competence (DigComp) Framework (Ferrari, 2012, 2013; Vuorikari et al., 2016). Including digital competency at policy level has been deemed necessary as almost half (44.5%) of EU's population aged between 16 and 74 years, like Daniel Blake, have been estimated to have insufficient digital skills (Vuorikari et al., 2016, p.3). Furthermore, "38% of workplaces in Europe lack digital skills", which harms their business, while "40% of people who use software at work do not know how to do so effectively" (Orlik, 2018a, p.9). As a non-disciplinary framework, DigComp has been used to identify and describe key areas of digital competence, intended to be used by citizens and policy-makers for planning training and education initiatives (Carretero, Vuorikari, & Punie, 2018). Similar policy initiatives exist internationally (see Alexander, Adams-Becker, Cummins, & Hall-Giesinger, 2017), e.g. Australia's National Innovation and Science Agenda (Coldwell-Neilson, 2017).

Many of the capabilities required for effective learning and working have a digital aspect (European Commission, 2016; UKCES, 2010; UKCES et al., 2014); however, the remit of national and European policies and frameworks remain largely at a generic level of digital skills, with no contextualisation for discipline-specific professionals in tertiary education. It is only very recently that the European Commission has adopted a Digital Action Plan (2018) including actions to support digital competence development in education, something that has not yet happened in UK governmental policy. Although the UK overall has a relatively high percentage of the population with basic digital skills (60-70%) as compared to other EU countries (European Commission, 2017), little is known about the digital capabilities of professionals relative to the skills required within their own disciplines. Had Daniel Blake been a professional engineer or manager, he simply could not have thrived without digital skills in today's knowledge society (Littlejohn et al., 2012). As Warren (2011) highlights, support for building a 'Digital Britain' (Department for Culture & Department for Business, 2009) should go beyond the narrow remit of producing highly-skilled computing graduates. Digitally-mediated innovation and knowledge-practices need to involve a wider range of professionals in different disciplinary and interdisciplinary contexts.

1.2.2 Changing knowledge-practices and the role of university

As Daniel Blake's example has shown, in all areas of our lives – whether social, political, cultural or economic – digital information and technologies permeate our actions and interactions (Beetham & Oliver, 2010; Littlejohn et al., 2012; Sinclair, 2013), a result of the move away from traditional industries, such as manufacturing or agriculture, towards services and the knowledge economy. In the UK and Europe this has increased the need for professional and managerial skills (CEDEFOP, 2009; Warren, 2011), leading to digitally-mediated knowledge-driven production and practices in the workplace (Littlejohn et al., 2012), of which engineering and management are good examples. Technologies are also affecting future employment trends with digital skills required for all jobs (Becker, Pasquini, & Zentner, 2017; Djumalieva & Sleeman, 2018; European Commission, 2016).

Digital technologies have not just shaped our work life (Nerguizian, 2011), but they are stated to be also transforming “what it means to work, study, research, express oneself, perhaps even to think” (Littlejohn et al., 2012, p.547), “often in dramatic and unexpected” (Orlik, 2018a, p.8) and transformative ways (Adkihari, 2011). Technology has become more accessible to non-computing specialists in the form of cloud and mobile computing, widening the scope of innovations to a range of different disciplines (Warren, 2011). All these have brought about significant changes in ways of working, with professionals collaborating across temporal and geographical boundaries in disciplinary and interdisciplinary communities (according to Dirckinck-Holmfeld, 2016; Weller, 2011). Whether in industry or HE research, digital technologies can impact on existing research interests, produce new research questions (Tsatsou, 2017) and methodological tools (Hughes, 2012). If, therefore, professionals need to keep abreast of disciplinary innovations as part of their initial education and beyond, HE curricula have to reflect these changes (Rowe, 2016, p.874).

There are two main macro-level vantage points from which digital capabilities can be viewed (according to Brown, 2017). In relation to the first perspective, there are those to whom digital competency is about employability and participation in society’s existing structures and improved life chances, reflecting the employability agenda of many governmental policies and initiatives, albeit extending to lifelong learning (Ferrari et al., 2012). This corresponds to viewing the university’s role “to ensure graduates are adequately prepared for working and participating in the digital economy” (Coldwell-Neilson, 2017, p.1). Since the Dearing Report (National Committee of Inquiry into Higher Education, 1997), employability has been established as a key concern of university education (Cranmer, 2006), which extends to digital skills (Confederation of British Industry [CBI] & National Union of Students [NUS], 2011; CBI & Universities UK, 2009). This means that the driver for embedding digital capabilities into programmes is to: meet the requirements of employers and professional bodies; the expectations of students entering HE with a range of technological backgrounds; and the priorities of the government and funding councils (e.g. in QAA, 2014). For instance, by 2025 almost half EU jobs will require higher qualifications awarded through tertiary academic and professional programmes (according to the European Commission, 2016). The primary concern of this neoliberal view is that degrees should provide Daniel Blake with the necessary digital skills to be able to find successful employment.

The other perspective is concerned with a more critical view of technologies. This is about a human-centred, human capabilities approach (Biggins et al., 2017), with an emphasis on wellbeing, human development and attention to technology-related widening participation and access/inclusion (Buckingham, 2007). Furthermore, it is about educating individuals to become 'socially critical' professionals (Hudson, 2009), who consider the ethical and humane perspectives behind technology use (Bali, 2014) and develop agency in order to address "the really big issues facing humanity in the digital era" (Brown, 2017b, n.p.). This corresponds to the Humboldtian perspective on the role of university, which is to instil a spirit of educational inquiry in students (Livesey, 2008; Simons & Elen, 2007) for the betterment of society and humanity. Universities' missions include both offering education that equips students for the public-service professions alongside producing new technologies and other innovations (Calhoun, 2006; East, Stokes, & Walker, 2014). This human capability approach (Nussbaum, 2011; Sen, 1999) has been an admittedly conscious influence on the UK HE digital capabilities agenda (Beetham, 2017a), which sees digital capabilities as contributing to social inclusion, citizenship and lifelong learning (Bayne, 2017; Carretero et al., 2018; Mihailidis, 2018; Noss, 2012). The concerns of our graduates, in this perspective, should include coming up with engineering inventions or management practices which would prevent exactly the kind of inequalities that Daniel Blake suffers. For professionals to be engaged in such transformative knowledge-practices, they need to be digitally capable. Or, as Passey et al. (2018) argue, have 'digital agency', which is a deeper, more holistic concept encompassing, and pointing beyond, digital competence. This human capabilities approach, which can be reconciled with the economic argument outlined above (Simons & Elen, 2007), underpins how I approach digital capabilities in professionals' tertiary education.

The question of what is expected of specific professionals, such as engineers and managers, remains essential in terms of maximising their impact (Warren 2011). More importantly, and as Brown's (2014, p.282) syllogistic argument points out in relation to sustainability, if digital discourse is shaping our understanding of the world, and the discourse is generated by those who contribute to it, then individuals (professionals) can, and need to have, a role in shaping it. Therefore, this thesis offers an insight into the digital capabilities that engineering and management students need to develop in order to thrive in these professions as graduates.

1.2.3 Higher education initiatives and drivers

Recent years have seen significant HE initiatives in the area of developing digital capabilities of students. JISC, whose remit is to "provide digital solutions for UK education and research" (JISC, 2017a), has foregrounded work on digital capabilities since 2009. Between 2011 and 2013, JISC conducted a three-year programme on 'Developing Digital Literacies' with over ten institutions taking part. QAA, whose remit is to ensure the standards and quality of UK HE programmes, selected digital literacy as one of two Higher Education Review themes in 2015-2016. This highlighted students' digital capability as a significant contributor to enhancing student learning. As part of their submission, universities were asked to offer examples of how digital literacy was embedded in curriculum design and assessment (QAA, 2014). Building on JISC's work, the Higher Education Academy (HEA) ran a 'Digital literacies in the disciplines' programme that funded approximately 60 mini-projects to promote this development and the sharing of good practice.

Since then, JISC (2017d) has established a 'Digital Student' strand exploring students' experiences and expectations with technology, which resulted in the recent formation of a community of practice on digital capabilities in order to help HE practitioners share ideas concerning the strategic embedding of digital capabilities. The Higher Education Funding Council for England (HEFCE) has facilitated the 'Changing the Learning Landscape' programme aimed at supporting the development of digital capabilities at strategic leadership level in tertiary institutions. In addition, JISC has also developed a digital experience insights service in order to provide benchmarked data about students' digital expectations and experiences (JISC, 2018).

Another driver of universities' digital agendas is the Teaching Excellence Framework (TEF), a marker for teaching quality at UK HE institutions (HEIs), which includes measurements of student satisfaction related to their digital learning environment (Austen, Parkin, Jones-Devitt, McDonald, & Irwin, 2016). A recent UCISA (Universities and Colleges Information Systems Association) survey reported that 35% of HEIs have taken action in relation to digital capabilities as a result of TEF (Fielding et al., 2017), suggesting that developing digitally-capable professionals is likely to remain a feature in the HE landscape.

1.2.4 Rationale

As highlighted in 1.2.1, digital agendas are receiving continuous attention in national policies, and in turn, higher education. If tomorrow's professionals are to meet the expectations of employers and professional bodies, then HE education needs to reflect changes as a result of technological transformations in their curricula (Rowe, 2016). Previous studies observed that some HEIs adopt a functional approach to digital capabilities, treating digital capabilities in a transferable, non-discipline specific context, as opposed to a professional, discipline-specific approach, which would be more effective (Beetham, McGill, & Littlejohn, 2009). If this latter approach is more effective, then we need a way of capturing such disciplinary examples of digital capability development. At the same time, these examples will necessarily be snapshots only, given that digital technologies, such as automation, are transforming disciplinary practices in a continuous and emerging way (Orlik, 2018). The main rationale for carrying out this study was to find a process and framework for capturing disciplinary digital practices and capabilities so they could be captured in specific disciplinary contexts and repeated for ongoing monitoring purposes.

In addition to these contextual reasons, I had a number of personal motivations for conducting this research. Firstly, my original motivation was rooted in my professional interest in enhancing my own practice in relation to digital capabilities and curriculum design. Secondly, as demonstrated in Chapter 2, there was a scarcity of literature at the intersection of curriculum design and discipline-specific digital capabilities. As argued above, the development of digital capabilities is an important agenda best pursued at programme level. A well-designed and implemented curriculum would enable students to carry on developing these capabilities in their lifelong professions. Hager (2004) suggested that this required "developing the gradually growing capacity to participate effectively in socially situated collaborative practice" (p.251). This necessitates a greater focus on the development of 'meta-skills' or capabilities that enable people to become self-managing practitioners and learners, rather than on specific, functional ICT skills (Lester & Costley, 2010). Accordingly, disciplinary understandings of what capabilities students would need as professionals are key to satisfying this aspiration. Thirdly, the aspiration of this study was to mitigate against Passey's critique (2017) of educational technology research for a lack of longitudinal studies that might provide sufficient evidence as to the success of outcomes. In contrast to single point evaluations, the perspectives of staff, students and employers were combined to cast some light on students' digital know-how during and after graduation, offering a proxy lifelong-learning angle to this study. Staff and students were invited to share experiences about how students cope with digital capabilities in university, and professionals to comment on graduates' digital capabilities, as well as the utility of higher education in preparing students for lifelong learning in the 21st century.

1.3 Digital capabilities: an issue for curriculum design

If universities have a central role in developing the digital capabilities of engineers and management professionals (Payton, 2012; Sinclair, 2013) in a context of generic digital national policies and well-developed frameworks, then curriculum teams need to be able to articulate what digital capabilities mean in their disciplinary/professional contexts and design these into their curricula. This study's problem statement is therefore located in the question: what exactly is meant by digital capabilities in different disciplines (Belshaw, 2012; Warren, 2011)? How should, for example, engineers, managers or historians prepare in order to succeed and thrive in a digital environment? For this, we also need to know graduates' digital practices in the workplace and whether those differ or agree with the curricular opportunities that universities provide to students (Coldwell-Neilson, 2017).

From a curriculum design perspective, there are often problems with current provision, e.g. "poor embedding of [digital] literacies into the curriculum" and "poor integration of information/digital literacies with academic/learning literacies" (Beetham, McGill, & Littlejohn, 2009, p.70). The same authors found evidence that some HEIs had taken a functional approach to digital capabilities (in the form of non-discipline-specific/general/transferable skills), whereas a professional ("focus on deployment of personal capabilities in specific task contexts") or an interpretive approach ("focus on how individuals understand tasks and how social contexts support that understanding"), or their combination, would be more effective (Beetham, McGill, & Littlejohn, 2009, p.26). It cannot be assumed that academics will embrace new technologies and innovative knowledge-practices (Conole & Dyke, 2004; Mistri, 2016; Oliver et al., 2007); these need to be adapted to disciplinary, pedagogical and institutional contexts (Oliver & Dempster, 2003).

Although a number of digital capability frameworks and definitions exist (Beetham, McGill, & Littlejohn, 2009; Buckingham, 2010; Ferrari et al., 2012; Vuorikari et al., 2016), few studies have applied or mapped these in particular disciplinary settings. Apart from the JISC projects and outputs mentioned above, only a handful focus on the digital capabilities of a given field, including construction management (Jupp & Awad, 2013), religious studies (Sinclair, 2013), English as a second language (John, 2014), and sustainability education (Brown, 2014). However, no such mappings exist for engineering or management, which is a gap that this study seeks to address, combining the perceptions of academics, students and professionals.

1.4 Study purpose

The aim of this study is to explore the curricular conceptualisations of digital capabilities from a disciplinary perspective. In a sense, my study is similar in aspiration to that of Walker and McLean (2015) who explore the professional capabilities that those working for the 'public good' (such as medics and health professionals) need to have. But in this thesis, I explore the digital capabilities that those undertaking a course in applied sciences, namely, engineers and managers, need to develop during their degree from different perspectives.

I determine which digital capabilities are prioritised in engineering and management programmes of study, and how they are designed, articulated and planned for in the formal curriculum. To be more precise, I explore how they may appear in the learning outcomes, teaching and learning activities and assessment tasks. I then investigate whether these capabilities actually materialise as lecturers and students enact and experience the curriculum, and to what extent they match the digital practices of engineers and managers.

In his thesis on defining digital literacies, Belshaw (2012) concludes that co-constructing a definition of digital literacies is "at least as important as the outcome" (p.5). Others also agree that the process of curriculum mapping is as important as the outcome itself (e.g. Littlejohn et al., 2012). In this spirit, my study weaves in the aim of illuminating this co-construction process to reflect on the appropriateness of my conceptual framework, which is discussed next.

1.5 Conceptual framework

The research originated from my interest in how digital capabilities are conceptualised in two applied disciplines in the HE curriculum. To this end, I developed a conceptual framework comprising two elements (lenses) to see how far they could enable me to view disciplinary conceptualisations of digital capabilities. One of these elements was a pragmatic framework that helped me elicit different kinds of digital tools and practices used in any given discipline. The other element was Shulman's (2005a, 2005b) concept of signature pedagogies, which I used to help highlight disciplinary characteristics of digital capabilities. I imagine this conceptual framework as a kaleidoscope viewed from two lenses, with both being necessary to see how digital capabilities are applied in the curriculum and what they mean for different disciplines (Figure 1.1). In this sense, taking a cue from Oliver (2002, p.2), I used a concept (Shulman's signature pedagogies) and a model (JISC's DigiCap-Framework) as tools to enable me to build a picture of disciplinary digital practices. In Chapter 3, I argue that this combination, i.e. my conceptual framework, is an original feature of this thesis.

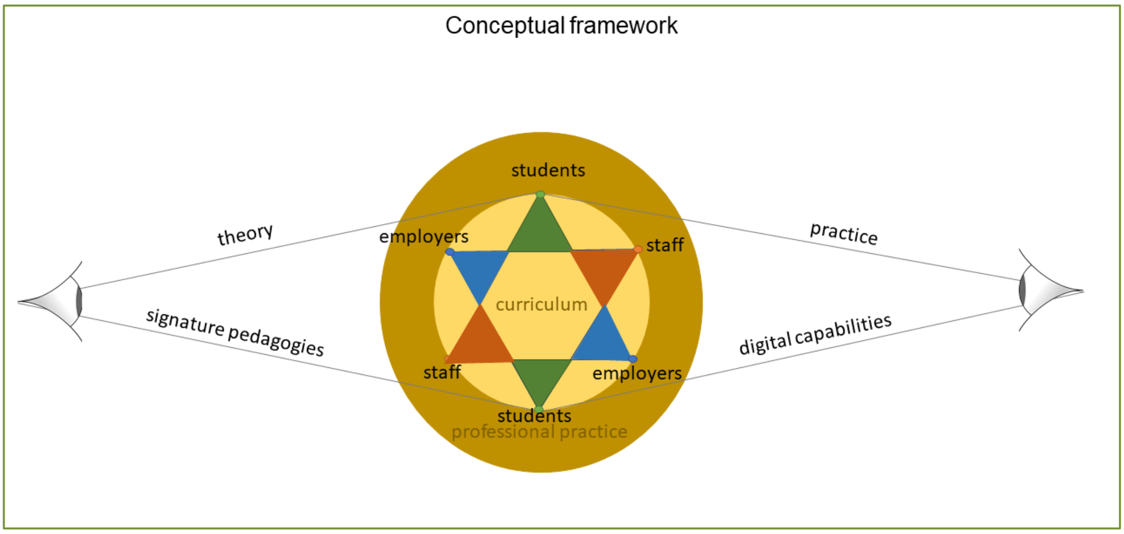

Figure 1.1 Conceptual framework - concept and practice lens

Shulman's 'signature pedagogies' are concerned with "the types of teaching that organize the fundamental ways in which future practitioners are educated for their new professions" (2005b, p.52). Signature here means individual/specific to the discipline. Shulman distinguishes three dimensions of signature pedagogies, namely *surface*, *deep* and *implicit* structures. Surface structures are the concrete learning and teaching activities; deep structures reflect the set of assumptions on how best knowledge, know-how and skills are imparted; and implicit structures reflect the values and beliefs underpinning the profession. Signature pedagogies are focused on how educators "want [students] to understand and practice disciplinary ways of thinking or habits of mind" (Chick, Haynie, & Gurung, 2012, p.2).

The theoretical concept of signature pedagogies is extremely useful, since Shulman is interested in the way students transition from learners to professionals, and how they can be supported through distinct pedagogies dependent on the profession's disciplinary characteristics. It is this focus on professional practice that is particularly beneficial for this study, as opposed to other approaches, such as Becher and

Trowler's 'tribes and territories' (2001)**,** who explore disciplines from a social practice perspective, as evident in academic and institutional manifestations.

For the practice-based lens, I have adopted JISC's Digital Capability Framework, hereafter abbreviated as the DigiCap-Framework (JISC, 2017b). It has been used extensively, and refined through the JISC Developing Digital Literacies programme (JISC, 2017c), drawing on earlier frameworks (Beetham et al., 2009). It includes six elements: 1) information and communications technology (ICT) proficiency; 2) information, media and data literacies; 3) digital creation, innovation and scholarship, hereafter referred to as 'digital problem-solving'; 4) digital learning and self-development; 5) digital communication, collaboration and participation; and 6) digital identity and wellbeing. My key rationale for adopting this model is that it conceives digital capabilities as more than functional skills such as operating a spreadsheet or a graphic-design software package, offering a pragmatic way of identifying digital practices in different disciplines.

1.6 Research questions

Based on my starting point in defining the notion of digital capabilities as situated and contextual, I expect to find that they will be conceived differently in the different disciplines. My primary interest, and thus my overarching research question (RQ), is a 'how?' query:

RQ: How are digital capabilities conceptualised in two different disciplines, namely engineering and management?

The findings to this question will enable me to consider effective ways to support curriculum teams in ensuring that their curricula are ready for today's digital world. The overarching research question can be broken down into answerable and specific sub-questions (Trowler, 2015) as follows:

1 **How are digital capabilities conceptualised/planned in the curriculum at modular level in different disciplinary contexts (in management and engineering)?**
   - 1.1 What digital capabilities are planned by academic staff to be developed as intended learning outcomes (ILOs), teaching and learning activities (TLAs), and assessment tasks (ATs)?
   - 1.2 How do these modular articulations fit in with programme and institutional levels of learning outcomes and subject benchmarks?

2 **How is the development of digital capabilities enacted and experienced by engineering and management students?**
   - 2.1 What are academics' perceptions of the digital capabilities being developed by engineering and management students as they enact the planned curriculum?
   - 2.2 What are engineering and management students' perceptions of developing the planned ILOs with respect to digital capabilities?
   - 2.3 Are engineering and management students developing any digital capabilities not articulated or planned for?

3 **To what extent do the curricular conceptualisations of digital capabilities indicate a match of the digital capabilities practiced by engineering and management employees/professionals?**
   - 3.1 What are the possible digital practices of employees/professionals of the same discipline (in management and engineering)?

3.2 Are there digital capabilities that engineering and management students possibly need to be developing whilst at university that they are not currently developing?

1.7 Research approach

My main study site is a research-intensive Russell Group university (Russell Group, 2014), UniA for short. This was selected mainly for pragmatic reasons of access. At UniA at the time of data collection, it was not a requirement for programmes to articulate how they intend to develop students' digital capabilities, although UniA's Education Strategy stipulates a drive to incorporate more active and authentic learning opportunities for students. However, some of UniA's schools/departments have mapped digital capabilities in their programme-level graduate attributes. I also wanted to include data from another university, UniB, which has chosen to map digital and information literacies explicitly as graduate attributes across *each* programme to ascertain any potential differences between the two approaches.

In turn, my study focuses on curricular provision, i.e. students' use of digital tools within disciplinary tasks in credit-bearing modules. Additional co-curricular (complementing the academic study of engineering/management students) or extra-curricular (e.g. general provision unrelated to subject area) activities related to digital capabilities are not examined. In terms of centrally-supported educational software, both UniA and UniB have a virtual learning environment (VLE) and e-portfolio system with additional software tools for specific programmes or schools.

With respect to methodology, the adopted conceptual framework lends itself most appropriately to a case study as it can help to understand an in-depth situation in detail (Yin, 2009), which suits qualitatively-oriented research questions (Prescott, 2013 quoting Tellis, 1997). The case study, therefore, is mainly qualitative in orientation to suit the *'how?'* research question, utilising a range of different data sources. These include documentary sources, such as programme and module documentation, semi-structured interviews to elicit the perspectives of staff members, focus groups and one-to-one interviews with a subset of students. Subsequently, staff members identified professionals from their respective industries to participate in interviews. The 'bounded system' for this study is interpreted as a particular disciplinary conceptualisation of digital capabilities in the formal curriculum, with comparisons made to digital practices of professionals. To make this manageable within the constraints of this thesis, two cases have been selected.

The rationale for choosing engineering (Case 1) and management (Case 2) in this study is threefold. First, they are both professional degrees with a likely trajectory in terms of employment. For instance, Chartered Engineering (CEng status) in the UK is regulated by the Engineering Council through the UK Standard for Professional Engineering Competence (UK-SPEC). Management is a more varied discipline, aligned to a range of professions. For instance, marketing professionals, a sub-discipline of management, are regulated by The Chartered Institute of Marketing. Second, I wanted the two cases to represent a science and a social science-based discipline in case their epistemological differences might have implications in relation to the foregrounded digital capabilities. Third, in my central support role, I need to be able to support any discipline with their curriculum design, therefore I wanted to choose disciplines in which I had no prior subject background.

1.8 Role of the researcher

My motivation to embark on this study stems from my role as a learning technologist in a central support unit. I have been a passionate promoter of digital capabilities at our university, and have worked to co-facilitate our institutional working group, which has contributed to our QAA review on the theme of digital literacy (QAA, 2014). Previously, I undertook research on the digital literacies of academic staff members (Powell & Varga-Atkins, 2013), acknowledging that their digital capabilities have an impact on those of their students (e.g. Beetham, McGill, & Littlejohn, 2009).

I have a remit to contribute to curriculum design and technology-enhanced learning sessions aimed at staff members from different disciplines (humanities, social sciences and sciences) and to support innovative practices (Hudson, 2009). These sessions include activities in which academics need to reflect on their own digital practices and capabilities, and consider what the digital capabilities their students need to develop. Insights gained from this thesis would help me learn more about how digital technology has transformed and disrupted knowledge-construction processes within engineering and management, so that I can support their curriculum design and review activities from a digital capability perspective. In turn, I hoped that the process of inquiry itself could be transferrable so that other disciplines' programme teams can be supported in challenging and improving their current curriculum design practices to develop digitally-capable professionals.

1.9 Organisation of the thesis

The remainder of the thesis is as follows:

- Chapter 2 provides a **literature review** on digital capabilities and the most influential related frameworks.
- Chapter 3 outlines my **conceptual framework** of three research domains and their intersection: digital capabilities, signature pedagogies, in the context of curriculum design.
- Chapter 4 details the adopted **research design**, the multi-case study methodology, its rationale and process from design to analysis.
- Chapter 5 presents my **findings** in engineering and management.
- Chapter 6 is a **discussion** of findings in relation to my conceptual framework, including a cross-case comparison.
- Chapter 7 **summarises** and **concludes** the study by outlining practical and theoretical implications, limitations and further research.

2 Chapter 2 - Literature review

The key conceptual concern of this study is 'digital capabilities' and the focus is their development in HE, more specifically in two applied professional disciplines. In this chapter, I review the complex and ever-expanding literature on digital capabilities in HE curriculum design, situating it in the wider context of workplace/professional education. Despite a significant body of work which exists on digital capabilities, including studies on curriculum design, students' digital skills and experiences, only a limited number of studies explore digital capabilities in specific disciplines. This is the gap which my study seeks to address.

2.1 Scope of the study

Due to the expansive literature on digital capabilities, I focus on specific themes covered within this study. The topics relating to digital capabilities which are *outside* the remit of this study include:

1. **Issues of digital access and inclusion** – discussed briefly in Chapter 1;
2. **Digital capabilities and international/cultural differences** – frameworks that may not work in different cultural and local contexts (Alexander, Adams-Becker, Cummins, & Hall-Giesinger, 2017; Brown, 2017);
3. **Digital capabilities of staff and postgraduate research students** (Anagnostopoulou, 2013; Bennett, 2012; Powell & Varga-Atkins, 2013) – staff have an influence on capabilities of students, partly because they design curricula and partly because they act as role models (Beetham, 2017b; Beetham et al., 2009; Fielding et al., 2017; Kluzer & Priego, 2018; Tsatsou, 2017);
4. **Barriers for embedding digital capabilities**, such as resources and time (Fielding et al., 2017; Jeffrey et al., 2011);
5. **Co- and extra-curricular provision** – any provision outside the taught curriculum (e.g. separate digital capability sessions offered by central services, whereas library support within taught modules is included);
6. **Student agency** – what students actually do and how they learn irrespective of the 'ideal' curriculum designed for them (Erickson & Shultz, 1992).

In summary, the study deals with designing effective undergraduate/postgraduate taught curricula in order to develop digital capabilities for students of applied professions in UK HE (see definition in sub-section 3.3.1). Three domains intersect in this - curriculum design, digital capabilities and disciplinary knowledge-practices - all of which take place in the wider context of professional practice and lifelong learning (Figure 2.1).

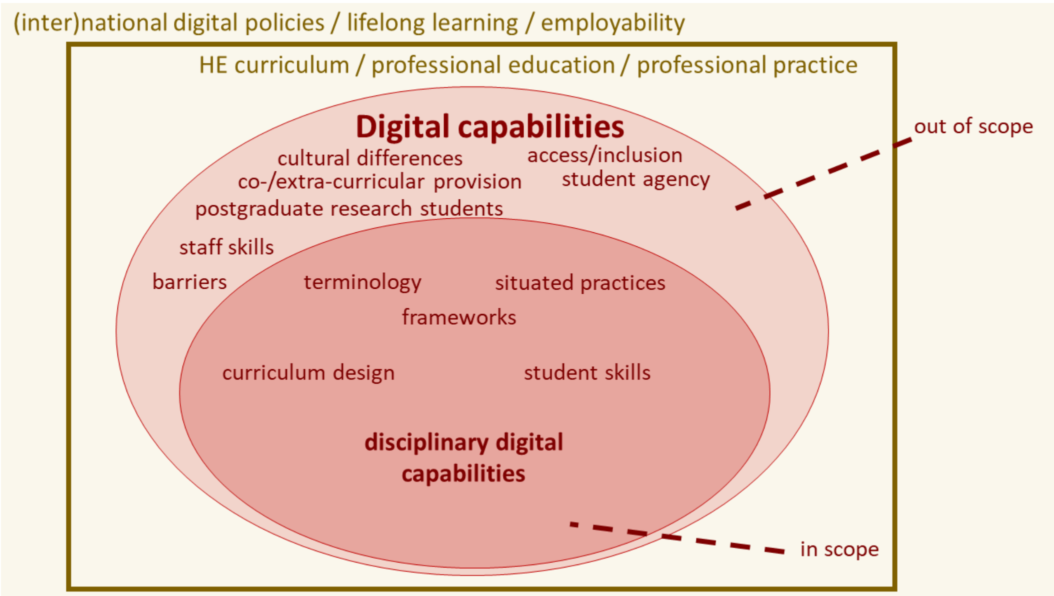

Figure 2.1 Scope and context of literature review

2.2 The notion of digital capabilities

The literature on the notion of digital capabilities itself reflects the much-debated nature of the concept (Belshaw, 2012; Brown, 2017). Interest in digital capabilities comes from many angles, whether policy-related (Wallis & Buckingham, 2016; Warren, 2011), academically-located research studies on HE staff/student digital capabilities (Jones, Ramanau, Cross, & Healing, 2010; Kennedy, Judd, Dalgarno, & Waycott, 2010), studies on the HE provision of digital capabilities support (Austen et al., 2016; Beetham, McGill, & Littlejohn, 2009; Fielding et al., 2017) or reports on HE institutional/national digital capabilities initiatives (Beetham, White, & Wild, 2013; Handley, 2018; JISC, 2017c).

2.2.1 Shifting terminology

Arguably, the reason for the extensive literature is due to digital capabilities acting as a "multi-faceted moving target" (Ferrari et al., 2012, p.171). This refers to the need for digital capabilities to change constantly in response to epistemological and social changes brought about by technological evolution and transformation (Handley, 2018; Higgins, 2016; Allison Littlejohn et al., 2012) in unforeseen combinations (Dron, 2011). Navigating the digital landscape requires flexibility, adaptivity and creativity (Belshaw, 2012; Sharpe, 2014). As Baume (2012) foregrounds in 'digital fluency', his preferred term, "our most valuable digital capability is probably to continue to review and enhance our digital capabilities" (p.3).

'Just' defining the notion itself has produced abundant articles (Bawden, 2008; Buckingham, 2010; Koltay, 2011), and even whole-length theses (e.g. Belshaw, 2012). Accordingly, the terminology itself is ever-shifting (Ferrari, 2012): from 'IT', 'application to IT' (CBI & Universities UK, 2009) through 'ICT' (information and communication technologies), 'new literacies', 'media literacy/cies' (Buckingham, 2006; Livingstone, 2004), 'multiliteracies' (Goodfellow, 2011; Lea, 2004; Street, 2003) to 'digital skills', 'digital literacy/literacies' (Beetham, McGill, & Littlejohn, 2009), 'e-literacies', 'digital fluency' (Baume, 2012), 'digital competences' (Ferrari, 2012; Ilomäki, Paavola, Lakkala, & Kantosalo, 2016) and, most recently, 'digital capabilities' (JISC, 2017b), '21st century skills' (Orlik, 2018b) or being extended to the wider concept of digital agency (Passey et al., 2018). Ilomäki et al. (2016) find no fewer than 34 synonyms for digital literacies. Whatever the preferred neologism, it usually stands as an umbrella term encompassing a range of capabilities.

As a result, a long line of literature reviews summarise the broad concept of 'digital literacy', a term used by Gilster (1997). Others have explored its origins and characteristics (Bawden, 2008; Coldwell-Neilson, 2017; Goodfellow, 2011; Goodfellow & Lea, 2007; Ilomäki et al., 2016; R. Kahn & Kellner, 2005; Lankshear & Knobel, 2008; Littlejohn et al., 2012; Martin & Grudziecki, 2006; Sharpe, 2014). These reviews set out to define digital capabilities in order to develop a common understanding (Coldwell-Neilson, 2017).

For the purpose of this thesis, I adopt JISC's broad definition of digital capabilities (in the plural), as "capabilities which fit an individual for living, learning and working in a digital society" (JISC, 2017c). This also recalls the human capabilities approach outlined earlier. I note its similarity with the EU's definition of digital competence as "set of knowledge, skills and attitudes needed today to be functional in a digital environment" (Ferrari, 2012, p.21). I use alternative terms interchangeably – e.g. digital skills or literacies – to reflect the literature or as used by study participants.

Digital capability, the focus of this thesis, is a broader conceptualisation related to professional development and pedagogy (Austen et al., 2016) and focused on what the student is capable of achieving (Beetham, 2017a). Admittedly, there will be occasions when distinguishing the two may not be straightforward.

2.2.2 Digital capabilities as situated practices

In policy-level initiatives there is a tendency to view digital skills as basic functional or technical skills (Hinrichsen & Coombs, 2013; Lea, 2013; Lea & Goodfellow, 2009), whereas in education they are seen as situated, social, cultural and disciplinary practices associated with higher forms of knowledge creation, creativity and innovation (Adkihari, 2011; Beetham & Oliver, 2010; Belshaw, 2012; Buckingham, 2007; Coldwell-Neilson, 2017; Goodfellow, 2011; Janssen et al., 2013; McDougall et al., 2018; Sharpe, 2013). While acknowledging that the literature on social and situated practices is extensive and definable in a myriad of ways (Alston, 2017), for the purpose of this thesis I refer to digital practices as examples of social practices, or "regular sets of behaviours, ways of understanding and know-how and states of emotion that are enacted by groups configured to achieve specific outcomes through their activities" (Trowler, 2014b, p.21).

As Gilster observes, "digital literacy is about mastering ideas, not keystrokes" (Bawden, 2008, p.20). To illustrate this with an example relevant to this study, a functional skill would include being able to use word processing or spreadsheets, as opposed to other professional activities such as engineers or managers connecting with others through social media or collaborating on digital artefacts. These practices depend on different factors, e.g. professional role, context, sector, education level or environment (McDougall et al., 2018; Orlik, 2018b). Belshaw expresses digital capabilities being situated practices, using a metaphor based on baking bread:

> There are many different types of bread, some including yeast, some without, some involving a lot of kneading and some not. However, all (I believe) involve the use of flour, water and heat meaning that there are essential elements that are configured in various ways for different results. (Belshaw, 2012, p.216)

This multi-faceted characteristic of digital capabilities also leads to the avoidance of threshold or competence setting (Belshaw, 2012), in preference to a capability-based approach focusing on the "future potentiality of the student to learn" (Higgins, 2016, p.1989). As stated previously, the terms 'competence' and 'capability' may not be as clear-cut (Taylor & Bogo, 2014); indeed, the DigComp framework uses 'competence' (Ferrari, 2013) in the sense of 'capability'. This is also a reason why 'digital literacy' has been replaced with the plural, 'digital literacies', denoting a myriad of social practices that can be contained within the concept (Belshaw, 2012; Brown, 2014; Lankshear & Knobel, 2008).

Academic interest from a range of sources has contributed to the multi-faceted nature of digital capabilities, such as literacy, library, media and culture studies, social sciences, including education and educational technology (Ilomäki et al., 2016; Koltay, 2011). As referenced in the Learning Literacies in the Digital Age (LLiDA) study (Beetham, McGill, & Littlejohn, 2009), these can be traced back to elements of JISC's Digital Capability Framework chosen for this study in the following ways:

- *Information literacy, digital scholarship and collaboration/communication* from literacy/New Literacy (and library) Studies, contributing the conceptualisation of digital capabilities (then digital literacies) as social practices at the intersection of academic literacies and technologies;
- *Media literacy* element: from studies of media and culture;
- *Critical and transformative aspects* of digital capabilities: from social sciences (including the educational technology literature).

These three influences are discussed next.

2.2.2.1 New Literacy Studies: From individual cognition to social practice

The digital literacies literature has outgrown from the domain of literacy studies (Belshaw, 2012). Literacy studies responded to technological change with a large body of work on 'new literacies' or New Literacy Studies (NLS), exploring the interrelationship of academic literacies and technological developments, i.e. reading/writing as practices of code-making and exchanging meanings in a new era of multimodal/multimedia 'texts' examining how technologies have potentially disrupted these original practices (Barton, Hamilton, & Ivanič, 2005; Hinrichsen & Coombs, 2013; Lankshear & Knobel, 2008; Lea, 2013; Lea & Jones, 2011; Street, 2003). One feature of NLS was that in examining students' use of technologies, it foregrounded literacy practices over technological ones (Bhatt, 2001; Ilomäki et al., 2016), and social and collaborative practices over individual cognition (Goodfellow, 2011; Jones, 2011). Another contribution that NLS brought to digital capabilities was highlighting that the development of digital literacies is not dependent on an individual's choices, but is influenced by other factors such as institutional culture, provision and access to technology, and, by association, curriculum design (Jones, 2011). At the time, research that explicitly addressed the interface between academic literacies and technologies was sparse (Crook, 2005; Goodfellow & Lea, 2007; Lea, 2004). However, NLS has greatly informed elements of the DigiCap-Framework's information literacy and digital scholarship. It is important to emphasise that NLS authors were interested in potential links between the ways students used technologies outside the curriculum (Lea & Jones, 2011) and how they used technologies in their academic courses. They were less interested in exploring the use of technologies in curricular tasks. Consequently, this study takes the cue from this characteristic and locates its focus on digital literacies *in* the curriculum. Thus, in contrast, my study is concerned with those capabilities required of professionals in the workplace and the role of the curriculum in preparing students for the capabilities expected of them.

2.2.2.2 Media and culture: media (and information) literacy

Recent definitions of media literacy, such as "the ability to use, understand and create media and communications in a variety of contexts" (Ofcom, 2017), are echoed in the definition of the DigiCap-Framework's media literacy element (see sub-section 3.2.2). Such definitions arise from the convergence of media and communications and literacy/library studies, as a result of recent technological changes transforming how we consume and produce information and communications. Traditional media, e.g. television or newspapers, have undergone extensive change, with most media channels reinventing their communication formats for new digital platforms, such as social media or smartphone applications. This has meant that whilst HE students might have been used to critiquing and understanding traditional media audiences, these scholarly skills have had to be extended to digital 'texts' (Buckingham, 2007, 2010; Hinrichsen & Coombs, 2013; Jones, 2011; Lea & Jones, 2011). At the same time, information and data have also expanded to be 'multimodal', i.e. encompassing different modes together, e.g. audio, text, hyperlinks, visuals and three-dimensional (3D) artefacts (Jewitt, 2009a; Kress & Van Leeuwen, 2006). Indeed, from a multiliteracy perspective, contents created in new media formats are an extension of digital texts, to which the principles of academic literacy apply, such as critical evaluation and information literacy (Lea & Jones, 2011). This conflation of media and information literacy (Wallis & Buckingham, 2016) is what Brabazon sees as providing "the metaphoric driving license for the information age" (2013, p.314), and therefore is an essential element of digital capabilities. Another aspect that media literacy definitions stress is the dual role of individuals (consumer and producer), which implies skills in producing multimedia content in the form of audio, video and web (Koltay, 2011).

2.2.2.3 Social sciences (and education): Critical and transformative

There are two other pervasive principles, 'critical' and 'transformative', underpinning the notion of digital capabilities, and which are derived from the social sciences and education domains. These are what Ferrari (2012) highlights as the glue that make the elements of a digital capability framework more than the sum of its parts.

'Critical' in this context bears a number of meanings – i.e. critical reflection and critical information literacy – and is one of the eight essential elements of digital capabilities identified by Belshaw (2012). As for 'critical reflection', there are authors who underline the importance of criticality in the choice of digital tools as well as the reflexivity evident in the forms and structures of communication (Anyangwe, 2012; Baume, 2012; Fisher, Denning, Higgins, & Loveless, 2012; Jones, 2011; Powell & Varga-Atkins, 2013). Hinrichsen and Coombs (2013) usefully distinguish between the external and internal dimensions of criticality. The external dimension is concerned with the "effects and social relations bound in technology" (p.21337), while the internal one relates to students' abilities to be able to develop a critical distance in relation to media (Koltay, 2011, p.212). This entails the capacity to distinguish between personal, social, public, political and academic discourses and communication practices in different digital environments (Sinclair, 2013, p.46), as well as developing a critical awareness of the nature of digital space and within it the "presence or absence of particular viewpoints" (Brown, 2014, p.286). Finally, it is this criticality that leads to action, social engagement and civic responsibility that makes our society better (Josie Fraser, quoted in Anyangwe, 2012; Mihailidis, 2018). One way to achieve this, as noted by Goodfellow (2011), could be through participation in professional, occupational and lifelong learning communities.

This socio-cultural and political dimension of learning and knowledge creation is made possible by the transformative power of digital technologies (Bartlett-Bragg, 2017). As the LLiDA report highlights, "how we work, think, communicate and learn" can profoundly transform as a result of education responding to technological changes (Beetham, McGill, & Littlejohn, 2009, p.8). For this reason, the authors use the phrase 'learning literacies for a digital age' (as opposed to 'digital literacies'). Digital capabilities can be instruments for disrupting power relationships in educational contexts in both positive and negative ways (McDougall et al., 2018), thereby offering universities a role in redefining their "relationship to knowledge in society" (Littlejohn et al., 2012, p.547).

One potential weakness of the DigiCap-framework, discussed in section 2.3, is that these two features, 'critical' and 'transformative', are not foregrounded**,** although they can be traced in certain elements of it. This is the reason why my study intends to highlight the critical and transformative aspects of digital capabilities.

2.2.2.4 Tension: broad/narrow conceptualisation of digital capabilities

The discussion above has demonstrated the difficulty of defining digital capabilities and has explored the notion from a situated practice perspective, highlighting three various domain influences that have contributed to the DigiCap-Framework adopted in this study. A review of digital capability frameworks found that the areas of digital capabilities most actively supported in UK HE were academic literacies, information and media literacies, and ICT-skills (Littlejohn et al., 2012).

However, the situated nature of digital capabilities leads to a tension that is especially pertinent to this study's focus on disciplinary conceptualisations of digital capabilities. This is a tension between striving to identify a generic set of capabilities whilst accommodating local contextual factors, and specific examples that support common understanding (Brown, 2017b; Orlik, 2018). A similar tension has been identified in relation to sustainable education by Susan Brown (2014). For example, a generic and broad definition of digital literacy is provided by Paul Gilster (1997, p.33), who identifies it as an "ability to understand and use information in digital contexts". On the one hand, it is this broad conceptualisation which has proved valuable to educators and researchers (Bawden, 2008), since it can act as an umbrella concept encompassing specific practices or technologies in different contexts, while withstanding time and changes to any of these. On the other hand, such broad definitions may not be meaningful in more specific contexts. If too narrowly articulated, the definition can become restrictive (Koltay, 2011).

This poses a problem for studies of digital capabilities. The scarcity of disciplinary studies of digital capabilities are due to this tension between narrow and broad conceptualisations. The solution used in this study and employed by others appears to adopt a two-pronged approach: a broad definition underpinned by a framework that attempts to capture and categorise a myriad of underlying situated practices in a specific context (Ferrari, 2013; JISC, 2017b; Vuorikari et al., 2016), e.g. identifying the digital capabilities required by students in UK HE (Janssen et al., 2013). These frameworks are discussed next.

2.3 JISC's Digital Capability Framework

Authors over the last decade have established, used, evaluated and adapted generic frameworks of digital competences/capabilities (Coldwell-Neilson, 2017; Handley, 2018). As part of, or in addition to these, a number of studies have also produced a review of frameworks (Dore & Geraghty, 2015; Bartlett-Bragg, 2017; Beetham et al., 2009; Brown, 2017a; Ferrari, 2012; Janssen et al., 2013; Sharpe, 2014**).** The two most commonly-used frameworks are the aforementioned European DigComp, a Digital Competence Framework for Citizens, and JISC's Digital Capability Framework (DigiCap-Framework) containing six elements (JISC, 2017b). The former is aimed at citizens across Europe, published in 2013, revised in 2016, and complemented with proficiency levels and examples of use in 2018 (Carretero et al., 2018; Ferrari, 2013; Vuorikari et al., 2016). The latter was an update of an original seven-element model introduced in UK tertiary education in 2009.

The two frameworks overlap in a number of areas, including digital creation, innovation, communication, collaboration, participation, engagement, digital identity and wellbeing (Biggins et al., 2017). However, DigComp2.1 (Carretero et al., 2018) is meant to be general in terms of its target audience (lifelong learners, citizens, employees). It is also a competence-based framework, which entails a threshold approach (individuals are either competent or not), which identifies eight proficiency descriptors in each of its five competence areas (information and data literacy, communication and collaboration, digital content creation, safety and problem-solving). In contrast, the DigiCap-Framework has always been suggested as a starting point for reflection (Handley, 2018) and has been largely adopted, utilised and modified across HEIs and related professional associations (see section 0). For these reasons, I have adopted the DigiCap-Framework to guide this study. I now offer an overview, with its elements detailed in section 3.2.

2.3.1 Evolution of the DigiCap-Framework

The comprehensive LLiDA study (Beetham, McGill, & Littlejohn, 2009) paved the way for the first iteration of the model. LLiDA reviewed the existing digital literacies frameworks and HE provision from the wider perspective of learning literacies, which was later updated (McGill & Beetham, 2015). The first model, by Beetham and Sharpe (2010), describes digital literacy as a uni-directional development process, running from access and functional skills through to higher-level situated practices and identity. It is also meant to reflect how individuals can be motivated to develop new skills and practices in different situations. The layered, pyramid representation of digital capabilities as access-skills-practices-attributes has since been modified to reflect that there are a number of ways of acquiring capability (Bennett, 2012). For instance, digital practices can develop both from accessing technologies as well as from a particular professional attribute or digital identity, e.g. wanting to connect with like-minded professionals in a particular discipline. This multi-directional development is visualised in the modified pyramid in Figure 2.2.

Figure 2.2 Beetham and Sharpe's (2010) 'pyramid model' of digital literacy development–enhanced with multidirectionality

Numerous studies and the early stages of the JISC Digital Literacies Programme have drawn on this model. As a result, some have suggested modifications and enhancements to address limitations of the model. For instance, separating skills from practices in such a clear-cut way suggested that important opportunities might be missed to effectively engage with digital practices (Hinrichsen & Coombs, 2013, p.3). A missing overarching element, critical reflection, was identified on the basis of a study on staff's digital literacies (Powell & Varga-Atkins, 2013), whose findings suggested that for digital practices to emerge, the synergy of three components were necessary: access to, and awareness of, technologies; and critical reflection (Baume, 2012) (see Figure 2.3). One critique of the pyramid model was that it was vague about the nature and importance of attributes (Sharpe, 2014).

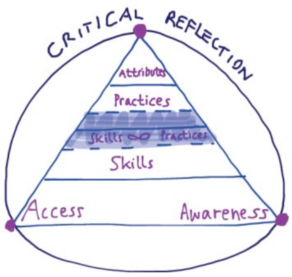

Figure 2.3 Modified Sharpe and Beetham-model (2010, by Powell & Varga-Atkins, 2013)

2.3.2 Overview of the Digital Capability Framework

Sharpe and Beetham's model was piloted and used extensively in the early stages of JISC's Digital Literacies programme (Handley, 2018), modifications and critiques helped to refine, which resulted in a new, different representation. Originally expressed as a hub-and-spoke model of seven elements, it was then refined to six elements, visualised as a Venn-diagram (Figure 2.4), which included: 1) ICT proficiency; 2) information, media and data literacies; 3) digital creation, innovation and scholarship; 4) digital learning and self-development; 5) digital communication, collaboration and participation; and 6) digital identity and wellbeing (JISC, 2017b).

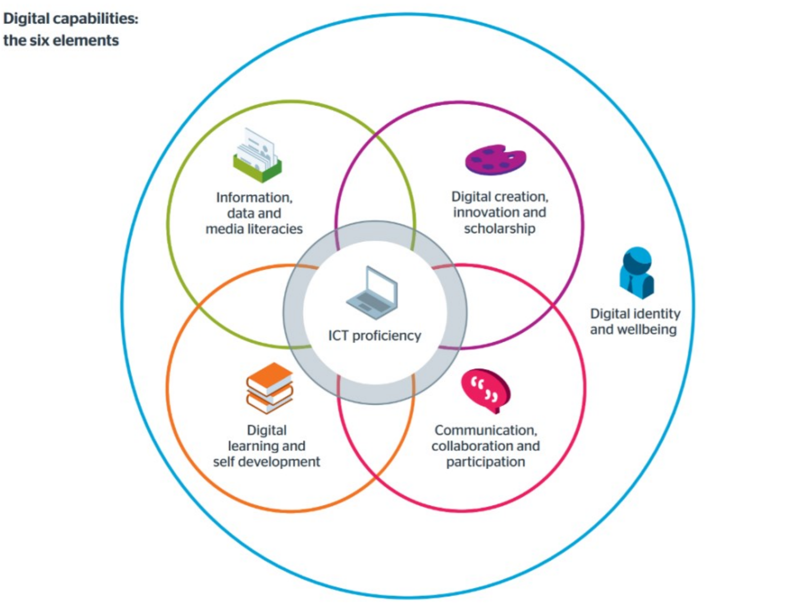

Figure 2.4 Digital Capability Framework (JISC, 2017b)

DigiCap is a typological framework which helps characterise the kinds of digital practices that professionals (and students) can undertake. ICT proficiency sits in the middle to express its foundational nature onto which all the other elements build, followed by the remaining four capabilities arranged in Venn diagram-like circles to illustrate their overlapping nature, and finally, digital identity and wellbeing, thereby encompassing all the others as an overarching, capstone capability. Helen Beetham (2017a) has described the DigiCap-Framework as being the result of 'flattening the pyramid' as represented in Figure 2.2 (Sharpe & Beetham, 2010). The top level of the original pyramid-shaped model (attributes) became the outer circle (digital identity/wellbeing), while its bottom layer (access) became the DigiCap-Framework's innermost circle (ICT proficiency).

A central feature of the DigiCap-Framework is that it is aimed at a generic, non-disciplinary context. Indeed, DigiCap has always been intended to invite local interpretation, i.e. to be co-created with its users, a process which is seen as important as the resulting definition or framework itself (Baume, 2012; Belshaw, 2012; Ilomäki et al., 2016). However, although the framework has been used widely in practice by institutions (see JISC's Digital Literacies Programme), not much academic literature, apart from Handley (2018), has attempted to reflect and critique it since its revision into its current Venn format. I also argue that studies illuminating this co-creation process in specific disciplinary contexts are rare. However, it is necessary to first focus on the literature pertaining to the intersection between curriculum design and the development of students' digital capabilities in order to argue the significance of this study.

2.4 Designing curriculum for digital capabilities

The backdrop to why educating digitally-capable professionals in the 21st century is important has been outlined in Chapter 1. These touch on lifelong learning (Beetham, McGill, & Littlejohn, 2009; Littlejohn et al., 2012), employment and competitiveness (European Commission, 2016; Hall, Nix, & Baker, 2012; Sinclair, 2013), social inclusion (Jeffrey et al., 2011; Vuorikari et al., 2016), civic engagement (Belshaw, 2012; McDougall et al., 2018), societal wellbeing (Biggins et al., 2017), the quality of HE teaching and learning (QAA, 2014), and the transformative power of technologies to change what it means to learn (Littlejohn et al., 2012). At the same time, it has been observed that the HE curriculum has gaps, or has been slow in terms of preparing graduates in this regard (Coldwell-Neilson, 2017; Handley, 2018; Jeffrey et al., 2011; Littlejohn et al., 2012), which results in the need for HEIs to consider how they can foster the development of such skills (Becker et al., 2017).

2.4.1 Effective curriculum design

In terms of effective curriculum design models for digital capability development, the literature states that, broadly-speaking, the three main models for digital capability development are:

- Institution-wide programmes with generic processes, and with specific skills practised/assessed in subject modules;
- Separate skill modules alongside subject-specific modules;
- Digital capabilities embedded/integrated into modules and programmes of study (Beetham, McGill, & Littlejohn, 2009).

Whatever the model, such capabilities cannot emerge organically. Education has a role in "inculcating, moderating and extending such practices" (Hinrichsen & Coombs, 2013, p.21337). In addition, research evidence seems to suggest that the latter, integrated model is the most effective (Beetham et al., 2009; Fielding et al., 2017; Ford, Foxlee, & Green, 2009; Hall et al., 2012; Kingsley & Kingsley, 2009; Sinclair, 2013). Furthermore, support at departmental and subject level has also been highlighted in successful implementations of change initiatives (Anagnostopoulou, 2013). The need for support and the existence of different models are reflected in the UCISA survey on digital capabilities with 37% of responding institutions stating that developing digital capabilities was embedded into programmes, with 74% of all institutions offering training in specific aspects of digital capabilities as required by courses, while 22% indicated they offered freestanding modules on digital capability. Only 5% signalled that developing digital capabilities was not embedded in the curriculum (Fielding et al., 2017).

The LLiDA report (Beetham, McGill, & Littlejohn, 2009) identified a number of challenges in implementing digital capability development in curriculum design. Some included institutional silos with students seeking help in different places, poor embedding in the curriculum (especially at the level of feedback and assessment), and poor integration of digital literacies with academic/learning literacies; central support was not reaching students when they were engaged in authentic, subject-specific tasks. Some generic effective principles for embedding developments of digital capabilities include:

- Learning skills in context and accessing guidance at point of need (Hall et al., 2012);
- Introducing approaches that are genuinely used by researchers and professionals in digital environments and exploring the changing modes of scholarship and professionalism (Beetham, 2017b; Littlejohn et al., 2012);
- Considering how "forms of academic communication are constructed and how different media are used to persuade, argue, make claims and occupy a stance" (Littlejohn et al., 2012, p.554);
- Creating and facilitating an environment with relevant digital tools (Littlejohn et al., 2012) which supports subject-specific knowledge as well as social and technical skills (Sinclair, 2013);

- Foregrounding academic skills and practices as opposed to the functional framing of technology (Hinrichsen & Coombs, 2013);
- Authentic tasks – many initial provisions and examples of digital literacy development come from work-based, authentic settings (Beetham, McGill, & Littlejohn, 2009). At the same time, work-based learning/authentic assessment studies do not appear to specifically focus on digital capabilities (Ashford-Rowe, Herrington, & Brown, 2014; Blaaberg, Kazmierkowski, Pedersen, Thogersen, & Tonnes, 2000; Campbell, 2000; Coon & Walker, 2013; James & Casidy, 2018);
- Learning contexts which promote students to be connected, confident, adaptable and intentional (Sharpe, 2014);
- Engaging students in a two-way dialogue in terms of understanding the role of technology in the context of their subject and also what students can bring to their study in relation to their existing digital capabilities (Beetham et al., 2013).

Echoing the LLiDA study, the UCISA report (Fielding et al., 2017) calls for more research to understand the ways and extent to which digital capabilities are integrated in the curriculum. In particular, one gap in the field of media literacy concerns the lack of identification of and little support for "critical aspects of reading media and creative practices of media production" (Littlejohn et al., 2012, p.553), which is also true of the reviewed frameworks, echoing similar shortcomings in UK education policies (Wallis & Buckingham, 2016). Good practices appear evident in the areas of information/academic/learning literacies and ICT skills (Beetham, McGill, & Littlejohn, 2009).

The JISC Digital Literacies/Capabilities Programme has produced extensive resources and toolkits to support curriculum integration[1]. In addition, Littlejohn et al. (2012) highlight a paradox: the effort invested in these general frameworks is somehow working against effective curriculum design requirements, i.e. the constant revision of knowledge practices and their embedding in specific disciplinary and professional contexts. It is at this paradox and with the gap in existing literature that I locate my study. I draw on a generic framework but offer insights into digital capabilities in a disciplinary context.

[1] See https://www.jisc.ac.uk/rd/projects/building-digital-capability

2.4.2 Students' digital capabilities

An important area to consider in curriculum design is students’ digital capabilities, which has been the focus of many research studies. The authors of generational studies who identified young people as Digital Natives, Net Generation, Generation X/Y or Millennials (e.g. Oblinger & Oblinger, 2005; Prensky, 2001), conceived of students entering university as a homogenous group with more advanced technological skills than those from older generations, an observation which has been disputed (Beetham et al., 2013; Jones, 2011; Jones et al., 2010; Kennedy et al., 2010). With respect to students’ digital capabilities, the following dynamics have been observed:

- Students’ levels of technology adoption are lower and at a less advanced level than predicted (Kennedy et al., 2010);
- Demographic variables other than age also influence digital capabilities and students’ experiences (gender, socio-economic status, etc.) (Kennedy et al., 2010; Warren, 2011) as well as other contextual factors (Sharpe, 2014);
- Frequent use of social media does not necessarily mean that students are capable of transferring such skills into professional/subject-specific contexts (Beetham et al., 2013; Kennedy et al., 2010; Littlejohn et al., 2012);
- Academic staff can overestimate students’ digital capabilities (Beetham, McGill, & Littlejohn, 2009) as can employers (Coldwell-Neilson, 2017);
- Device ownership does not necessarily translate beyond basic functionality use (Margaryan, Littlejohn, & Vojt, 2011);
- Students can over-estimate their own capabilities (Sharpe, 2010); in a study where 94% of participants described their skills as ‘average’ to ‘very good’, only 39% demonstrated these levels in a practical test (Coldwell-Neilson, 2017, p.5);
- Over-confidence can be a barrier to students’ development of digital capabilities (Jeffrey et al., 2011; Sharpe, 2014);
- Students may be technologically proficient but lack the ability to critically evaluate digital tools and resources (Sinclair, 2013; Warren, 2011);

- Discrepancies exist between practices valued in academic teaching and assessment and learners' everyday technology use and media engagement (Littlejohn et al., 2012);
- Students are guided and highly influenced by their tutors in their technology use and adoption (Beetham, McGill, & Littlejohn, 2009; Littlejohn et al., 2012; Margaryan et al., 2011);
- Students need guidance, scaffolding and support in developing digital practices as learners and would-be professionals (Bartlett-Bragg, 2017; Jeffrey et al., 2011).

Although young people may be users of new media, some appear to lack critical capacity to understand how such media content is produced. Similarly, some students demonstrate an uncritical adoption of websites and digital tools, unaware of risks of data privacy and security (Beetham, McGill, & Littlejohn, 2009). These studies explored students' digital capabilities in generic contexts, as opposed to relating them to particular disciplinary tasks. This also means that literature about the digital capabilities of particular professions and fields of expertise is lacking.

2.5 Digital capabilities in given disciplines

Having explored effective curriculum design principles for developing HE students' digital capabilities, identifying students' current skill gaps, I now turn to the importance of contextualising digital capabilities in applied disciplines. Taking my cue from previous studies that summarise university provision of digital capabilities in UK HE generally (Beetham, McGill, & Littlejohn, 2009; Littlejohn et al., 2012), I argue that since then little work has detected effective curriculum design intended to develop digital capabilities from a disciplinary perspective.

2.5.1 Digital capabilities and professional education

Various authors have argued for the importance of digital literacy skills in programmes leading to professional qualifications (e.g. Hall et al., 2012). Beetham posits that "digital capability is not a separate aspect of learning but integral to being effective in a subject area, or a vocation or profession" (2017b, p.2). The 2017 Digital Literacy Impact study explores the link between HE provision for digital capabilities and the success of graduates who enter employment as professionals (Becker et al., 2017). This impact study found that HE students who had curricular provision to develop their digital capabilities, developed confidence in their digital know-how, in turn positively impacting on their occupational success as professionals. Digital literacies do not just enable professionals to utilise technologies and applications in their field as well as allowing them to share relevant information and research, but also helps them to stay relevant and contribute to their effective communication and collaboration. Moreover, being engaged in such developments fosters an agile and open mind-set in professionals, leading to lifelong learning as well as gains in confidence and improved self-regulation and self-direction (Becker et al., 2017).

Similar synergies between digital capabilities and other learning literacies have been observed elsewhere. For instance, authors have reported on the positive relationship between self-efficacy, attitude to technology and motivation to learn, and digital skills (see Jeffrey et al., 2011; Phelps & Graham, 2008), as well as self-regulated learning using a method of connecting with learners with similar goals and development needs (Littlejohn, Milligan and Margaryan, 2013). If student learning is facilitated in a safe, collaborative and supportive learning environment, it has been shown to contribute to increased self-efficacy and confidence (Jeffrey et al., 2011). Confidence can also mean an understanding that a digital environment can be "more forgiving" in relation to experimentation compared to physical environments, while actions can be "undone", thereby enabling an increase in learners' risk-taking (Belshaw, 2012, p.211).

2.5.2 The insufficiency of generic frameworks

I will now turn to examining why generic frameworks are insufficient for disciplinary explorations of digital capabilities. Being digitally capable has been shown to help professionals thrive in their field, putting the onus on universities to maintain the relevance of their programmes (QAA, 2014) while reflecting changing knowledge practices and the nature of subject expertise within respective academic disciplines as a result of technological innovations (Beetham, 2012 quoted in Sinclair, 2013). Studies suggest that subject-specific disciplinary tasks using relevant technologies, i.e. embedded curriculum design, seem to be an effective way for developing digital capabilities (Coldwell-Neilson, 2017; Littlejohn et al., 2012; Payton, 2012). Despite this recommendation for striving towards embedded curricular development, the 2017 UCISA survey on digital capabilities indicated that only 20% of responding universities said that they recognised student achievement in this area in credit-bearing modules (Fielding et al., 2017). This comes five years after the finding that students rarely have opportunities to develop their digital know-how integrated in their disciplinary context (Littlejohn et al., 2012) while frameworks used for assessing such development tended to be more instrumental than "providing a basis for building an identity as a digitally capable graduate, scholar or professional" (Littlejohn et al., 2012, p.552). However, since this 2012-study, when only two institutions embedded graduate-level digital capabilities (ibid, p.553), as part of the JISC Digital Literacies programme, a number of HEIs have adopted digital literacies as their graduate attributes and/or have produced lists of discipline-specific literacies (Handley, 2018), but which have not entered the realm of academic literature.

Despite the above-mentioned HE institutional initiatives, recent findings highlight huge variation across departments and even within programmes with respect to required digital capabilities and a tendency to focus on providing digital content rather than embedding digital capability in programmes (Fielding et al., 2017). At the same time, it is still unknown whether graduates are digitally prepared for the workforce (Coldwell-Neilson, 2017). In fact, 41% of HE students reported that they felt unprepared for a digital workplace (Newman, Beetham, & Knight, 2018), which points to the need for disciplinary efforts to embed digital capabilities at programme level, as well as ensuring that the HE curriculum keeps up-to-date with the professional workplace, which then requires both programme and institutional-level approaches.

2.5.3 Transformative knowledge-practices in different disciplines

As discussed above, numerous studies have been devoted to conceptualising the general notion of digital capabilities. However, few examples exist that explore digital capabilities in specific subjects, e.g. digital reading skills (John, 2014; Khadawardi, 2016). One study examined the 21st-century skills required of engineering students (Fisher, Bagiati, & Sarma, 2014) but omitted digital capabilities in its investigation. Another study, written from a sustainable education perspective, explored the digital capabilities needed for interdisciplinary pedagogies (Brown, 2014). The two most pertinent studies which explore digital capabilities from a particular disciplinary context include construction management (Jupp & Awad, 2013) and religious studies (Sinclair, 2013). The reason why they are particularly pertinent is because they account for the impact of changing knowledge-practices as a result of technological innovations in their respective fields, while exploring what these mean for HE curriculum design. I summarise each study here.

Jupp and Awad (2013) focus on new forms of digital literacy required by construction management professionals by exploring the way a technological innovation, BIM (building information modelling), transformed this field. BIM methodology made it possible to virtually design and simulate the operation of buildings, enabling digitisation of not just products but the process itself (e.g. virtual construction prototyping). This brought about a paradigm shift in the industry (Holness, 2008; Jupp & Awad, 2013). It is now possible to model, simulate, analyse and visualise both the product and process of construction without leaving one's computer desk. This is a huge shift from thinking about problems, to constructing (physical) solutions, to learning a "new way of thinking through making" (via 3D/4D virtual modelling and simulation) (Jupp & Awad, 2013, p.2), thereby enabling students to engage in abductive problem situations in a digital problem-based learning setting. Such changes in disciplinary knowledge-practices have added complexity to project management necessitating a more multidisciplinary approach and different ways of engaging with technology, which require a new form of digital literacy for construction professionals, and so, changes to the university curriculum. In addition, Jupp and Awad suggested that adopting a design-led approach in authentic learning settings could be a good curricular approach to respond to these changes.

Sinclair's (2013) study is similar to Jupp and Awad's work in that it follows the epistemological impact of digital technology – the internet, smartphones or social media – on the field of religious studies, and how this needs to be reflected in what and how it is taught in HE degrees. For instance, Sinclair (quoting Cowen, 2011) emphasises that digital technology has affected how religions are studied and how information about religious traditions, groups and practices is communicated. For instance, technologies and social platforms have widened networking and sharing opportunities for students and scholars of religion globally while heightening concerns around ethical issues. However, there are more significant changes at play here. Technologies have shaped religious practices, beliefs, identities and belonging, in other words, deeply affecting "the delivery, reception and experience of religion" (Cowen, 2011, p.470). For example, there are places of interactive worship via avatars and online forums as well as applications dedicated to providing religious services. HE students of religion, therefore, need to be exposed to the challenges and opportunities of digital technology and its impact on their discipline.

At an institutional level, two universities, Oxford Brookes and Bath, have produced disciplinary articulations of digital literacies (Oxford Centre for Staff and Learning Development, Oxford Brookes University, 2013; University of Bath & JISC, 2012a, 2012b). The Bath outcomes involved definitions of digital literacies articulated by each faculty; sets of statements regarding the digital attributes, practices, skills and opportunities for access that learners in each faculty are expected to develop; and a baseline report which included the views of staff at all levels and across all institutional provision (Anagnostopoulou, 2013).

At the professional level, JISC with the HEA has produced a disciplinary articulation of digital capabilities for university-level educators, called the 'digital lens to the UKPSF' (JISC, n.d). The NHS Health Education England has done significant work in adapting JISC's DigiCap-Framework for health & social care professionals (2017). What is lacking, as evidenced by this handful of examples above, is a co-construction of conceptualisations of digital capabilities at programme and disciplinary levels.

What the above two studies (Jupp & Awad, 2013; Sinclair, 2013) have in common is their taking stock of how digital technologies have profoundly transformed (or disrupted) the knowledge-practices of their respective disciplines and what this means for the digital capabilities required of their HE students. They are examples of the importance of how the concept of digital capability needs to be explored in a subject-specific context for effective curriculum design in order to develop digitally capable professionals for our digital society.

2.6 Summary

The literature review demonstrates two gaps. Firstly, despite the need for disciplinary conceptualisations of digital capabilities, there is a paucity of such studies. This current thesis attempts to fill this gap in two applied professions, engineering and management. Secondly, in order to support any such effort in a discipline beyond engineering and management, a common process is needed, which can be applied in any discipline, something that has not yet been proposed in previous studies. This study intends to support this process by developing a conceptual framework to help researchers or curriculum designers undertake a review of a given discipline in the context of technological changes, thereby understanding what digital capabilities their professionals need to develop and how to reflect these in a revised curriculum.

3 Chapter 3: Conceptual framework

The study's conceptual framework can be imagined as a two-ended kaleidoscope, a combination of a practice- and theory-based lens, namely JISC's Digital Capabilities Framework (DigiCap-Framework) and Shulman's (2005b, 2005c) signature pedagogies, respectively. The practice-based lens helps with exploring digital capabilities while Shulman's signature pedagogies assists with the disciplinary angle. Both lenses offer a different perspective on the domain of this thesis, which is effective curriculum design in applied disciplines. I argue that this framework is a unique conceptual combination of digital capabilities and signature pedagogies, which in turn is an original feature of this thesis. To my knowledge, no studies have explored digital capabilities through the lens of signature pedagogies.

3.1 Study domain: curriculum design

The research domain of my conceptual framework is curriculum design preparing HE students to transition to professional practice in two disciplines, engineering and management. The relationship between the two domains as well as the curriculum's workplace influence is visualised in the two concentric circles in Figure 3.1. I focus on what intended curricular activities university educators have designed into their programmes. I treat this study as an exploration of an 'ideal' planned and intended curriculum, and how students enact this planned curriculum, although only for a limited period given the study's duration. Therefore, I exclude student agency in adapting and applying what is offered in the curriculum and/or co- and extra curriculum.

Figure 3.1 Domain of study: curriculum design leading to professional practice

From a curricular perspective, I draw on the principle of constructive alignment (Biggs & Tang, 2011). Constructive alignment is a frequently-adopted curriculum design approach, underpinning programme design learning theory (Beetham & Sharpe, 2013; Gulikers, Bastiaens, & Kirschner, 2004; P. Kahn, 2015; Kotzee, 2010; Walsh, 2007). It is widely used by the HE Quality Assurance Agency (QAA) and underpins the subject benchmarks (e.g. Jackson, 2002). Constructive alignment is a student-centred approach to design, focusing on what students learn, as opposed to what is taught to them. It stands for *constructivist* understanding and *alignment* in the design of outcome-based teaching. Alignment refers to a conscious matching between intended learning outcomes (ILOs), teaching and learning tasks (TLAs) and assessment tasks (ATs) in the design process with appropriate assessment criteria.

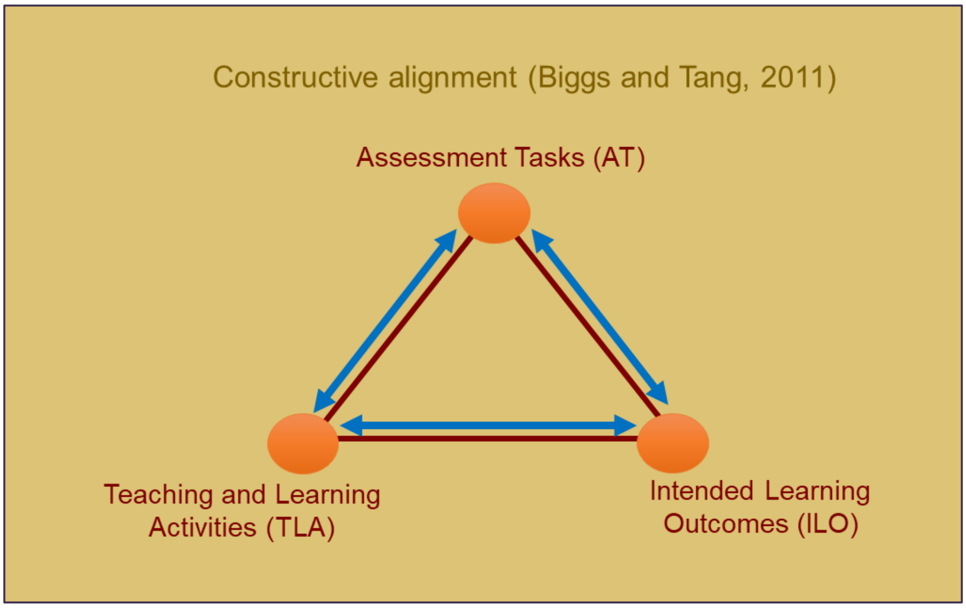

Figure 3.2 Constructive alignment

Constructive alignment works at various curricular levels, namely module, programme, and institutional (the latter sometimes termed ‘graduate attributes’). In this study, I analyse curriculum designs at a modular level as they are situated within their wider programme, as well as subject and professional bodies’ benchmarks. Constructive alignment is based on the SOLO (Structured Observed Learning Outcomes) taxonomy (Biggs & Collis, 1982), which is a model that describes the increasing levels of complexity in students’ understanding. Biggs and Collis differentiate between two kinds of knowledge: declarative and functioning. Declarative is akin to the lower- and functioning to the higher-order thinking domains in Bloom’s taxonomy (Bloom, Engelhardt, Furst, Hill, & Krathwohl, 1956). Accordingly, I explore teaching activities and assessment tasks, including assessment criteria, to identify opportunities for students to develop their digital capabilities, and indicate where these may appear, whether in learning outcomes, teaching activities and/or assessment tasks. A similar mapping was undertaken by Lam and Tsui (2016), although their study was predominantly a documentary analysis of competency and subject statements in the teaching profession, and did not include digital capabilities.

My study is concerned with two design aspects. First, it attempts to ascertain the skill development model necessary to promote digital capabilities, whether it be embedded skills within subject domains or separate skill development (Cranmer, 2006). This entails looking for articulations of digital capabilities in intended learning outcomes and skill statements in subject-specific modules (Beetham & White, 2013; Biggs & Tang, 2011; James & Casidy, 2018; Yorke, 2011). Although curriculum design from a disciplinary angle is intentionally supported by the QAA benchmarks, there is scant literature exploring the development of digital capabilities from a disciplinary angle in the HE curricula. In addition to a lack of experimental research in relation to digital capabilities from a curriculum design perspective, there is also little literature combining different perspectives such as staff, students' and employers' conceptualisations of digital capabilities in one study.

Second, my study is concerned with the kinds of digital capabilities students develop as a result of curriculum design. The concept of the 'planned-enacted-experienced' curriculum (Erickson & Shultz, 1992; Matthews et al., 2013; Matthews & Mercer-Mapstone, 2018) – i.e. distinguishing between what educators plan for, what students and teachers enact or do – and how students receive or experience the curriculum and achieve the intended learning outcomes, are important in understanding how disciplines develop digital capabilities. In addition to zooming in on how digital capabilities are conceived of in the curriculum in terms of alignment, I also aim to reflect on constructive alignment itself in order to consider its appropriateness as a principle supporting curriculum design.

3.2 Practice lens: the six elements of the DigiCap-Framework

Section 2.3 outlined my rationale for adopting the DigiCap-Framework as the practice-based lens through which digital capabilities are identified in the curriculum and in the workplace (Figure 3.3). When exploring engineering/management modules' teaching activities, learning outcomes and assessment tasks, I use this framework to categorise the kinds of digital practices students and professionals need to undertake; therefore, I introduce the elements of this framework next.

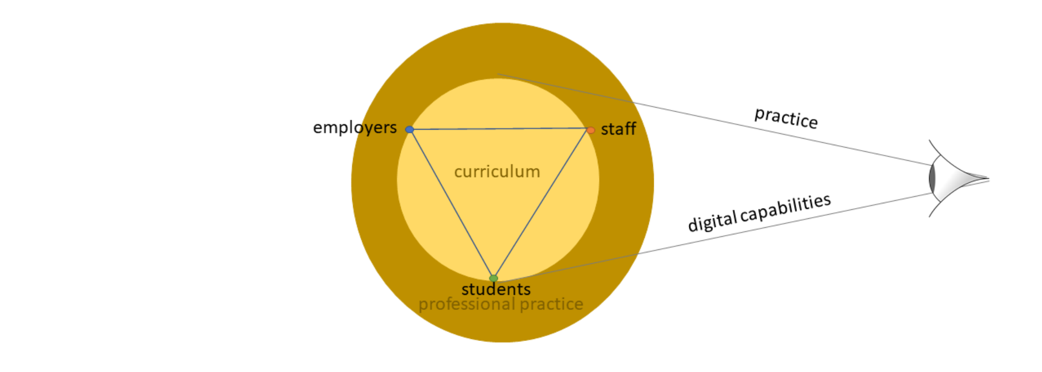

Figure 3.3 Practice lens: DigiCap-Framework

The next sections detail these six elements of digital capabilities as described in Section 2.3 and Figure 2.4; all definitions abridged from JISC's DigiCap-Framework (2017b).

3.2.1 ICT proficiency (ICT)

ICT proficiency (1-ICT) is concerned with basic digital skills that underpin the other five elements, e.g. data/information/media literacy, digital communication/ collaboration, etc. and refer to the capacity to use ICT-based devices, applications, software and services, web browsers, writing/presentation software in order to carry out tasks effectively, efficiently and productively (JISC, 2017b).

3.2.2 Data, information and media literacy (DL/IL/ML)

JISC emphasises the 'critical' aspect of this element and breaks it down into three areas, namely data, information and media literacy. I have separated this element into its three sub-areas in order to reflect the literature review's conclusion that media literacy seemed to be the least provided-for element in the studies explored (Beetham, McGill, & Littlejohn, 2009).

Data literacy (2a-DL) refers to the capacity to collate, manage, access and use digital data in spreadsheets and other media to record and use data as well as ensuring the collection and use of data within legal, ethical and security guidelines (JISC, 2017b).

Information literacy (2b-IL) is the capacity to find, evaluate, manage, curate, organise and share digital information, and at higher levels involves a critical awareness of provenance and credibility and the ability to reference appropriately in different contexts while applying the rules of copyright and open alternatives, e.g. creative commons (JISC, 2017b).

Media literacy (2c-ML) refers to the capacity to read communications critically in a range of digital media – text, graphical, video, animation, audio, haptic etc. while at higher levels it involves the capacity to appreciate audience, purpose, accessibility, impact and modality while understanding digital media production as a practice and an industry (JISC, 2017b).

As seen in the Literature Review chapter, previous academic studies have influenced the articulation of these elements. In particular, digital technologies have 'empowered' students to become multimedia producers (Buckingham, 2007, p.52).

3.2.3 Digital problem-solving (PS)

The third digital capability element comprises three sub-parts; for brevity it will be referred to as 'digital problem-solving' (3-PS) (Beetham, 2017a).

Digital creation is the capacity to design and/or create new digital artefacts and materials, including digital writing, imaging, audio and video production or editing. Advanced levels include the ability to code or design apps/applications, games, virtual environments and interfaces (JISC, 2017b). *Digital innovation* refers to the capacity to develop new practices with digital technology in organisational settings and in specialist subject. Higher level digital innovations involve the ability to lead organisations, teams and subject areas in new directions in response to digital challenges and opportunities (JISC, 2017b). *Digital research and scholarship* involves the capacity to collect and analyse research data using digital methods, or even developing new digital tools/processes or designing new research questions and programmes (JISC, 2017b).

Most of the uses of discipline-specific digital tools belong to this digital capability element. Other examples of digital problem-solving include subject-specific tasks and disciplinary innovations which utilise digital tools or data. At times it is difficult to distinguish innovation, which might occur as a result of HE research and scholarship, from development that emerges in industry professional practice. Just as BIM technology is likely to have become professional practice in construction engineering (Jupp and Awad, 2013), it also likely to be driven by research and scholarship.

3.2.4 Digital collaboration/communication (CC)

The fourth element is digital communication/collaboration (4-CC), which is broken down into three areas. *Digital communication* refers to the capacity to communicate effectively in a variety of digital media and digital forums, in accordance with different cultural, social and communicational norms. It also refers to designing communications for different purposes and audiences (JISC, 2017b).

Digital collaboration involves the capacity to participate in digital teams, to collaborate effectively using shared digital tools and media, to produce shared materials, and to work effectively across cultural, social and linguistic boundaries (JISC, 2017b). *Digital participation* refers to the capacity to participate in, facilitate and build digital networks, to participate in social and cultural life using digital services and forums, to create positive connections and build contacts and to behave safely and ethically in networked environments (JISC, 2017b).

This element is concerned with both local teams' daily practices and their collaboration with others, as well as wider communications within professional or interdisciplinary communities of practice, including social media.

3.2.5 Digital learning/development (LD)

Digital learning/development (5-LD) involves the capacity to identify and participate in digital learning opportunities, to use digital learning resources, to use digital tools (personal or organisational) for learning including recording and reflecting on learning, to undertake self-assessment and participate in other forms of digital assessment (JISC, 2017b).

Learning/development concerns university students and professionals in slightly different ways. For students, a curricular activity includes any learning activity, whereas for those already working, this element refers to continuing professional development and lifelong learning as a subset of their daily practice.

3.2.6 Digital identity and wellbeing (IW)

The sixth, final element is digital identity and wellbeing (6-IW) which encompasses all the other five elements. Its two main aspects are digital identity management and digital wellbeing.

Digital identity management involves the capacity to develop, project and maintain a positive digital identity or identities and to manage one's digital reputation (personal or organisational) across a range of platforms and to collate and curate personal materials across digital networks (JISC, 2017b).

Digital wellbeing refers to the capacity to look after one's health, safety, relationships and work-life balance in digital settings, to act safely and responsibly in digital environments, to use digital media to foster wellbeing and to act with concern for the human and natural environment when using digital tools (JISC, 2017b).

Digital identity and wellbeing, therefore, manifest themselves in the curriculum in different ways. Although not explicitly mentioned, this is also the element that entails the use of social media. Digital identity/wellbeing has gained even more prominence (Biggins et al., 2017) due to recent changes to information security (see the EU's General Data Protection Regulation enforced from 25 May 2018 onwards) and online data breaches, e.g. Facebook/Cambridge Analytica scandal (Hern & Pegg, 2018). The 'civic' element (Belshaw, 2012) is incorporated here in the form of social justice, ethical behaviour and online safety (Beetham, McGill, & Littlejohn, 2009).

In the Findings chapter, I use the DigiCap-Framework's six digital capability elements to analyse the selected modules while categorising the learning outcomes, teaching/learning activities and assessment tasks that engineering and management students undertake. As expressed by the Venn-diagrammatic representation in Figure 2.4, it is expected that some of these six elements will overlap with each other. One of the characteristics of this framework is its descriptive nature. In section 7.3.2, I critically reflect on the appropriateness of the DigiCap-framework.

3.3 Theoretical lens: signature pedagogies

I now turn to the rationale for adopting Shulman's signature pedagogies as the study's theoretical lens, chosen to highlight digital capabilities' disciplinary characteristics (Figure 3.4). I offer a brief review of their main characteristics and principles, highlighting those of engineering and management in particular. I will also emphasise the underexplored link between technology and signature pedagogies.

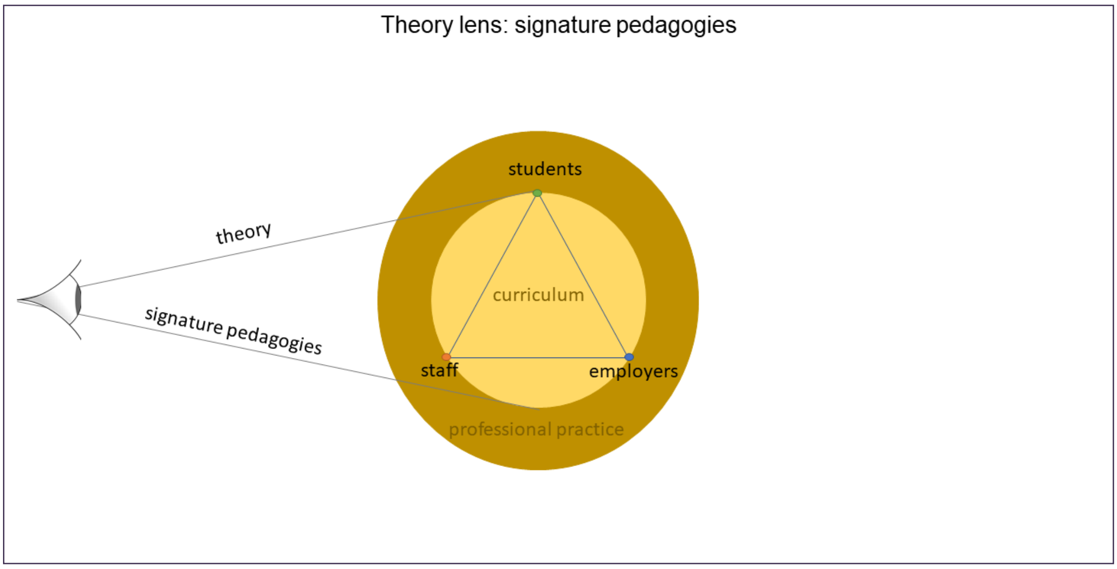

Figure 3.4 Theoretical lens: signature pedagogies

3.3.1 What is a discipline?

The main focus of this study is the disciplinary characteristics of digital capabilities. Since developing students' digital capabilities takes place through planning, enacting, and experiencing the curriculum, it makes sense to adopt the domains in curriculum design in which digital capabilities are meant to be developed. This means developing a subject or disciplinary perspective on digital capabilities.

I would first like to acknowledge the complexity of defining what a discipline is, which others have tackled at great lengths (Becher, 1989; Becher & Trowler, 2001; Neumann, 2001; Trowler, Saunders, & Bamber, 2012). Berger (1970) identifies a discipline as a "specific body of teachable knowledge with its own background of education, training, procedures, methods and content areas" (quoted in Trowler, Saunders, & Bamber, 2012, p.5).

Generally speaking, according to cognitive dimensions there can be various divisions of disciplines, e.g. hard/soft and pure/applied (Becher, 1989), where hard usually belongs to the quantitative (universal laws, causal propositions, i.e. typically sciences), and soft to the qualitative paradigms (typically arts and social sciences); as well as pure (self-regulating and not applied to worldly-problems) and applied (regulated by external influence and applied within professions and to problems) disciplines (Trowler et al., 2012, pp. 18-19).

Even at the national level, curriculum design principles are organised by subjects and disciplines (QAA benchmarks – see, e.g., Engineering), then in turn, in programmes and modules. Indeed, up until 2010, HE policy organised support in the form of disciplinary Learning and Teaching Support Networks, followed by the Higher Education Academy's subject centres. Within this study**,** a discipline is interpreted as a subject identified in QAA benchmarks and/or JACS (Joint Academic Classification of Subjects) codes, the latter maintained by the HE Statistics Agency in the UK.

The other reason for using a disciplinary lens is that critiques posit that constructive alignment, and its underpinning SOLO taxonomy, underplays the possibility that different disciplinary characteristics of knowledge might need differentiated curriculum design approaches (Bernstein, 2000; Maton, 2013). Kahn (2015), for instance, argues that (quoting Kelly & Brailsford, 2013) HE research should engage with disciplinary traditions as a key element. Tight (2014) also observes that HE research lacks disciplinarity, while Bager-Elsborg (2017) argues that teaching cannot be detached from its disciplinary context.

This study focuses on applied disciplines in which students usually have a relatively clear trajectory in terms of progression to a particular profession. An engineering student is likely to become an engineer, or a medical student a medic. For this reason, Shulman's (2005b) signature pedagogies seemed to be particularly apt as a theoretical approach, because he is concerned with the 'signature' ways involved in how students become professionals in their chosen fields.

Before presenting the characteristics of signature pedagogies, I highlight two limitations of this approach. Firstly, the extent to which one chosen subject can be seen to represent hard/soft disciplines is naturally limited. Secondly, it is not possible to account for all the different contexts of one profession, e.g. sectors, company types and its sub-disciplines; for instance, a mechanical engineer may need different skills than an aerospace engineer. However, the fact that my study is also keen to observe the transferability of a conceptual framework to identify disciplinary digital capabilities in other disciplines and contexts might mitigate against these limitations.

3.3.2 Characteristics of signature pedagogies

Signature pedagogies is a term coined by Lee Shulman (2005b) to describe: "the types of teaching that organize the fundamental ways in which future practitioners are educated for their new professions" (p.52). A central feature of signature pedagogies is its concern with professional disciplines. Shulman (2005b) stresses that while critical thinking and cognitive understanding are essential in all education, the difference between professional and other forms of university education is that the former has a role to prepare students to *act* – e.g. treating a patient, consoling a bereaved family member or advising someone on a court case. Shulman (2005b) is interested in how different disciplines try to educate students to become thriving professionals in their chosen fields; that is, Shulman attempts to define what is distinctive in legal education that develops students' capacities to think like a lawyer, or in medical education that enables them to become and think as a doctor, or in religious education that helps nurture a successful clergyman. Examples of distinctive education include engineering's design studio, medicine's bedside teaching, architecture's studio crit, and law's case method. Such education prepares and acculturates students to their professional practice. These pedagogies – hence the term 'signature' – are distinctive features which are "pervasive, routine, and habitual" (Shulman, 2005a, p.22). Signature pedagogies parallel the concept of digital capabilities, particularly in their concern for enabling students to become successful practitioners and lifelong learners after graduation.

Shulman (2005b) distinguishes three dimensions, namely surface, deep and implicit structures. Surface structures are the more concrete learning and teaching activities; deep structures reflect the set of assumptions on how best knowledge, know-how and skills are imparted; while implicit structures reflect the values and beliefs underpinning the profession or discipline in question. The distinctive nature of each of these dimensions is particularly useful from a curriculum design perspective. Surface structures equate to Biggs's constructive alignment (1996) between teaching/learning activities and assessment, while learning outcomes and graduate attributes can relate to both deep and implicit structures. One particular advantage of adopting Shulman's work is to be able to interrogate these underlying deep and implicit structures in the selected programmes in order to see whether and how they impact on conceptualisations of digital capabilities.

The other advantage is that signature pedagogies identify a connection between education and professional practice in the workplace, which is a key characteristic of my research focus. Shulman's concern with professional education has emerged from the observed gap between the HE curriculum and professional practice (Beck & Eno, 2012; Dotger, Harris, & Hansel, 2008). This is related to another key concept connected to signature pedagogies, that of pedagogies of uncertainty (Shulman, 2005a). The challenge of education in professional disciplines (e.g. medicine or law) is that it has to prepare students to act in any complex situation that arises, enabling them to be able to make decisions even in situations when not all knowledge is available – e.g. how to treat a patient whose diagnosis is uncertain. Indeed, pedagogy needs to prepare students for this uncertainty.

There is a temporal and dynamic element to signature pedagogies that both Shulman and his critiques highlight. On the one hand, signature pedagogies are forever changing and need to be reviewed as society as well as digital technologies are changing around them (Caldwell, Osborne, Mewburn, & Nottingham, 2016; Lucas & Hanson, 2016; Shulman, 2005b). For instance, bedside instruction has been a signature medical pedagogy, with consultants, doctors, other health professionals and students visiting patients for diagnosis and subsequent discussion. However, due to medical advances, the opportunity for bedside teaching has diminished with patients spending less time in hospitals as in-patients (Shulman, 2005b).

On the other hand, there is a danger in signature pedagogies being used beyond their utility (Shulman, 2005a, p.56), thereby limiting understanding of the given subject. Critical reflection on their usefulness is needed so that they do not constrain the discipline's development and teaching (Passey, 2012). Other critiques, such as Hyland and Kilcommins (2009), argue that the quest for signature pedagogies can result in over-simplifying and distorting teaching approaches, in their case, the case method in legal education. The concept of emerging signature pedagogy might be useful in this scenario (Beck & Eno, 2012).

3.3.3 Disciplinary examples

Since Shulman first explored signature pedagogies in medicine, health, religious studies, engineering and law, a number of other studies have progressed the concept. Two comprehensive books deal with signature pedagogies, each with a chapter on a different discipline (Chick et al., 2012; Gurung, Chick, & Haynie, 2009), including subjects such as nursing, economics, social work and political science. Other scholars have focused on law (Hyland & Kilcommins, 2009); academic development (McAlpine, Amundsen, Clement, & Light, 2009); science, technology, engineering and mathematics (STEM) subjects (Crippen & Archambault, 2012); mathematics (Passey, 2012); social studies (more specifically history) (Beck & Eno, 2012); creative arts (Hall & Thomson, 2017); education and educational leadership (Caldwell et al., 2016; H. Meyer & Shannon, 2010; Parker, Patton, & O'Sullivan, 2016); and teacher education (Dotger, 2015; Dotger et al., 2008; Sappington, Baker, Gardner, & Pacha, 2010), suggesting that signature pedagogies still have relevance.

3.3.3.1 Signature pedagogies in engineering

Engineering education was one of the original subjects for Shulman's (2005d) exploration of signature pedagogies, which resulted in the following observation:

> *"An engineer is someone who uses math and science to mess with the world by designing and making things that other folks can use." After a brief pause, several of them continued, "And once you mess with the world, you're responsible for the mess you've made". (p.11)*

Shulman (2005d) posits that successful professional education needs to develop 'habits of the hand, mind and heart', emphasising that beyond knowledge and collaboration, engineers' education needs to operate within a "matrix of social and environmental responsibility" (p.11). Engineers are also conceived of as "initiators, integrators and innovators" (McLean & Walker, 2012, p.592) working for the good of humanity. Dym et al. (2005) focus on design thinking and project-based learning as two signature engineering pedagogies. McNair et al. (2015) argue that engineering as a discipline itself is interdisciplinary in nature, as it works with subjects and ways of thinking, ranging from mathematics (pure science) to applied contexts. Collaborative working in engineering is the focus of Kahn and colleagues' (Kahn, Goodhew, Murphy, & Walsh, 2013) exploration of membership in an engineering network supporting research on teaching and learning. One pervasive signature pedagogy in the field of engineering education is the CDIO (conceive-design-implement-operate) approach (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014).

Other studies explore how certain technologies can play a part in the education of engineers. Crippen and Archambault (2012), for instance, explore how mash-up technologies can enhance inquiry-based instruction by enabling students to learn and think as scientists. Maclaren et al. (2013) report on the use of digital pens in supporting engineering students' mathematical and diagrammatical reasoning processes.
The most pertinent and detailed work on signature pedagogies in engineering is by Lucas and Hanson (2016) who identify six elements of "engineering habits of the mind", including systems-thinking, adapting, problem-finding, creative problem-

solving, visualising and improving. Two specific educational approaches are then discussed – engineering design process and learning from professionals – which are seen as hallmarks for cultivating engineering habits of the mind. Lucas and Hanlon (2016) highlight an important signature element reinforcing “professional formation and professional preparedness” (p.9). Another important signature element in engineering education is asking students to make their thought processes visible (Shulman, 2005c). When engineering students need to design an artefact in groups or law students have to prepare to argue for or against a peer’s argument, then they cannot remain invisible in the learning process. Such pedagogies require students’ participation and dialogical interaction (Hyland & Kilcommins, 2009).

3.3.3.2 Signature management pedagogies

Signature pedagogies are an under-explored area in management, notwithstanding that the discipline itself is popular among undergraduates (UUK, 2016). My literature search yielded fewer than a handful of relevant articles. One is an editorial in a management education journal (Schmidt-Wilk, 2010), inviting readers to consider three aspects – hearts, minds and hands – in management education, noting that integrity (habits of the heart) is missing from management curricula. Hull argues (2017) that knowing *how* to apply expertise (as opposed to subject expertise) is an essential part of management education. Another study explores how to prepare accounting students for professional practice, focusing on their identity development (Wilkerson, 2010), whilst another argues that economics does not have a signature pedagogy (Maier, McGoldrick, & Simkins, 2012).

Although there are a number of engineering and management signature pedagogy studies, few of these exist at the intersection of digital capabilities and signature pedagogies, which is the topic of the next section.

3.3.4 Technologies and signature pedagogies

The few studies of signature pedagogies focusing on the use of technologies include for instance, Maclaren et al. (2013), who have investigated the use of digital pens in mathematical reasoning. Beck and Eno (2012) identified signature pedagogies in the field of history using technology – e.g. podcasts, wikis, video, visualisation tools, blogs, geospatial software and social networking. Passey (2012) explores what signature pedagogies are associated with different educational technologies used in mathematics education, and the link between technology use and those emerging practices that can be defined as signature pedagogies. Crippen and Archambault

(2012) discuss how inquiry-based learning can be applied in the use of emerging technologies, e.g. data mashups and cloud computing, underpinned by an aspiration to educate students not only in scientific knowledge but also about the modern world's socio-scientific issues.

Despite Shulman (2005a) pointing out that signature pedagogies require constant reviewing due to technological changes and that the technological landscape has significantly altered with the widespread use of social media, mobile technologies and cloud computing, only a limited number of articles have been written that concern themselves with the intersecting domains of technology use and signature pedagogies and none dealing specifically with students' digital capabilities. This is despite various observations on the way technology has transformed how we learn by opening up opportunities for new methods of social and educational engagement (Jones, 2011), enabling connections between people, places and ideas (Becker et al., 2017) while facilitating the construction of our professional identity and security (Littlejohn et al., 2012; Schmidt & Cohen, 2014; Sinclair, 2013) or lowering the technological skills required for digital innovation (Warren, 2011). Others have underlined university education's need to follow the new digital paradigms emerging from innovative modes of understanding in professional practice (Jupp & Awad, 2013).

As Warren (2011) highlights in relation to value creation in the digital domain, individuals are required to develop digital capabilities that allow them to "perform intuitively in the digital environments" (p.232) through a range of cognitive and communicative skills that solve social problems. Warren observes three kinds of knowledge-workers: 1) '**consumers**', the largest group, who access and use materials created by others; 2) '**creators**', who are actively involved in creating and uploading materials for others, and 3) '**disruptors**', the smallest group, who invent new business models and attempt to disrupt or change current processes and industries. Moving from consumers to creators and disruptors requires digital skills, together with creativity and design, which in turn enables students and professionals to create value in "novel and unforeseen ways in new contexts and settings" (Warren, 2011, p.233). These categories prove useful when making sense of professionals' digital practices from the perspective of signature pedagogies.

3.4 Research gap and significance

The conceptual framework of this study is at the intersection of three domains. The primary domain is curriculum design, situated in the wider context of professional practice and work-based learning and drawing on the principle of constructive alignment. The study focuses on disciplinary digital capabilities and practices of professionals, which they need to acquire during their university study. This focus is looked at from two angles: a digital capability (drawing on JISC's DigiCap-Framework) and a disciplinary (drawing on Shulman's signature pedagogies) focus respectively. These are combined to form the study's conceptual framework (Figure 3.5).

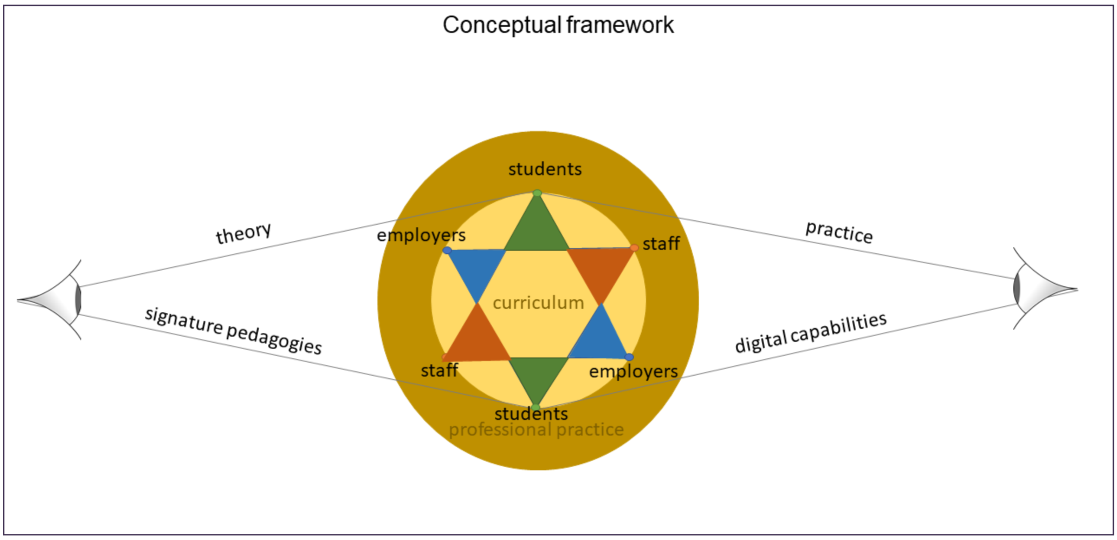

Figure 3.5 The study's conceptual framework

As demonstrated above, out of the signature pedagogy research in engineering and management, few studies explore digital capabilities specifically, although a number of them touch upon technology-enhanced learning, which is outside this study's focus. Even scarcer are studies at the junction of disciplines' changing (digital) knowledge-practices and how universities need to adapt their curricula to meet the needs generated by students' digital capabilities (Jupp & Awad, 2013; Sinclair, 2013). The only study which links digital literacy and signature pedagogies is from Bruce and Casey (2012) who identify enquiry-based learning as a "pedagogical sweet-spot" for developing digital capabilities. Despite its pertinence, it is not a discipline-specific example of digital capability development, which is the research gap my study hopes to address (Figure 3.6).

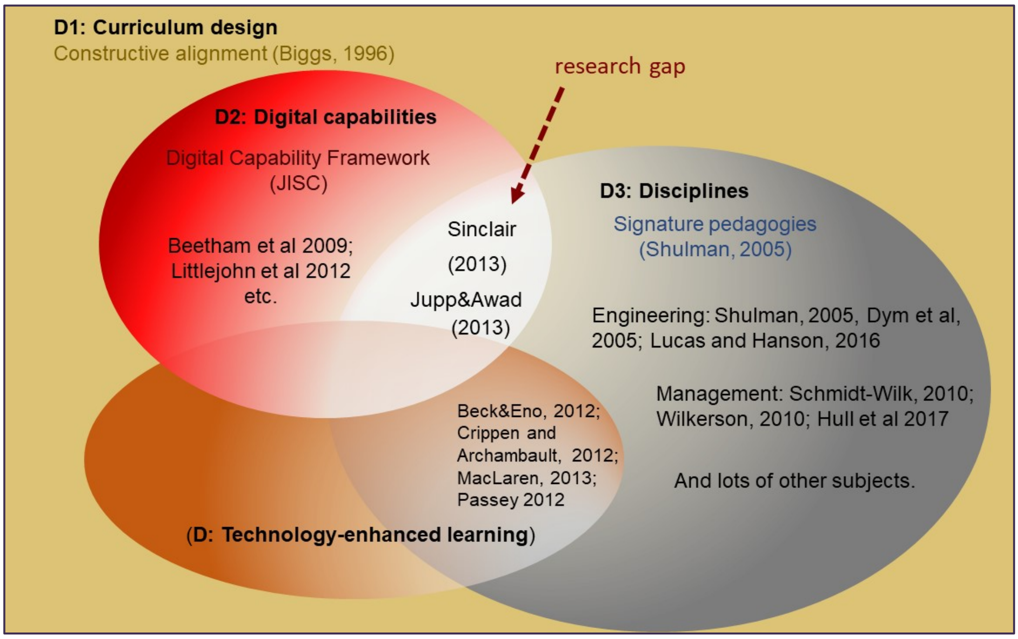

Figure 3.6 The conceptual framework's research domains indicating research gap

As for the significance of and need for this study, in-depth studies and programmes (Beetham, McGill, & Littlejohn, 2009; JISC, 2017c; Littlejohn et al., 2012) have all emphasised the importance of contextualising digital capabilities in different disciplines. At the same time, signature pedagogies need to be updated to reflect digital paradigm-shifts in professional subjects' revised curricula to ensure that graduates are ready for the world of work (Becker et al., 2017).

Although interdisciplinary working and applying signature pedagogies from one discipline to another are both regarded as great sources of learning, helping to advance disciplinary knowledge (Adkihari, 2011; Calhoun, 2006; Shulman, 2005b; Tsatsou, 2017), it will not be possible to include such an interdisciplinary angle in this study. Examples of interdisciplinary innovations include medicine's virtual simulation pedagogy applied in the field of teacher education (Dotger, 2015; Dotger et al., 2008) in order to conduct parent-teacher meetings or to support the development of pastoral care and teachers' behaviour management of students. In addition, Caldwell et al. (2016) utilise studio crit, a signature pedagogy in architectural design, in the field of postgraduate supervision. Other authors focus on interdisciplinary working itself and how it can bring about knowledge when professionals from different disciplines collaborate, bringing with them their different mental habits, hands and hearts that collide and transform each other's knowledge and understanding. McNair, Davitt and Batten (2015) look at how biologists, chemists and engineers worked together on a joint artefact, an underwater fish-fin robot.

Nevertheless, given the reasons above that indicate the significance and need for the current study, it is a more-than-appropriate time to conduct research that undertakes this process in two applied professions, with the desire that the process of inquiry will be transferable to other disciplines.

4 Chapter 4: Research design

This chapter outlines how I have investigated my research problem, beginning with the underlying philosophical assumptions that helped shape my research design, the strategies of inquiry I have chosen to fit with these, and the methods I used for collecting, analysing and interpreting data (Creswell & Plano Clark, 2011). I also discuss quality-related issues pertaining to my chosen methodology.

4.1 Epistemological and ontological orientation

I first consider the knowledge claims I am making (Creswell, 2003). My ontological position is critical realist (Bhaskar, 1993); I believe that realities underlying knowledge exist, although these realities are not necessarily observable as positivists would claim (Delanty, 2005a; Lakomski, 1992). Critical realism acknowledges that knowledge is emergent and constructed by social actors, meaning that social reality exists outside the consciousness of individual minds, but also it can be 'known' through constant negotiation and renegotiation (Delanty, 2005b). This is what Beck (1996) terms 'constructive realism'.

Epistemologically, I draw on pragmatist principles (Dewey, 1938). Pragmatism is not committed to any philosophical assumptions, but concerned with what provides the best understanding of the problem, inquiry or action (Creswell, 2003). Theories are instrumental as to how much they work for the inquiry being undertaken (Johnson & Onwuegbuzie, 2004). Pragmatism views knowledge as "being both constructed *and* based on the reality of the world we experience and live in" (Johnson & Onwuegbuzie, 2004, p.18). This chimes with my ontological perspective.

This pragmatist stance is, I feel, justified by the complexity of my study topic. Pragmatists acknowledge that "organisms are constantly adapting to new situations and environments" (Johnson & Onwuegbuzie, 2004, p.18), which rings particularly true when researching fast-changing digital technologies. Pragmatists appreciate the social, historical and other contexts surrounding research, thereby opening the door to multiple worldviews and methods (Creswell, 2003; Teddlie & Tashakkori, 2009), which is underpinned by a needs-based approach to research method selection. I now turn to relating these knowledge claims to my research focus.

4.2 Knowledge claims and digital capabilities

At least two ontological/epistemological layers are in play here. First, there is my ontological/epistemological orientation as a researcher exploring digital capabilities. Second, there is the ontological/epistemological position of my interviewees who are representatives of their own disciplinary traditions.

In terms of these two layers, firstly, as a researcher, I concur with the notion of digital capabilities being highly contextual and situation-specific (see Chapter 2), which suggests an interpretive stance. Ontologically, I argue that technologies (and capabilities) can exist irrespective of people's awareness of them. For instance, it may be that an engineer is using an email-based mailing list to keep up-to-date with their community of practice, but when prompted to discuss digital capabilities, they might not recall this as digital practice. Further, individuals construct subjective judgements as to who can be considered digitally capable, or indeed what capabilities are relevant to them. For instance, students can be over-confident in relation to their digital capabilities (Jeffrey et al., 2011) with a gap between their perceptions (interpretivist) of their actual capabilities (positivist). Therefore, I cannot justify restricting my view either to a positivist or interpretivist stance. I view digital capabilities from a critical realist perspective, using the DigiCap-Framework as a reference model against which I compare individuals' digital capabilities. In addition, and to support my critical realist stance, I observe various 'real' structures surrounding curriculum design, e.g. subject benchmarks, industry guidelines, governmental and institutional policies, even if unobserved/able by some, as they impact on curriculum design, irrespective of how others construct their own perception of digital capabilities.

Secondly, the relevant disciplines have specific ontological and epistemological traditions that need to be considered. My study is rooted in understanding how different professionals conceptualise digital capabilities within their disciplines. Strivens (2009), in interrogating beliefs about learning in the context of a given discipline, argues that its epistemology is a key factor in understanding student learning. If we take the hard/soft and pure/applied categorisation of disciplines into account, there are different epistemological traditions that characterise each one (Trowler, Saunders, & Bamber, 2012). The traditional alignment of pure sciences being positivist and social sciences interpretivist seems to be an over-simplification; most disciplines traverse each paradigm simultaneously. This is especially the case for applied sciences, such as engineering, which tend to address human, environmental and social issues, concluded by Figueredo (2008). Consequently, this thesis needs to account for epistemological pluralism (Miller et al., 2008).

For these reasons, a pragmatist orientation seemed most suited to this study (Belshaw, 2012; Hudson, 2009). This meant that it was possible to ask participants to explain how they conceived digital capabilities, irrespective of their epistemological tradition. As a pragmatist, I also avoided proving a theory; however, by employing the DigiCap-Framework, I did not leave it completely up to participants to construct their own meanings concerning digital capability.

4.3 Researcher position

I am a learning technology developer at UniA. I am neither strongly attached to any particular paradigm in my current central role, nor with regard to my educational background. My undergraduate (English language/literature, and information science) and my postgraduate degrees (information management, and computer science) straddle the sciences, humanities and social sciences.

In terms of the relationship between my position as a researcher and my study, I concur with Mercer (2007) who argues that insider/outsider positions are better conceived of as two ends of a spectrum which can move and change within the same data collection points. For instance, due to my central position and my pragmatist stance, I perceived myself as an outsider when it came to the disciplines of engineering and management. This enabled me to approach participants with a fresh eye (Rabe, 2003), without presuming any prior disciplinary knowledge. This was useful as I was able to get participants to explain how *their* discipline worked.

As far as the institution was concerned, as a member of staff at UniA, I was familiar with its institutional policies and technologies. On a practical level, being a staff member helped me gain access to lecturers (East, Stokes, & Walker, 2014), who in turn were able to recommend others for interview. The challenges of being an insider researcher identified by East, Stokes and Walker (2014), such as asking less probing questions or desire for solidarity, did not pose an issue.

I also need to briefly mention one potential bias arising from my position as a researcher. I am a white European female researcher in the UK. These characteristics, my choice of disciplines and chosen sites have likely influenced the study and its outcomes. Digital economies are uneven globally (Chakravorti, Bhalla,

& Chaturvedi, 2017), within Europe (European Commission, 2017) and even within a country (Blank, Graham, & Calvino, 2018). One of my study's limitations is that it does not deal with the perceptions of potentially marginalised groups or the wider critical issues regarding digital exclusion (Ashworth, 2017).

4.4 Research questions

As signalled in Chapter 1, the study's overarching research question is:
"*How* are digital capabilities conceptualised in two different disciplines, namely engineering and management?"

This is broken down into feasible and answerable sub-questions:

1 **How are digital capabilities conceptualised/planned in the curriculum at modular level in different disciplinary contexts (in management and engineering)?**
   - 1.1 What digital capabilities are planned by academic staff to be developed as intended learning outcomes (ILOs), teaching and learning activities (TLAs), and assessment tasks (ATs)?
   - 1.2 How do these modular articulations fit in with programme and institutional levels of learning outcomes and subject benchmarks?

2 **How is the development of digital capabilities enacted and experienced by engineering and management students?**
   - 2.1 What are academics' perceptions of the digital capabilities being developed by engineering and management students as they enact the planned curriculum?
   - 2.2 What are engineering and management students' perceptions of developing the planned ILOs with respect to digital capabilities?
   - 2.3 Are engineering and management students developing any digital capabilities not articulated or planned for?

3 **To what extent do the curricular conceptualisations of digital capabilities indicate a match of the digital capabilities practiced by engineering and management employees/professionals?**
   - 3.1 What are the possible digital practices of employees/professionals of the same discipline (in management and engineering)?
   - 3.2 Are there digital capabilities that engineering and management students possibly need to be developing whilst at university that they are not currently developing?

4.5 Case study methodology

The thesis aimed to understand how digital capabilities were interpreted and conceptualised by staff at a curriculum design level, focusing on a few selected lecturers, their modules and respective programmes so as to better support curriculum teams. The words ‘explore’ and ‘how’ from the study’s research questions lent themselves to a qualitative orientation. I now turn to explaining why case study was chosen to match these questions.

4.5.1 Rationale for choosing a case study

A case study methodology is defined as:

> …an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. (Yin, 2009a, p.18)

Case study is “small-scale research with meaning”, which offers a holistic analysis of one (or a few) case due to its nature, of being complex and being studied in-context (Tight, 2017, p.8). These characteristics seemed to suit my ‘how?’ research question best (Creswell, 2014; Yin, 2009a) compared to any other main qualitative methodologies, namely phenomenology, grounded theory, ethnography and narrative analysis (Creswell, 2013). The strength of a case study methodology is that it can help understand an in-depth situation in detail (Flyvbjerg, 2006; Yin, 2009a) as it explores its uniqueness and ‘particularity’ (Simons, 2009, p.3) as a ‘bounded system’ (Bryman, 2012) while prioritising context by situating the case (Creswell, 1998). It uses multiple sources of information drawn from interviews, documents and reports (Creswell, 2013; Yin, 2009b). All these features made case study a natural choice for this thesis (Cohen, 2007; Denzin & Lincoln, 2011) and my primarily qualitatively-oriented research questions (Prescott, 2013). Of the typologies identified by Yin (2009a, p.176), this is an *exploratory* case study, since its purpose is to:

> …generate in-depth understanding of a specific topic (as in a thesis), programme, policy, institution or system to generate knowledge and/or inform policy development, professional practice and civil or community action. (Simons, 2009, p.21)

4.5.2 Five components

The five components of a case study are:

1. Research questions;
2. Propositions (if any);
3. Units of analysis;
4. Logic linking data to propositions;
5. Criteria for interpreting findings (Yin, 2009b).

This study's (1) **research questions** focus on the 'how'. The (2) **proposition** is the rationale and direction underlying the study (Yin, 2009a, p.28). In my case, one proposition could be that:

> *Digital technologies are transforming and/or disrupting the disciplines, which can impact on signature pedagogies.*

In addition, that:

> *Different disciplines may prioritise different elements of digital capabilities.*

These propositions help in identifying the case and my unit of analysis. I am interested in how digital capabilities are prioritised and conceived of in different disciplines. It makes sense to adopt the 'discipline' (namely engineering and management) as my *case*, and a study that has multiple (or to be precise, two) cases for potential comparison, making this a multiple-case study methodology (Yin, 2009a).

In turn, a (3) **unit of analysis** defines what the case is. Typically, this could be an individual or an organisation. In this study, I have focused on curriculum design; therefore, it makes sense to assign a curricular unit as the unit of analysis. Module and programmes are the result of design decisions made by staff and, where relevant, industry regulations and stakeholders, so it made sense to make the module the unit of analysis, a semester-long unit of teaching in the UK at university level and the respective programme of study in which the module sits. A module is designed by a module leader and experienced by students who study on the module.

With respect to case study typology, there are two kinds: holistic (with a single unit of analysis in each case) or embedded (with multiple units of analysis within a case). For this study, the embedded design seemed appropriate as it enabled the exploration of different modules and programmes within a single discipline (case) (Figure 4.1).

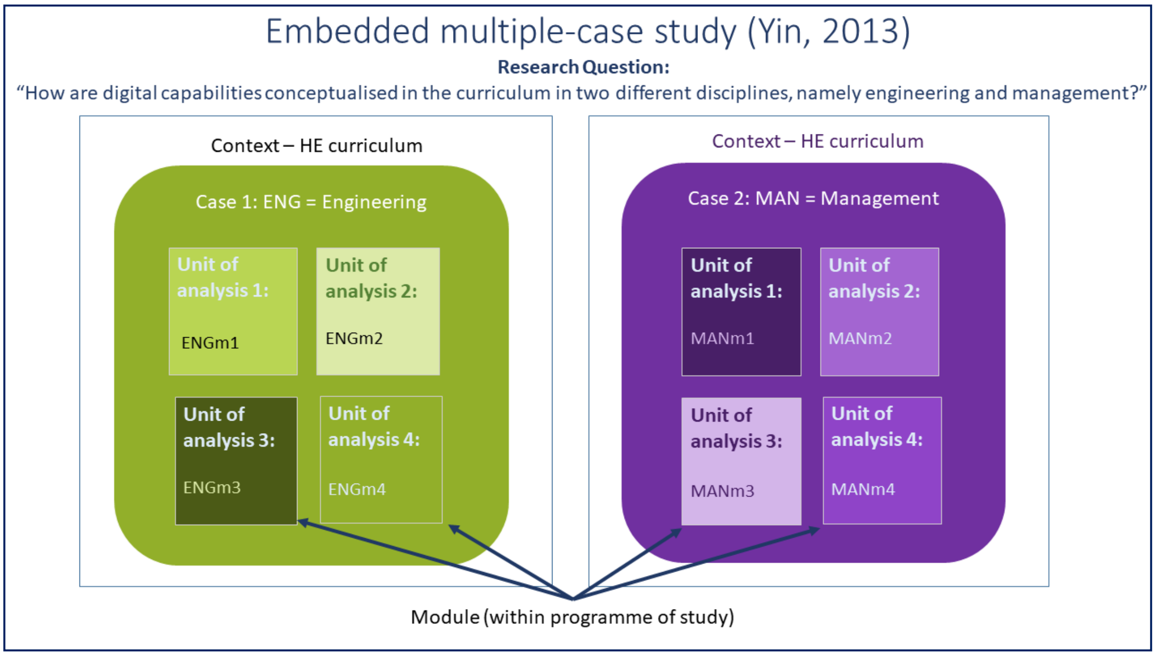

Figure 4.1 Multiple-case study with embedded units of analysis (Yin, 2009b, p.46)

As Yin outlines (Yin, 2009b), the context surrounding the case and units of analysis are also important, which I have expanded to documentary sources and to subject level benchmarks (see sub-section 0). The final aspects of the case study, the logic (4) linking **data to propositions** and (5) **criteria interpreting findings,** are discussed in the Data Analysis section (0). The next section details my sampling rationale.

4.6 Sampling

It was necessary to choose at least two cases, or disciplines, to be able to establish whether different disciplines prioritise or conceive of digital capabilities differently, or not. Within each case, different modules were intended to be selected in order to generate a more general sense of the discipline. The participants who could best help understand the central phenomenon under study, digital capabilities, were staff, students, and professionals/employers, preferably those who contributed to the module design or delivery (Creswell, 2012a).

4.6.1 Sampling the case: the disciplines

There were two reasons for selecting two applied, professional disciplines via purposive sampling (Cohen, 2007; Creswell, 2012a, 2013). One was that the concept of signature pedagogies (Shulman, 2005) had been mainly explored in professional disciplines, such as medicine, law and engineering. The other was due to the purpose of the research in establishing potential gaps between the HE curriculum and the workplace with respect to students' digital capabilities. For this, 'applied' disciplines (Tight, 2015, p.279) with typical employment trajectories seemed most suitable.

The sample size being two (cases) was decided for practical reasons. This number was deemed manageable within my study remit. The final consideration was to select one 'hard' (more science-based) and one 'soft' (humanities and social sciences) discipline (Becher, 1989; Neumann, Parry, & Becher, 2002; Tight, 2015) in case epistemological differences were to influence how and which elements of digital capabilities might be prioritised. It is acknowledged that both disciplines encapsulate a range of sub-disciplines making the above binary distinction much fuzzier in reality.

4.6.2 Sampling the units of analysis

The study sites and units of analysis were chosen and based primarily on practical reasons of access to documentation and participants as a staff member at UniA (Creswell, 2012a). I also chose one module per case to be located outside my institution so as to have a reference point to an institution, UniB, where it was an institutional requirement to map digital literacy as an explicit graduate attribute in each programme of study. The two institutions differed in nature (research- and teaching-intensive), but from a curriculum design perspective, which was my primary focus, these differences seemed negligible given that their curricula are both regulated by the same QAA processes in UK HE.

I selected four units of analysis for each case, i.e. four modules in engineering and four in management. Four is a number that will enable potential trends, similarities and differences to be observed within the discipline and provides ample information due to the range of data to be collected within each unit of analysis (interviews, artefacts, a survey, etc.). More data would have expanded the remit of the thesis beyond what was feasible. The modules from these two disciplines were selected using purposive sampling (Cohen 2007), matching the following criteria as much as possible:

- digital capability as part of intended learning outcomes or activities;
- employer contribution or inclusion of authentic assessment tasks (Ashford-Rowe, Herrington, & Brown, 2014; Blaaberg, Kazmierkowski, Pedersen, Thogersen, & Tonnes, 2000; Campbell, 2000; Coon & Walker, 2013; James & Casidy, 2018);

The rationale for the latter criterion was because it was expected that collaborative and authentic tasks were more likely to require students to develop digital practices. Three groups of stakeholders were identified for each unit of analysis as contributing perspectives to the design and experience of modules and programmes:

- **staff** leading on the modules (module leaders);
- **employer(s)** or **professionals** working in engineering or management;
- **students** enrolled on the modules (Figure 4.2).

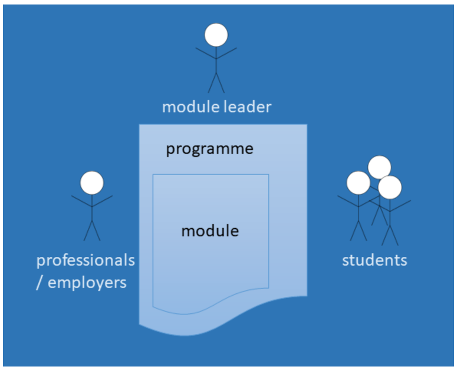

Figure 4.2. Study participants

Since data collection had to take place during a very short time window (July-November 2017), the modules were selected based on being semester 1 modules. Due to this short time window, I did not have scope to select each potential module and sample purposively by level, topic and sub-discipline. Instead, I selected the initial modules by approaching module leaders through personal contacts and via programme directors. After the initial interviews, I used the snowball method (Miles & Huberman, 1994), which was helpful in that colleagues were able to suggest other modules which were likely to include digital assessment tasks. To keep the data generated manageable, one module was selected for analysing student perspectives in detail.

Module leaders helped identify professionals and students. It was somewhat difficult to engage professionals. My main aim was to engage professionals contributing to the selected modules, but where this was not possible, they were selected on the basis of working in either management or engineering. At that point, my main interest was exploring the digital practices of a particular profession in general, as opposed to focusing on choosing participants who graduated from UniA or UniB from the same degrees. I used the snowball method, contacting participants already interviewed, UniA's alumni and my wider social network, aiming to identify participants whose work had not been familiar to me previously, so that I could be as objective as possible when eliciting their working practices. Only one alumnus was identified for management, who had graduated from UniA with another degree subject. This meant that all of the professionals had graduated from their respective fields from universities other than UniA or UniB. Although it would have been ideal if this was the case (so that they would have been able to comment on how their UniA/UniB degrees prepared them for their current workplace), they were all from other institutions. I also attempted to have some representation of different types of businesses (e.g. a global, national or small- and medium-sized enterprise (SME), but as my methodology did not aim for generalisability, but to gather a rich picture of digital practices, this was not a primary sampling decision.

4.7 Data collection

Prior to data collection, in summer 2017, two expert interviews were conducted with Professor Rhona Sharpe and Helen Beetham. Professor Sharpe is a prominent researcher in digital literacies who had been instrumental in ensuring that each Oxford Brookes University programme embedded digital literacies as graduate attributes. Helen Beetham is an educational consultant who was one of the leaders of JISC's Developing Digital Literacies Programme between 2011-2013 (JISC, 2017a), the Digital Student Study (JISC, 2017b) and has been leading efforts to establish a JISC 'Digital Capabilities Tracker/Insights' (JISC, 2017c) service on the digital experiences and expectations of students at HEIs (Newman, Beetham, & Knight, 2018). These interviews helped with synthesising the literature review: by highlighting the different strands identified in section 2.2; and illuminating the evolution of the DigiCap framework. This latter focus then helped me formulate this study's conceptual framework for the process of curriculum design for digital capabilities, for instance, by adopting the revised DigiCap-framework as opposed to the original model (Beetham and Sharpe, 2010).

Subsequently, data collection methods were chosen to suit the nature of my inquiry. Each unit of analysis drew on a range of data collection methods, including documentary analysis, interviews with module leaders and professionals. Further data collection methods, including student focus groups, interviews, and module observation were conducted for one module per case.

The multiple sources of data (Creswell, 2013) were identified and mapped to each research question (see section 4.4). Table 4.1 shows the alignment between the research questions and the data-gathering methods and how the purpose relates to elements of my conceptual framework (signature pedagogies and digital capabilities). I consulted Yin (2009b, p.102) for the strengths and weaknesses of each source to aid my preparation.

Data collection method	**Purpose**	**Linked RQs**	**Instrument used**
Documentary analysis of module and programme specifications	To identify curriculum design principles and signature pedagogies in engineering and management.	1.1 1.2	n/a
Interviews with module leaders	To explore staff perceptions and considerations of design decisions and perceptions of students' development of digital capabilities in the discipline (surface, deep and implicit structures).	1.1 1.2 2.1 2.3	Staff interview guide
Interviews with employers/professionals	To explore the digital practices of those who are already professionals/employees in the workplace.	3.1 3.2	Employer interview guide
Student focus groups and interviews	To identify the range of digital capabilities developed.	2.2 2.3 3.2	Student interview guide
Observation of classroom/virtual sessions & resources	To explore the planned and enacted curriculum.	1.1 2.2	Researcher journal

Table 4.1 Mapping of data collection methods to research questions

In the next section, I take each method in turn to offer more detail.

4.7.1 Staff interviews

The perspectives of module leaders were essential as they had designed the modules and learning outcomes. I was interested in individuals' perspectives, which suited the interview method, enabling me to follow a line of questioning on signature pedagogies and how digital capabilities played a part in their designs. Semi-structured interviews were deemed the best way to explore these individual views, as opposed to structured or unstructured interviews, since the former would have been too restrictive to explore different design considerations and the latter too open to keep to the aspects of my framework. Based on the conceptual framework, an interview topic guide (Ritchie & Lewis, 2003) was prepared, including questions on signature pedagogies and digital capabilities and practices (see Appendix A). Sinclair's (2013) study prompted me to formulate what became an insightful interview question, namely, "What digital technology has had a profound impact in the field of X? What has changed in the field as a result of digital environments, digital technologies?"

The interview guide was piloted with an engineering module leader. Slight modifications were made as a result, including re-ordering some questions to ensure a better flow and inserting a question regarding participants' disciplinary background. The pilot interview was included in the main study as it did not differ significantly from the rest of the interviews and provided valuable detail.

Altogether, nine interviews – four engineering and five management – were conducted in line with the guidance identified by Creswell (2012b). Participants were given a pseudonym and an alphanumeric ID, according to discipline, from ENG1 to ENG4, and MAN1 to MAN5 (Table 4.2). In one case, there were two module leaders of the same module (MAN4 and MAN5), so the number of units of analysis (i.e. the modules) remained unchanged: eight altogether.

The four module leaders in engineering were: Thomas (ENG1), Mike (ENG2), Dylan (ENG4) at UniA, and Gill (ENG3) at UniB. Their disciplinary background ranged from materials and industrial design, mechanical engineering to electronics. All had had industrial experience. The five module leaders in management were Sam (MAN1), Rob (MAN2), Lesley (MAN4) and Patrick (MAN5) at UniA, and Laura (MAN3) at UniB, with backgrounds from operations, through marketing to risk analysis and finance (see Table 4.2). Lesley and Patrick co-led on module MANm4. After my initial interview with Patrick, he prompted me to interview Lesley as well, as Lesley had more oversight of one of the assessments, which was a synoptic, reflective task. Both interviews were useful in elaborating the design principles of the module as well as adding useful perceptions of their students' digital capabilities.

I pre-sent the interview questions to my interviewees so that they could consult them and prepare if they wished, thereby attempting to bracket personal bias (Creswell, 2012a). I emphasised that the questions were to guide the discussion rather than to be strictly followed. Some consulted them, while some did not.

Participant ID	**Site**	**Module area**	**Programme title**	**JACS code**
ENG1-Thomas	UniA	Materials design	Industrial design (BEng) Mechanical and Materials Engineering (BEng)	3D52 HJ35
ENG2-Mike	UniA	Design	Engineering (BEng)	H100
ENG3-Gill	UniB	1.Data acquisition 2.Engineering Management	1.Electrical engineering 2.Automotive engineering (MEng)	H5 H3
ENG4-Dylan	UniA	Product visualisation	Industrial design (BEng)	3D52 6G11
MAN1-Sam	UniA	E-business	Business Management (BA)	NX00
MAN2-Rob	UniA	Risk management	Programme and Project Management (MSc)	N3/BLPM
MAN3-Laura	UniB	Market research	Business and Marketing Management (BSc)	N5
MAN4-Lesley	UniA	Corporate Communications	Business Management (BA)	NX00
MAN5-Patrick	UniA	Corporate Communications	Business Management (BA)	NX00

Table 4.2. Staff interviews (ENG=engineering, MAN=Management)

Seven interviews were conducted and audiotaped in person (at UniA), and two via Skype (UniB). Although this is something I considered and reflected on, in line with an earlier study (Lo Iacono et al., 2016), I did not observe any distinctive difference in terms of data with respect to whether the interview was conducted online or face-to-face. For instance, I recall that both interviewees were eager from minute 0 and very forthcoming with their views and ideas. I was able to take non-verbal cues of when their answers were coming to an end and prompt them further or move to new questions. The mere fact that I was interested in their teaching helped us create a positive and collegial environment, and I did not have a sense that the format of the communication had impacted on the outcome of the interview in any way. I also pre-shared my interview questions with them via email so they were well briefed.

The first two transcriptions were done by myself to familiarise myself with the data and refine my interviewing style (Kvale & Brinkmann, 2009). The rest were completed by a professional transcriber who acted within ethical and confidential procedures. I checked each transcription by listening to the audio tape to keep myself as close to the data as possible. The transcripts and summaries were sent back to the interviewees for member-checking for accuracy; they also had the option to suggest their pseudonym. I felt that this procedure helped promote a transparent and trustworthy interview process (Mercer, 2007), which was especially helpful with professionals whose interviews I will discuss next.

4.7.2 Professional interviews

Originally, it was intended that the same number of professionals (n=4), who contributed to the selected modules as part of employer engagement, would be selected for each case. Since the research question concerned exploring some typical indicative digital practices of engineers and managers, a restricted number was deemed sufficient. However, after some difficulties with engaging professionals during the short time window for data collection, the net was cast wider and six professionals were approached in each case. Of these, eleven professionals said they would be willing to be involved, and were interviewed, five in engineering and six in management, from a range of organisations. The topic guide was amended to accommodate a workplace context, including questions about professionals' use of digital technologies, whilst keeping a focus on aspects of my conceptual framework (signature pedagogies and the elements of the DigiCap-framework). The same interview process was applied; participants were anonymised similarly, adding '*emp'* to signal their employer status (e.g. ENG5emp) (see Table 4.3).

The five engineering professionals interviewed included ENG5emp-George, a structural engineer who had just started his own business having worked for a global company for 20 years; ENG6emp-Paul, an infrastructure engineering consultant; ENG7emp-Craig, who had risen from the ranks of an apprentice engineer, then engineer to director level at a global company (who is also a part-owner of a small commercial enterprise); ENG8emp Jack, a senior mechanical design engineer at a metrology company; and ENG9emp-Adam, a project manager for a military course on military plants with a background in plant equipment and civil engineering.

The management professionals were: MAN8emp-Felix, a managing director of a SME specialising in medical technologies, originally a polymer chemist; MAN9-Lucas a director of technical learning and development at a global consultancy who used to work as a rail engineer for nearly 30 years; MAN11emp-Michael, an environmental scientist working in waste management, who gradually progressed from a technician role to project manager; MAN7emp-Don who moved into a technical, product-marketing role from being a production engineer in the automotive industry; MAN10emp-Rebecca, a co-founder of her own marketing business who had studied literature. MAN6emp-Dermot, an IT Manager for a financial company, graduated in IT, and he was the only one with a postgraduate management qualification.

Participant ID	Disciplinary background	Role	Company profile	Company type
ENG5emp-George	Engineering	Owner	Structural engineering	global; SME
ENG6emp-Paul	Engineering	Infrastructure engineering consultant	Consultant	global; self-employed
ENG7eng-Craig	Engineering	Managing director; part-owner in SME	Design and Manufacturing	global; SME
ENG8emp-Jason	Engineering	Senior mechanical engineer	Design and Manufacturing	global
ENG9emp-Adam	Engineering	Engineer and lecturer	Military / civil engineering	national
MAN6emp-Dermot	IT and management	IT Manager	Financial products	national
MAN7emp-Don	Engineering & marketing	Product marketing engineer	Design and Manufacturing	global
MAN8emp-Felix	Chemistry	Managing director	Biomaterials company	SME
MAN9emp-Lucas	Engineering (& management)	Director of learning and development	Project management consultancy	global
MAN10emp-Rebecca	Canadian literature	Co-owner of marketing agency, copywriter	Marketing agency	SME
MAN11emp-Michael	Environmental sciences	Project manager	Waste management company	national

Table 4.3. Interviews with professionals

4.7.3 Student focus groups and interviews

The primary aim of conducting student focus groups was to explore students' engagement with the curriculum in detail. The reason for selecting focus groups was that this method had previously been recognised to encourage students to discuss their shared experience (Cousin, 2009), in this case, their learning. To make it manageable and coincide with my data collection window, I selected one module from each discipline running in the then current semester. I opted for a second-year engineering module with learning tasks that included digital aspects (ENGm2) and a third-year marketing module (MANm4) which invited a guest employer (MAN10emp-Rebecca).

Module leaders also suggested that I would obtain better quality data from focus groups than surveys, due to students' survey fatigue (Porter, Whitcomb, & Weitzer, 2004), which also suited my qualitative orientation. Both module leaders helped identify volunteers. Once I was familiar with the learning design of the modules, I drafted the focus group topic guide to find out what activities students took part in and whether they developed the digital capabilities that they were meant to be developing, and any other unplanned ones. The questions were informed by my conceptual framework, i.e. using prompts associated with the DigiCap-framework.

My original intention was to run focus groups with these two groups of students. However, due to the short data collection time window, I had to adapt and work with those staff and students who were able to contribute. This, however, suited my pragmatist orientation, because it meant that I did not lose opportunities for data collection. A set of mini-focus groups were conducted with the selected engineering students during one of my observation sessions. I called these mini-focus groups as they were shorter than a usual 60-90 minute group session. In engineering, it was possible to arrange another focus group comprising student representatives across years 1-4. In management, due to scheduling problems, it was not possible to get the identified volunteers altogether at one time, so I ended up conducting five one-to-one interviews. These adaptations, however, suited my pragmatist orientation. It meant that I was able to explore students' digital practices in these interviews in more detail. Using the same questions and my in-depth knowledge of the modules and assessment tasks, I was able to prompt and probe students for details about their practices, something I might not have been able to do in the same way had I conducted a focus group. Accordingly, I did not feel that any detail was lost due to having to change my collection method from focus group to interview in this case. With the support of one of the participating lecturers, it was possible to arrange an additional focus group with first-year marketing students.

Where timely, a sandwich lunch was provided as an incentive. Informed consent was sought from all participating students. Altogether, 13 student data sources were collected: seven engineering focus groups (six shorter, mini-focus groups with students on a mechanical engineering programme); five management interviews; and a focus group with students on a marketing programme (see Table 4.4).

Student participant or focus group ID	Focus group (FG)	Mini FG (n=6)	Interview (one-to-one)	Year of study
ENGstd-FG1*		x		2
ENGstd-FG2*		x		2
ENGstd-FG3*		x		2
ENGstd-FG4*		x		2
ENGstd-FG5*		x		2
ENGstd-FG6*		x		2
ENGstd-FG7	x (n=8)			1-4
MANstd1-Eleanor			x	3
MANstd2-Eloise			x	3
MANstd3-Charlotte			x	3
MANstd4-Maria			x	3
MANstd5-Odi			x	3
MANstd-FG1	x (n=3)			1

Table 4.4. Student focus groups and interviews

*individual students are not identified in the transcripts

4.7.4 Observation

It was possible to organise two observation sessions in the selected engineering module (ENGm2). The purpose of the observations was to help me, as a non-participant (Creswell, 2012a), to witness the way in which students engaged with the designed digital activities in class. The first session selected was a workshop with students working in groups on their design, after an initial information-gathering stage; and the second observation point was selected so that I could see how students were using 3D software to design their product in the computer laboratory a much later . In management, I attended a lecture in MANm4 to experience authentic learning in action at which a marketing professional, MAN10emp-Rebecca, was the guest lecturer talking to students about her business.

4.7.5 Researcher journal/reflections

I collected researcher reflections by taking notes while: identifying participants; straight after data collection points; after checking/summarising transcripts; and during analysis when making coding decisions. I also discussed my interviews with a small peer group of fellow PhD students to keep researcher bias to a minimum (Silva, 2011) and in order to reflect on my interview technique.

4.7.6 Documentary sources

Module leaders usually acted as gatekeepers to the available documentary sources. Most of them were only available to me after the interviews, which is the reason why I have chosen to list them last. These sources, coded in Nvivo, included:

- subject benchmarks for engineering and business and management (QAA, 2015b, 2015a);* and the associated Accreditation of HE programmes for Engineering (see details following);
- module and programme documents: some provided by the participants, some located on UniA's intranet;
- other documents or artefacts related to the module or course, e.g. module handbooks, or websites produced by students;
- researcher journal and reflections, notes made after the interviews, observations and throughout the research.

**Note: the relevant QAA subject benchmarks have been chosen according to the JACS codes* (HESA & UCAS, 2017)*: for engineering H0-H9 and for management N0-N9.*

The documentary analysis at subject and professional level is based on the following benchmarks and frameworks (hereafter abbreviated as ENG0x or MAN0x):

- **ENG0a**: The '*QAA subject benchmark statement for engineering'* (QAA, 2015b) – this document in itself did not stipulate any learning outcomes but referred to those identified in the next source, ENG0b.
- **ENG0b:** The Engineering Council's '*Accreditation of higher education programmes: UK standard for professional engineering competence'* (Engineering Council, 2014; UKSPEC for short) – takes the various programmes such as Bachelor of Engineering (BEng), Master of Engineering (MEng), Bachelor of Science (BSc), Master of Science (MSc) and associates them with Incorporated and Chartered Engineering routes. It stipulates the standard of HE programmes in engineering and is rooted in the following document. From UKSPEC (Eng0b), I used the learning outcomes defined for Bachelors (Honours) degrees accredited as partially meeting the educational requirement for Chartered Engineers (CEng).

- **ENG0c** (also as UK-SPEC): The Engineering Council's published competence framework '*UK-SPEC: UK standard for professional competence*' (Engineering Council, 2013). This standard is ordered into five areas of engineering competencies; for the purpose of this thesis, I selected the standard for CEng as this is the standard to which my selected university programmes aspires.
- **ENG0d**: This is an internal UniA's mapping document, which maps engineering programmes and modules against ENG0c.
- **MAN0**: The *'QAA subject benchmark for Business and Management'* (QAA, 2015a).

The rest of the naming convention of my data-set is explained as follows.

4.7.7 Data management and naming conventions

I wanted to create a system which helped me to easily identify the type of data source and case just from its name. Due to the 'messiness' of my data-set, adopting a suitable identification system required iterative refinements (Bazeley, 2013). Accordingly, the following naming convention is used throughout the thesis:

- **Cases**: engineering (ENG) and management (MAN);
- **Units of analysis ID**, i.e. m=module: alphanumeric identifier to show case and module number, e.g. ENGm1…ENGm4 and MANm1…MANm4;
- **Documentary sources**: ID of unit of analysis followed by document type e.g. ENG1a, ENG1b, ENG1c ('a' for programme specification, 'b' for module specification, 'c' for module handbook, d-i for other types);
- **Participant ID** (**staff**): same as the unit of analysis e.g. ENG1-4, MAN1-5;
- **Participant ID** (**employer/professional**): ENGemp5-9, MANemp6-11;
- **Student focus groups**: ENGstd-FG1, MANstd-FG;
- **Student interviews**: ENGstd-1-5.

4.8 Data analysis

An essential feature of a case study is linking data to propositions and criteria, thereby facilitating data analysis and the interpretation of findings (Yin, 2009b). This study's proposition was that different disciplines prioritise different aspects of digital capabilities in their curricula or that they even conceptualise the six elements differently. Data analysis was also a way of exploring whether my conceptual framework, drawing together features and elements concerned with signature pedagogies and the DigiCap-framework, was productive (or not) in answering my research questions. I drew on thematic analysis to produce a summary of digital capabilities within a given case (engineering, then management). After this, I synthesised these findings across the cases, comparing engineering with management, using framework analysis (Ritchie & Lewis, 2003).

As part of this preparation, I checked, anonymised and revised transcripts, and formatted them so that they could be easily imported and autocoded by participants in my chosen computer-aided qualitative software package, Nvivo. I chose NVivo over atlas.ti for two reasons. Firstly, Nvivo seemed to have a better functionality for handling interview-type data (Wright, 2017) and, secondly, it included framework analysis as one of its analytical functions. I will describe these analytical techniques in turn.

4.8.1 Thematic analysis

4.8.1.1 Transcript summary

As a first stage of thematic analysis (Braun & Clarke, 2006), i.e. familiarisation with the dataset, I produced a bullet-point summary of each transcript, arranged under headings of my conceptual framework (levels of signature pedagogies and the six elements of digital capabilities). This overview helped with sense-making (Bazeley, 2013) and prepared the grounds for further analysis, anchoring it back to the two aspects (lenses) of my conceptual framework.

4.8.1.2 Poems as analytical technique

I summarised each lecturer's transcript in a poem. This idea derived from Bazeley (2013), who suggested that playing with different formats of communication can enhance the process of sense-making, whether it be through a poem, a diagram, or a concept map, just as multimodal authors had highlighted previously (e.g. Jewitt, 2009; G. R. Kress & Van Leeuwen, 2006; Mavers, 2009). In addition, Cahnmann

(2003) emphasises that poems, while enhancing different forms of expression, can also play a role in stimulating ideas and concepts in qualitative researchers' repertoires.

Creating these poems helped me identify the salient points of each interview and what I felt were important points about the discipline or the approach for developing digital capabilities. I selected one poem to frame my findings for each discipline (see sub-sections 6.1.1 and 6.1.2). I found that a recital of the engineering poem (see audio recording) at a conference also made my findings more accessible, and enjoyable, for the audience (Varga-Atkins, 2017). Although not a novel technique in qualitative research itself (Cahnmann, 2003; Kress, 2011), to my knowledge, poems have not yet been used to develop insights about digital capabilities or signature pedagogies. As I was searching for the rhymes and lines, they helped me weave my analysis of signature pedagogies and digital capabilities together, foregrounding links between these two aspects of my conceptual framework. For instance, I was able to concisely articulate engineering's implicit values and its typical use of software in one stanza (as discussed in sub-section 6.1.1.1).

4.8.1.3 Member-checking

In order to cross-check my initial analyses, I sent each participant their transcript with my poem and summary. Some responded and sent minor corrections, while many were happy with them and commented on having enjoyed the poems. I imported the transcripts and additional documentary sources into Nvivo to commence coding.

4.8.1.4 Initial coding of transcripts

Generating initial codes and identifying patterns in the data-set was the second step in my thematic analysis (Braun & Clarke, 2006). In the process of identifying themes, I combined both deductive and inductive approaches (Ryan & Bernard, 2003). The deductive approach meant that I created nodes (NVivo's term for code) based on themes in my conceptual framework (i.e. DigiCap-Framework and the three levels of signature pedagogies) as well as the following propositions:

> *Different disciplines may prioritise different areas of digital capabilities. AND Digital technologies are changing (transforming and/or disrupting) the disciplines; which also means that signature pedagogies are changing.*

For instance, I coded the six capability elements (Figure 4.3):

> (1-ICT) ICT proficiency; (2a-DL, 2b-IL, 2c-ML) Data, information and media literacy as 3 sub-areas; (3-PS) Digital problem-solving and creation; (4-CC) Digital communication and collaboration; (5-LD) Digital learning and development; and (6-DI) digital identity and wellbeing.

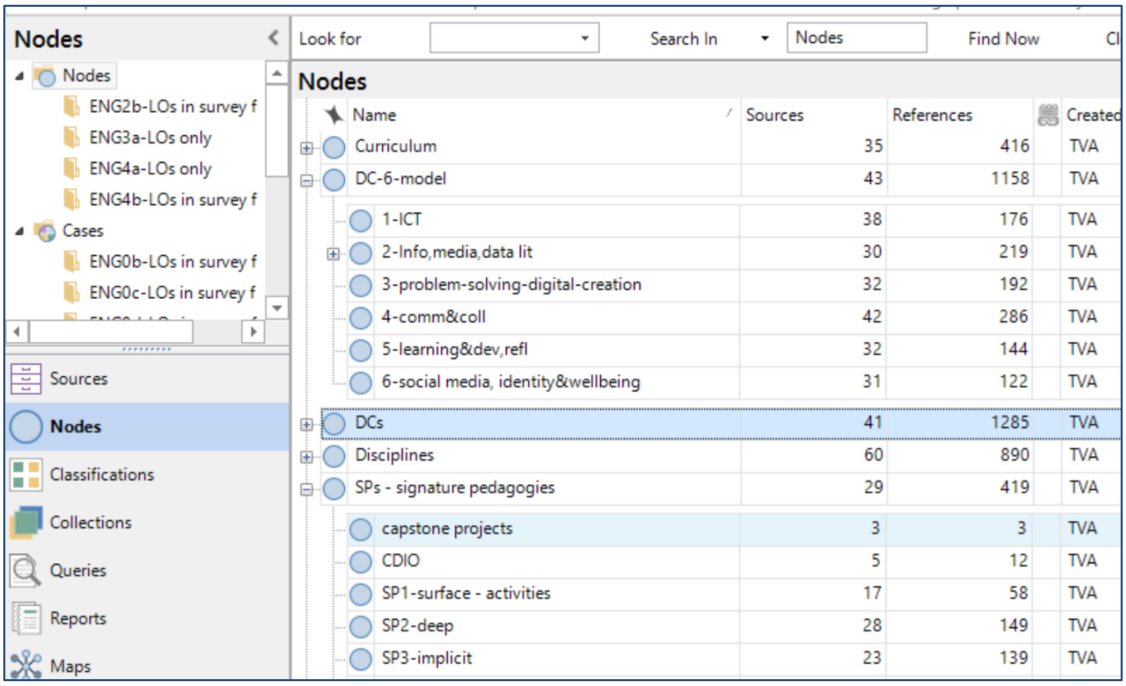

Figure 4.3 Example coding showing some deductive node trees

In addition to the signature pedagogy levels (implicit, deep and surface), I also coded for both the curriculum design level (programme or module), disciplines (engineering, management) and interview types (lecturer, student or employer/professional). Following Bazeley's (2013) advice, I started coding with two disparate transcripts – first engineering, then management – I then refined the codes; the rest of the transcripts were processed using these deductive codes.

Identifying themes or inductive codes was the third step in my thematic analysis process (Braun & Clarke, 2006). I converted my manual annotations on printed transcripts into Nvivo or coded the scripts there directly. I then reviewed, defined and named themes, similar to Tesch's eight step process (cited in Creswell, 2014, p.198). I assembled the coded sources in each capability node to carry out a preliminary analysis (Creswell, 2014) by each digital capability element, and compiled descriptive information about each unit of analysis to help with the within-case synthesis, and then looked for relationships (Creswell, 2014) between the two aspects of my conceptual framework (digital capabilities and signature pedagogies).

The advantage of combining deductive and inductive coding was that I was able to test each aspect of my conceptual framework. I was able to confirm that the DigiCap-framework was appropriate in categorising types of digital practices, as well as identifying the three domains of signature pedagogies. Further, evidencing the contribution of my conceptual framework, I was able to identify relationships between signature pedagogies and disciplinary digital practices in engineering and management.

4.8.1.5 Coding documentary sources

In documents such as programme/module specifications and subject benchmarks, I focused on analysing learning outcomes, skills-as-outcomes and, in the professional frameworks, competency statements. I coded each learning outcome/statement against the six digital capability elements from the DigiCap-framework. It became apparent that although some of the written outcomes did not explicitly articulate a digital capability, the nature of the learning outcome would have necessitated some digital skill or process. Thus, not wanting to lose these situated practices where digital capability was implied, I also decided to code for whether the element in question was explicitly articulated or implied. As implicit was harder to define, I used a more fine-grained coding scale:

- Explicit: learning outcome mentions 'technology' or types of digital capability, or their synonyms, explicitly;
- Implicit-likely[2]: the activity is likely to happen with some technological mediation but is not explicitly articulated in the text (e.g. where simulation/modelling or collaboration were concerned). I made these judgements by cross-checking my interview and observation data;
- Unsure-possibly: it is not obvious whether the learning outcome has a digital capability aspect; possibly so, but less so than in the 'likely' category;
- Not-likely: it is unlikely that the learning outcome involves digital capability.

This analytical step yielded an important consideration when testing my conceptual framework - it highlighted that the DigiCap-framework aspect needed to consider

[2] Please note that the term 'implicit' here is used in the above sense, and is not equivalent to Shulman's third level of signature pedagogies: 'implicit value'.

explicit/implicit articulation of digital capabilities from a curriculum design perspective.

4.8.1.6 Formulating findings

Having immersed myself in the data, I began formulating my findings, which acted as a further analytical step. I mapped each module in their respective discipline. Then, taking each perspective in turn, I described the development of each of the six digital capability elements in three categories: a) curriculum incorporating lecturers and documents; b) students; and c) professionals. This was useful for detailing *how* digital capabilities were developed or practised. I spent a lot of time mapping the documentary sources at different levels of curriculum design (assessment activity, module, programme and subject) which are presented in the Findings, Chapter 5.

4.8.2 Framework analysis

In testing my conceptual framework, I wanted to explore the potential links between signature pedagogies and the kinds of digital capabilities developed in engineering and management, I synthesised the three perspectives (curriculum/students/professionals) under my findings in relation to each respective digital capability element. To support this interpretive process, I drew on framework analysis, a conceptual analysis framework (Ritchie, 2011; Ritchie & Lewis, 2003) which gathers descriptive accounts through detection (content and phenomenon), categorisation (refining and describing), and classification (higher level of abstraction) (Ritchie & Lewis, 2003). I used framework analysis to identity which digital capability element(s) were foregrounded in the selected modules' assessment tasks.

Framework analysis is also known as thematic charting, as it summarises key data from individual cases (units of analysis) in tables in rows and columns (Ritchie & Lewis, 2003). Although NVivo now provides a framework analysis tool, I found it easier to produce a custom-made table with six rows (per digital capability) and four columns (per module) for each discipline. I summarised the digital element of the assessment tasks in their respective cells (see sub-sections 5.1.2.7 and 5.2.2.7) Some elements seemed to be more foregrounded than others (e.g. expressed in assessment criteria/weighting or task importance), which I indicated by strength of shading: the more the element was foregrounded, the darker the cell was shaded. This visual emphasis helped me to detect patterns and associations (Ritchie & Lewis,

2003) between a discipline's signature pedagogies and digital capabilities. I designated digital capabilities to be a characteristic of a given discipline 'signature digital capabilities', which also suggested that my attempt at combining these aspects for proposing a conceptual framework would be productive. This analysis also enabled a cross-case comparison between engineering and management, outlined in Chapter 6.

4.9 Ethical considerations

Ethical approval was granted by Lancaster University's Faculty of Arts and Social Sciences Ethics Committee in April 2017. As a researcher, I have adhered to the BERA educational research guidelines (BERA, 2011), treating participants fairly, sensitively and without prejudice. Each participant received an information sheet, a consent form, and a topic guide for their optional consultation prior interview. I was not involved in teaching the selected students; my central role in the institution only involved a focus on quality enhancement and assurance in curriculum design. Thus, there were no power issues between students or staff and myself as a researcher. My data collection was informed by Patton's checklist (2002, pp.408-409). No major issues emerged regarding informed consent, confidentiality or power issues between the researchers and participants who agreed to take part in the study (Creswell, 2012a).

One consideration, however, concerned anonymity. Even after removing identifiers, for those close to the institution it could have been possible to work out lecturers' names from the module titles, but as module titles with their associated learning outcomes were important to include as contextual information, I followed Yin's principle of including potentially identifying details in the study if justifiable and agreed to by the participants (Yin, 2009, p.181). For this reason, I consulted lecturers and sent back their module summary (the only area of concern for identifiability), together with the finding/discussion chapters (outside these concerns), asking them to confirm if they were happy with the level of anonymity provided, which they were. I offered them the option to send feedback and observations about my findings. Lecturers did not send any requests for corrections or amendments to the findings. I sent transcripts and summaries to students and professionals for member-checking. Four professionals suggested the removal of certain sentences in their transcript, which they felt could potentially identify their organisation.

4.10 Quality issues in qualitative research

In qualitatively-oriented studies, positivist concepts such as validity, reliability and generalisation are incongruous (Cohen, 2007; Maxwell, 1992). Instead, I will foreground: (1) trustworthiness; (2) replicability; and (3) transferability, in order to underline my attempts to ensure the quality of the present study. This chimes with Hammersley (2007) who argues that the criteria for good qualitative research are diverse and this needs to be respected. This section engages with each principle in turn; any additional limitations are discussed in the Conclusion (Chapter 7).

4.10.1 Trustworthiness versus validity

Qualitative research foregrounds meaning and interpretation in favour of the data (Cohen, 2007). Maxwell (1992) argues for descriptive, interpretative and theoretical validity in qualitative research. *Descriptive validity* refers to the factual accuracy of the account (i.e. that it is not distorted), while *interpretative validity* is concerned with the ability of the researcher 'to catch the meaning, interpretations, terms, intentions that situations and events, i.e. data, have for the participants/subjects themselves, in their terms' (Cohen, 2007, p.135). Meanwhile *theoretical validity* is concerned with the extent to which the research explains the phenomena. I will address these three areas of validity under the umbrella term 'trustworthiness'.

Trustworthiness in qualitative research means that results are credible and dependable (Lincoln & Guba, 1985) and whether the arguments made are strong. This concerns whether the explanation of the results can be sustained (Cohen, 2007) and if the study helps to illuminate a phenomenon that might otherwise be enigmatic (Eisner, 1991; Golafshani, 2003). I deployed the following strategies (Shenton, 2004) to ensure trustworthiness:

- using well-established research data collection methods, such as interviews, focus groups, documentary analysis, etc.;
- being familiar with the culture of one of the participating organisations as an insider researcher;
- triangulating different methods (interviews, documentary analysis) to overcome each method's potential weakness (Creswell, 2014; Steenhuis & Bruijn, 2006);
- drawing on a wide range of informants (in my case staff, students and employers) (Shenton, 2004);

- using tactics (e.g. asking students to honestly state what they did, rather than trying to match what they thought I would like to hear) to help ensure participant honesty during interviews;
- member-checking with participant transcripts (East et al., 2014), seen as one of the most important aspects for ensuring trustworthiness (Cohen, 2007, p.149);
- writing reflective commentaries in my researcher journal after data collection points and during analysis;
- explaining my background, qualifications and experience as a researcher in my study;
- including a thick description in Chapter 5, Findings of the phenomenon studied (Creswell, 2014); which is also described by Cohen as the ‘honesty, depth, richness and scope of the data’ (2007, p.133), that Shenton (2004) claims as enabling findings’ transferability and for comparisons to be made.

One weakness of my study – as compared to Shenton’s (2004) research – is that I did not use random sampling. Purposive sampling ensured that I was able to find professionals to take part and that I chose modules with digital tasks. Another potential shortcoming in terms of trustworthiness was that it was not possible to undertake a negative case analysis (Creswell, 2014). In my study, this may have involved choosing a module with no technology or lecturers who were explicitly averse to using technology in their teaching. On reflection, I would probably have struggled to identify any module that did not involve some kind of digital learning activity. Either way, my interest was in the critical thought-processes of lecturers, students and professionals choosing to use technology (or not) in given disciplinary contexts.

4.10.2 Replicability versus reliability

Similar to validity, research reliability needs to be re-interpreted for qualitative studies. In quantitative studies, reliability entails that results remain consistent over time and can be reproduced using the same methodology. For Cohen (2007), this implies the study’s ‘fidelity to real life, context- and situation-specificity, authenticity, comprehensiveness, detail, honesty, depth of response and meaningfulness to the respondents’ (2007, p.149). In Shenton’s (2004) view a dependable study’s methodology needs to be described in-depth to enable someone else to replicate it.

The strategies I used to increase replicability included a detailed summary of data collection and analysis; an explicit statement as to my position as a researcher including my potential biases; and details of my choice of informants and the analytical constructs used (LeCompte, Preissle, & Tesch, 1993). A further aspect of reliability refers to the stability of the observations made (Cohen 2007): if these modules had been observed at a different time or place, would the same observations have been made? Since digital technologies change rapidly, this remains a pertinent question.

4.10.3 Transferability versus generalisability

Quantitative research is interested in extending results in a research setting to a wider population. Qualitative research, however, foregrounds generalisability, i.e. the generalisability of propositions or theories over generalising findings to individuals, sites or places outside the study (Flyvbjerg, 2006; Maxwell, 1992; Stake, 2006; Yin, 2009a). If anything, the strength of case study, and qualitative research, is in developing *particularity* (Greene & Caracelli, 1997; Thomas, 2016) over formal generalisation, which is what Flyvbjerg (2006) calls the 'force of the example' (p.12).

This study did not set out to claim that my findings would be generalisable to other disciplines, or indeed fully covering all aspects of engineering and management and its sub-disciplines, but to provide insights into the way two disciplines conceive of digital capabilities in their curricula. What I *can* claim, however, is that: a) the theoretical proposition (that digital capabilities are situated and discipline-specific) is shown; and b) the way I have gone about exploring my subject, i.e. the process, is transferable to other settings and disciplines.

5 Chapter 5 Findings

This chapter presents findings that relate to the overall research question, i.e. how are digital capabilities conceptualised in the curriculum at modular level in two cases (engineering and management), with four units of analysis (modules with their relevant programmes and benchmarks/frameworks). With respect to my conceptual framework, these are presented in relation to its practice lens - the DigiCap-Framework's six elements - broken down into curricular (staff), student and professional perspectives. The findings validate if this aspect of my framework is appropriate to capture digital practices in the context of the selected disciplines. For the abbreviations of source documents and naming convention of participants, see sub-section 4.7.7.

5.1 Case 1: Engineering

5.1.1 Modules

I present each module in a table summarising the given module's details, aims, learning outcomes, teaching approaches and activities, and a brief description of the module assessment task(s). Where a module is delivered across a number of programmes, I have chosen one of these modules for analysis.

5.1.1.1 ENGm1: Materials design

ENGm1 is a third-year module on materials design led by ENG1-Thomas at UniA.

Module title	**Materials design**
Programme	Mechanical and materials engineering (BEng)
Professional Body Standard Requirements (PBSR)	IMechE, UK-SPEC
Year	3
Credit	7.5
Length	1 semester
Aims	To develop and apply understanding of the important factors in materials and process selection for engineering components and design, and the planning and execution of activities associated with the professional materials design engineer. To provide an

Module title	Materials design
	experience of materials design associated with the manufacture of engineering components.
Learning outcomes (LO)	• ENG1b-LO1-Understand structure - manufacturing - property - costing relationships in engineering components. • ENG1b-LO2-Develop industry and research experimental investigatory skills required to "reverse engineer" engineering components. • ENG1b-LO3-Improve and apply group-work skills including communication and project planning. • ENG1b-LO4-Develop communication skills using wikis and posters for presenting technical information.
Assessment methods/tasks (AT)	• AT1: Course work (50%): wiki of manufactured artefact; • AT2: Poster (50%): a) poster of materials investigation; b) working scale-model of manufacturing process; Group marks are peer-moderated.
Teaching and learning approach and activities (TLA)	• Lecture*6 - introducing the activities, seminars and guidance during the projects. • Laboratory Work*12. • Group-work - for training/teaching on project-specific techniques.

Table 5.1 Unit of analysis 1: ENGm1

Students work in teams to 'reverse engineer' – take apart – a manufactured artefact, e.g. a hedge trimmer or a spark plug, and document their findings in a wiki, using multimedia, e.g. photographs, animations, images, text, hyperlinks, referencing sources. Students also work in a group to design and build a working scale model of an industrial materials manufacturing facility, such as a rolling mill, die caster, sheet metal press, etc. They use 3D-CAD (computer-aided design) software to design the scale model while the components are built using 3D printing or laser-cut in their active learning laboratory. Students complement the scale model with a display poster that explains the industrial process, its engineering context, and any commercial manufacturing/costing issues. The two assessment tasks (wiki and poster), are graded in teams but peer-moderated to reflect individual contribution in students' final marks.

5.1.1.2 ENGm2: Product design

ENGm2 is a second-year UniA module on product design led by ENG2-Mike.

Module title	**Product design**
Programme	BEng Mechanical and Materials Engineering
PBSR	IMechE, UK-SPEC
Year	2
Credit	15
Length	2 semesters
Aims	The aim of this module is to teach the fundamentals of the 'Total Design' process within a group-based engineering design project.
Learning outcomes	• ENG2b-LO1 Demonstrate knowledge and understanding of The 'Total Design' process. • ENG2b-LO2 Demonstrate knowledge and understanding of Design based on industry standard product specifications (BS7373). *…[omitted rest]* • ENG2b-LO31 Able to show experience and enhancement of the following discipline-specific practical skills using ProENGINEER Wildfire/Mechanica and Cambridge Engineering Selector. • ENG2b-LO32 Able to show experience and enhancement of presenting design information orally. • ENG2b-LO33 Able to show experience and enhancement of group working.
Assessment	• AT1: Initial Product Design Specification (20%). • AT2: Formal report of the design concept (20%). • AT3: 3D-design of the product (20%). • AT4: Design report (group) (30%). • AT5: Group presentations (10%). AT1-4 are peer-moderated, all group tasks.
TLAs	• Lectures*12, group-based practicals and tutorials.

Table 5.2 Unit of analysis 2: ENGm2

Teams write a product specification in the first semester, e.g. for a smoothie maker, including their various concepts, their concept variant analysis methodology to make an informed decision as to the product they will be designing, and other science considerations as they progress with their design. The two assessment tasks in this semester are the product specification (AT1) and a formal report of their design concept (AT2). The latter includes a Gantt chart of the team's Semester 2 project schedule. The team-based element is supported via in-class group process-related activities throughout the semester. In the second semester, the design is developed into a virtual 'proof of concept' in 3D CAD and described using a full set of technical drawings and traditional engineering techniques. The three assessment tasks are the product's 3D CAD design (AT3), the 'Proof of Concept' (AT4) design report including materials to be used and how it will be manufactured, and the group presentation (AT5).

5.1.1.3 ENGm3: Engineering management

ENGm3 is a master's-level module on engineering management led by ENG3-Gill at UniB.

Module title	**Engineering Management**
Programme	MSc in Automotive Engineering
PBSR	IMechE, UK-SPEC
Year	Masters
Credit	20
Length	1 semester
Aims	The module examines the process of business development. Students will gain a good understanding of the commercial pressures that operate in a motorsport/automotive setting.
Learning outcomes	*Only available at programme level.*
Assessment	• AT1: Business plan (25%) • AT2: Peer feedback on formative business plan (10%) • AT3: Presentations (15%) • AT4: Examination (50%) AT1-3 are group-based, AT4 is individual.
TLAs	• Lectures*12. • Seminars*15. • Case studies. • Industrial (guest) lectures.

Table 5.3 Unit of analysis 3: ENGm3

Students develop a convincing business plan in groups, which includes a clear specification of the business or product, its customer base, a competitor analysis, together with justified and correct financial information indicating how the product or service will perform. In addition, students start on the business proposal, which they submit for formative feedback from the tutor and two other groups. There are four summative assessment tasks. Each group is required to submit constructive feedback (AT3) on two other proposals. The groups then refine their proposal for an end-of-semester summative submission (AT1). Each group is also required to present their business idea in front of their peers (AT2). Finally, students take an individual examination (AT4).

5.1.1.4 ENGm4: Product visualisation and simulation

ENGm4 is a second-year module led by ENG4-Dylan at UniA.

Module title	**Product visualisation and simulation**
Programme	BEng Industrial Design (also, Mechanical and Materials Engineering)
PBSR	Institution of Engineering Designers (IED), UK-SPEC
Year	2
Credit	15
Length	2 semesters
Aims	1. To teach the principles of virtual reality (VR) systems, visualisation techniques and simulation practice to an introductory level. 2. To inculcate an appreciation of the role that visualisation and simulation plays in the development of new or existing products to an introductory level.
Learning outcomes	Students should be able to demonstrate: • ENG4-LO1 an introductory knowledge and understanding of modern product visualisation and simulation techniques. • ENG4-LO2 an ability to deploy basic techniques to produce introductory level product visualisation and simulation. • ENG4-LO3 an ability to design and construct a basic virtual environment.
Assessment	• AT1 (50%) coursework and AT2 (50%) portfolio of work
TLAs	• Lectures*20; • Laboratory practicals*24.

Table 5.4. Unit of analysis 4: ENGm4

ENGm4 develops students' understanding of product visualisation and simulation techniques. Students are introduced to VR systems and related hardware, e.g. sensors; display systems; stereovision; and colour theory through lectures and hands-on computer laboratory practicals. For their assessment tasks, students produce an individual report on an ideal VR system (AT1), and create and animate a 3D-model of a teaching room on campus (AT2).

5.1.2 Curriculum

Having outlined the modules and their main teaching and assessment activities, I now present how the six digital capability elements (see section 3.2) are planned into these modules based on interviews with academics, documentary analysis of programme/module specifications, as well as professional frameworks.

5.1.2.1 ICT proficiency

ICT proficiency for engineering students includes basic ICT skills, such as using Microsoft (MS) Office as well as digital applications for project and risk management. Although programme-level outcomes (e.g. "knowledge and understanding of management techniques, including project management, that may be used to achieve engineering objectives" in ENG1a-LO16) do not refer explicitly to project management software, module assessment tasks include the use of these, e.g. MS Excel or Gantt charts (ENGm1/ENGm2).

5.1.2.2 Data, information and media literacy

I have chosen to separate data, information and media literacy as they appeared to be distinct areas in engineering.

5.1.2.2.1 Data literacy

As engineers need to generate, manage and interpret large amounts of data, developing data literacy as a key capability is essential. It involves generating, managing and representing data for problem-solving issues encompassing materials, experiments and simulations, e.g. the use of MS Excel or programming. Professional frameworks articulate data literacy, for instance, as the application of "quantitative and computational methods in order to solve engineering problems" (ENG0b), or, in programme-level outcomes, the "knowledge and understanding of mathematical and statistical methods" or the "ability to apply quantitative and computational methods" (ENG2a-LOs).

In electronics and electrical engineering, large amounts of data are acquired from "complex systems with lots and lots of sensors. Sensors interact and it becomes very interesting and complex to do without some sophisticated software" (ENG3-Gill). For this reason, engineering students need to enhance their programming and computational skills, e.g. MATLAB or simulation tools, while being able to "deal with complex issues both systematically and creatively, make sound judgements in the absence of complete data" (ENG3-Gill).

5.1.2.2.2 Information literacy

In engineering, information literacy comes into focus when tasks involve commercial, economic, social and environmental contexts. Engineers need to be aware of the legal and safety requirements as well as the relevant ethical, social, commercial and environmental factors relating to the problem they are solving (e.g. ENG0b, ENG2a-8). Information literacy is vital for helping students' critical analysis and decision making, in which they require support from academics (Beetham, McGill, & Littlejohn, 2009). Learning and assessment tasks involving these areas appear to develop students' abilities to search, critically evaluate and synthesise relevant information from disciplinary sources.

In Gill's ENGm3 module, teams develop a business plan with financial information indicating how the product/service will perform "as if they were going to a bank as a small or large business to get funding". The assessment criteria consider competitor analysis, marketing strategy, the proposal's credibility within realistic timescales and the quality of financial data and referencing. All of these require students to demonstrate data and information literacy, as in Mike's ENGm2, where students "have to look at legislation …can you fly a drone anywhere you like? …Are there any other British standards that govern the design and manufacture of these things?".

ENG2-Mike points out that information literacy development is approached at programme level. It starts with first-year students receiving library training on data trustworthiness, academic integrity and referencing. By their fourth year, students can confidently evaluate, interpret and synthesise results.

5.1.2.2.3 Media literacy

Media literacy overlaps with content communication, and is discussed in sub-section 5.1.2.4.1. Although engineering is a visual discipline relying on visual modes of communication, media literacy does not tend to feature explicitly in its learning outcomes, apart from ENGm1.

5.1.2.3 Digital problem-solving

I am using 'digital problem-solving' as a shorthand for DigiCap-Framework's digital creation, innovation and scholarship element (see sub-section 3.2.3). This is where most of the subject-specific digital problem-solving tasks belong. It is also the element which is influenced by the sub-disciplines, with different sub-disciplines using different kinds of software for problem-solving, confirming previous findings (Becker et al., 2017)**.** The use of most specialist engineering software comes under the digital problem-solving heading, such as: "apply advanced problem-solving skills, technical knowledge and understanding, to establish rigorous and creative solutions that are fit for purpose for all aspects of the problem" (ENG1a-LO), which does not tend to explicitly articulate the digital elements. The curricular approach involves giving students a sense of the breadth of industry-standard software available in order to prepare them for professional practice:

> Somebody can graduate from us and they may never actually use it again, but they've got then that baseline outcome of learning that enables them to interact with everybody else in the industrial world.
> ENG4-Dylan

Instead of developing detailed skills to use a specific tool, e.g. a 3D-CAD package, the aim is to get students to acquire the principles underpinning the use of such software. This is also intended to future-proof graduates, since software is updated continuously. For more detail on engineers' use of software see sub-section 5.1.4.3, and for using modelling and simulation as a signature capability see sub-section 6.2.1.1.

5.1.2.4 Digital communication/collaboration

Digital communication/collaboration practices in engineering curricula seem to fall into three main areas: 1) communication of content/knowledge to 'technical and non-technical audiences'; 2) team communication; and 3) synchronous/asynchronous collaboration between team members which may or may not involve the digital artefacts discussed as follows.

5.1.2.4.1 Digital communication of content (also media literacy)

In the modules selected, communication of content involves preparing presentations and reports to "communicate their work to technical and non-technical audiences" (ENG0b) while finding or creating images, diagrams, and correctly referencing sources. Engineering students typically produce product specifications, presentations, reports, designs and work with visual artefacts (e.g. diagrams, 2D/3D-objects, simulations or virtual reality). Here two Framework elements overlap, namely media literacy and digital communication, partly because the content communicated is digital and multimodal (Jewitt, 2009b), and also because it this digital content that is communicated to particular audiences (Bawden, 2008; Buckingham, 2007). However, perhaps because these visual processes are endemic to engineering, they are not stated explicitly in learning outcomes, or perhaps in engineering a more nuanced differentiation is needed between media and visual literacy (Koltay, 2011). Few modules articulate media literacy explicitly (ENGm1, ENGm4), which I discuss as follows.

ENGm1 illustrates the development of digital media literacy perfectly while detailing development of students' "communication skills using wikis and posters for presenting technical information" (ENG1b-LO4). The wiki task's assessment criteria explicitly involves media literacy (worth 40% of this task in addition to technical content and presentation):

> wiki structure and functionality/usability**,** including overall structure and organisation (15%), visual appearance (15%), and effective internal navigation and external hyperlinking (10%).

The poster task develops students' ability to design a visual poster using presentation software to communicate to a 'well-educated non-specialist' audience, such as first-year engineering/science students. The poster captures the real industrial process and the team's approach to designing the scale model, including the compromises that they had to make. Again, the poster task's assessment criteria are intended to identify the communication/media literacy capabilities being developed (in grey):

> Communication of most important scientific and technical information:
> Understanding: demonstrates understanding of the relevant concepts;
> Presentation: eye-catching and visually attractive; high quality images to inadequate graphics;
> Layout: clean, logical and accessible through to inadequate;
> Research: well-researched and referenced (showing evidence of analytical, critical and synthetic treatment of information).

Other modules emphasise the communication of content in similar ways. Apart from disciplinary problem-solving software, MS Office products are mainly used for this. It is unclear if students receive any training for multimedia content production other than being instructed in software use as mentioned above. Becker et al. (2017) have highlighted that a majority of students received minimal media-literacy training, which might also be the case here.

5.1.2.4.2 Team communication

This tends to overlap with collaboration, which is discussed as follows.

5.1.2.4.3 Asynchronous/synchronous collaboration

To distinguish it from communication, 'digital collaboration' here is understood as a team-process involving the discussion or sharing of an artefact using digital technologies. Mike's ENGm2 students work in teams to design a product, such as a smoothie maker or a humanitarian drone, and produce a British Standards (BS) product specification. In the second semester, the team develops their chosen design in 3D-CAD, accompanied by a 'Proof of Concept' design report using technical drawings and traditional engineering techniques, e.g. materials/manufacturing processes, which the teams then present.

Students receive team-working support throughout the year. They are required to minute meetings, share and assemble their concepts and CAD designs, and collaborate on writing reports. Although the digital aspects are not singled out in the module's learning outcomes, 6 out of the 27 learning outcomes deal with collaboration and communication, such as group work or written communication. These are aligned with the programme-level outcomes, with students also developing an "understanding of, and the ability to work in, different roles within an engineering team" (ENG2a-28, SK1 and SK4). In turn, students learn to collaborate based on their common design/artefact, thereby preparing them for real-life engineering projects.

With respect to collaborative digital tools, the module leader sets up a shared drive and a VLE group area, otherwise teams are left to self-organise their collaborative tools in terms of scheduling meetings or sharing resources, whether they are using institutional or other tools such as WhatsApp, texts or alternative means. It appears that digital collaboration capabilities are supported partly by the curriculum, with staff facilitating the group process and ensuring institutional digital tools are available, whilst allowing collaboration to emerge organically according to the teams' particular preferences.

5.1.2.5 Digital learning/development

All student activity at university encompasses learning and development. In all four modules (ENG1-4), learning and development skills are modelled and enhanced through digital resources via the use of a VLE and online resources (e.g. MOOCs, Massive Open Online Courses, and YouTube videos), lecture capture, in-class polls, online submission of coursework, peer evaluation and note-taking tools. At a programme-level, students "plan self-learning and improve performance, as the foundation for lifelong learning/CPD [continuing professional development]", which requires them to "plan and carry out a personal programme of work, adjusting where appropriate" (ENG2a-SK2&3), although without explicit reference to digital tools. ENG2-Mike promotes mind-mapping tools. Furthermore, ENG2-Mike and ENG3-Gill identify reflection as a potential area for development, which appears to be a difficult issue for engineering students; students need prompting to make a record of the various skills and digital capabilities they have developed.

5.1.2.6 Digital identity/wellbeing

Implied (as opposed to explicit) digital outcomes are also more characteristic of digital identity relating to professional behaviour, as in the "understanding of the need for a high level of professional and ethical conduct in engineering and a knowledge of professional codes of conduct" (ENG1a). With respect to professionalism, ENG1-Thomas notes that when students give presentations to employers, "they turn up in a suit and tie. [This] wouldn't happen in physics or chemistry …they view it as being part of their profession." It is unclear to what extent all students have the opportunity to develop or appreciate positive professional digital identity across a range of platforms by developing a personal style and digital participation values such as acting safely and responsibly in digital environments. ENG2-Mike notes that mechanical engineering students' use of social media, especially LinkedIn, is more likely to be supported by the careers service alongside the curriculum.

In contrast, and as ENG3-Gill explains, nurturing a 'digital presence' for students of automotive engineering is a key sub-disciplinary characteristic. The sponsors, who are the 'celebrities' of the industry, are central to supporting the full cycle of engineering development. Students need to return the favour by publicising their work on social media, websites, and brochures. Gill observes that students' digital know-how can surpass that of their tutors. The latter see their role as stewards, acting as guides to students' digital practices, without having to be digital gurus themselves. In one task, Gill's students peer-evaluate the web presence of other Formula One teams and collaborate with marketing students who offer constructive feedback on how to improve their digital presence. Such interdisciplinary collaboration can benefit students in terms of driving their enterprise and innovation, as this is the moment when they realise that their analytical skills can be applied in other contexts (Adkihari, 2011).

Academics play an important role in promoting an awareness of the ways in which students can benefit from creating a positive online presence as an engineering professional. The important role of academics in encouraging technology adoption has been highlighted by previous studies (Jones, 2011; Kennedy et al., 2010; Littlejohn et al., 2012). ENG2-Mike's students keep in touch with their international peers via Twitter and Facebook; using social media has been shown to support collaboration (Abella-García, Delgado-Benito, Ausín-Villaverde, & Hortigüela-Alcalá, 2018). Mike enthusiastically says, "We're gonna social media the hell out of that [project] because it's impressive!" while pondering, "I would imagine that soon, whoever you work for, if it's not a confidential project, that everyone will be doing social media". Whether this is a direction that is evident in industry or an extension of universities' focus on recruitment, or both, could be further explored.

5.1.2.7 Overview

After exploring how each capability element is integrated into the engineering curricula, it is possible to provide an overview of the focus of each element in each module based on the analysis above, especially by exploring the assessment tasks and criteria which appear to be the best indicators of the presence of digital capability elements. The darker the colour, the higher the focus on the DigiCap-Framework-element (see Table 5.5 below). Text in square brackets signals if the element was not relevant, not discussed or was only indirectly implied or had minimal significance. It appears that in the engineering curricula, digital problem-solving and collaboration/communication (including media literacy) would seem to be the most significant elements, followed by information/data literacy. Digital identity appeared to be the least articulated element.

	ENGm1: materials design	**ENGm2: product design**	**ENGm3: engineering management**	**ENGm4: product visualisation**
1-ICT	AT1/AT2-word-processing skills for report writing	AT1-word-processing skills for product specification and Gantt chart/Excel for project scheduling; AT4-design skills for poster	AT1/AT4-report writing and presentation	AT1-portfolio & report writing
2a-DL		AT2-design concept using data analysis	AT1-financial data analysis for business proposal	
2b-IL	Background research of components (AT1) and materials for scale model (AT2)	AT1-searching for standards, patents, market/customer info relating to product	AT1-business proposal including customer needs, financial analysis & forecast	AT1- critical analysis of academic/other sources of literature

	ENGm1: materials design	ENGm2: product design	ENGm3: engineering management	ENGm4: product visualisation
2c-ML	AT1-communicating outcomes and process of reverse engineering in a wiki; AT2-visual literacy for engineering/non-technical audience	[AT1-managing/using/referencing images]; AT4-using images in report	[AT1: visual representation of data]	[visualisation overlaps with PS & ML];
3-PS	AT1-reverse engineering a product using various equipment/experiments; communicating findings in a wiki; AT2-CAD of scale model	AT3- CAD/Pro-Engineer design of artefact, BoM - some components fully/partially and assembly of components; use of Cambridge Engineering Selector		AT1/AT2: using visualisation/ simulation software
4-CC	AT1/2 group projects communicating multimedia content in wiki and poster; digital collaboration within groups VLE and others	[VLE tools for group collaboration] AT4-report to communicate content to technical audience; AT5-group presentation slides	AT2: peer feedback AT1/AT3: convincing argument and evidence in presentation	[N/A, mainly individual work]
5-L&D	[not discussed] - VLE resources, criteria, handbook, lecture capture	AT2-mindmapping tools for design concepts	[not major part - VLE resources]	[self-taught via software tutorials]
6-DI	[N/A]	[N/A]	[not in this module but key in motorsport]	[N/A but discussed]

Table 5.5 Mapping the DigiCap-Framework-element in engineering modules

These disciplinary digital capabilities are the result of a carefully orchestrated progression as students go through the various modules from their first to final year, mainly guided by academics and by the assessment tasks' requirements in relation to the uptake of software- and peer-learning opportunities.

5.1.3 Students

I have drawn on limited data gathered at a particular mid-semester point in ENGm2 and from a cross-year focus group (see sub-section 4.7.3). Generally, students appear to be developing the digital capabilities that are planned for them in the curriculum. Student and staff perceptions on students' digital capabilities also seem to converge.

5.1.3.1 ICT proficiency

On entry, students arrive with general ICT proficiency; however, they seem to lack know-how in presenting and managing data. Students generally use the VLE or AppsAnywhere to access their files and university applications off-campus (ENG-FG7). Others use freeware project management tools such as Slack, Trello, Facebook or Doodle to help manage their team tasks.

5.1.3.2 Data, information and media literacy

5.1.3.2.1 Data literacy

Not many students transition to university with the required data literacy: "I am always surprised about how little [students] have actually used the packages, like [MS] Excel, to present data" (ENG1-Thomas). Academics' perception is that the university has a role in developing students' data literacy. Such skills are developed continuously, starting with a first-year slot-car project (ENG4-Dylan). Students did not mention being engaged in data literacy tasks at the time of the interview, but a major part of ENGm2 includes searching and analysing information related to their chosen product, e.g. competitors and the market, which requires managing and interpreting data.

5.1.3.2.2 Information literacy

From their arrival at university, students' information literacy grows progressively. Students can overestimate their information literacy (Brabazon, 2013), which is probably why the university offers ample subject-specific opportunities to facilitate their information literacy development. The second-year students cited consulting web searches, product and competitor reviews, websites, library resources, patents and other legislative or safety requirements (for blenders, for example) as well as the British Standards 7373 specification (FG1-6). One focus group (FG2) made use of their Chinese member's linguistic competence by consulting Chinese product sites. These accounts appeared to confirm that students achieve the intended information literacy outcomes. Progression is also demonstrated by how one student described their critical judgement of information: “Let’s say McDonalds, [it’s] a relatively trustworthy company. Basically, I can use them for market research. Because I am betting on that they did the job well” (ENGstd-FG6). By graduation, students seem adept at researching market and customer needs and the requirements of various patents and standards.

5.1.3.2.3 Media literacy

Students display a range of media capabilities. Whilst in some cases students might have no “idea how to lay a poster out to convey the information and what a good poster should look like” (ENG1-Thomas), other assessment tasks or collaborative design projects result in creative digital multimedia outputs. Students have some formal and some optional opportunities to hone their visual capabilities. For instance, a fourth-year student has created videos and animations using MovieMaker and PowToon (ENGstd-FG7) as part of an assessment task. The co-curricular Formula One team’s outputs – e.g. brochures, websites and social media posts – are an “exemplary benchmark as to what students can do with digitalisation” (ENG4-Dylan). Notwithstanding co-curricular opportunities, extending opportunities to develop students’ media literacy within curricular tasks would reach more students.

5.1.3.3 Digital problem-solving

As for students’ capabilities, staff seem to agree that students develop their digital problem-solving during their study, the extent of which depends on their level of engagement in their independent study time. A few students mentioned learning additional 3D-modelling software (AutoDesk), demonstrating their enthusiasm to extend their learning beyond required tasks. In FG7, undergraduates reported developing MATLAB and CREO skills or using additional tools such as online calculators. One student expressed the wish to learn to program in Python.

The module chosen for focus group discussion (ENGm2) did not involve this capability, so the data reported here is limited to employer and staff perceptions. ENG8emp-Jack remarks that if graduates acquire scientific principles during their time at university, they are able to “sit down with our CAD and use it without even batting an eyelid”. In Jack’s view, nine out of ten engineering graduates “can use CAD to a good standard”.

5.1.3.4 Digital communication/collaboration

Students quickly pick up how collaboration works within teams and adopt digital practices, e.g. understanding that a shared folder might have to be changed because other team members worked on it. Staff feel that what students need guidance on is group working, intercultural skills and professional communication/collaboration practices.

Staff agree that – and in agreement with the findings of Jones and Healing (2010) – students are more than adept at deciding on their preferred intra-team communication method. Students use "high street-tech, communication software, and [it] is just so second nature, we don't even deal with it" (ENG2-Mike). Lecturers may provide a group tool on the VLE, but leave groups to decide their preferred tool, chiming with Tay and Allen's (2011) finding that students prefer to use the "tools at hand" (p.161) such as WhatsApp or Facebook. However, to what extent students are asked to critically reflect on their technology choice is uncertain.

Most staff also agree that although students are adept at communicating, they need guidance in professional communication (ENG1-Thomas, ENG2-Mike), especially when it comes to email etiquette, which has also been observed by Kearns (2013). Students get 'explicit' email instruction in their first year and further opportunities later on during real-life design projects, e.g. by having to write to the director or the chief technician (ENG2-Mike).

Students can also pick up the professional norms of communication of teams or institutions via modelling. The reason why ENG2-Mike's students can WhatsApp him at 10pm at night with "badly written, no sense of format, no sense of respect for the reader" is because he has made it clear that when they are working on exciting live projects, he is happy to receive these messages if students want a quick answer. In addition to tutors, peers, especially senior peers, can also substantially influence the take-up of collaborative digital tools (Beetham, McGill, & Littlejohn, 2009; Kearns, 2013).

5.1.3.5 Digital learning/development

As for digital learning/development, students mention using:

- online polling in classes, which makes lectures more “two-way”;
- lecture-capture recordings: helpful when they “struggle with accents or for revision purposes”;
- VLE discussion forums for asking questions about lectures;
- using video tutorials “for everything! There is everything, tutorials, explanations, how can I say, templates” (FG7);
- notes or post-it note apps on smartphones to make notes;
- participating in a MOOC created by their lecturer to look at videos, the course blog and to answer questions.

Using these tools demonstrates that institutional availability and resources can have a large influence on students’ digital practices (Jones, 2011).

5.1.3.6 Digital identity/wellbeing

Students may arrive as ‘savvy’ social media users, but when it comes to disciplinary uses, they need academic guidance (Jones et al., 2010). Academics seem to believe that students’ social media practices develop in school, albeit such practices not being necessarily aligned to professional behaviour. Students’ perceptions of digital identity did not emerge in focus groups, but academics frequently commented that students “are better than me”, especially in relation to the co-curricular Formula One teams. ENG3-Gill remarks that “I feel bad [that] I am pushing them in this direction, because I am not as competent myself but really it does help them …to promote their work”.

5.1.3.7 Overview

With respect to students’ development of digital capabilities from their own and staff’s perspectives, a similar picture emerges as highlighted in sub-section 5.1.2.7. The most prominent elements seem to be data/information literacy, problem-solving and communication/collaboration, with the least prominent being digital identity. Students display three different strategies when faced with optional technology adoption, which correspond to those identified by Prescott (2013), albeit based on academic staff, namely: ‘enthusiasts’; ‘pragmatists’; and ‘risk-aversives’. Some engineering students seem to be keen to invest in learning a new, sophisticated industry-wide software, and have no problem seeking out video tutorials to learn it (enthusiast). However, another group reports that instead of a 'powerful' programme such as MS Project, they use an MS Excel spreadsheet to create a Gantt chart for their assignment (pragmatist). Yet another student feels that for a high-stake assessment task he would "just go with what I know" (ENGstd-FG4) (risk-averse). However, curricular requirements can override personal preferences. When MS Project is required for a task, students do use it. This confirms the important influence of educators (Margaryan et al., 2011) manifesting itself in effective curriculum design and institutionally-available technologies (Jones & Healing, 2010) in students' adoption of digital practices.

5.1.4 Professional engineers

Having explored the curricular opportunities for digital capabilities, I now turn to engineers' digital practices, based on interviews and documentary analysis of professional frameworks (see sub-section 0). Table 5.6 shows the result of mapping the competency outcomes of the professional framework of Chartered Engineers (ENG0c) against the DigiCap-Framework described in section 3.2. As not all outcomes articulated digital capabilities explicitly, mapping also considered where these capabilities were implicitly, possibly or unlikely to be present. Accordingly, the most focal elements (explicit or likely/implicit) appear to be digital problem-solving and collaboration/communication, followed by information/data literacy.

	Learning outcomes			
DigiCapF-element	explicit	implicit-likely	unsure-possibly	not-likely
1-ICT proficiency	1	13	3	0
2a-DL-data literacy	0	8	2	0
2b-IL-info lit	4	7	2	0
2c-ML-media literacy	0	1	0	0
3-problem-solving	6	15	4	0
4-comm/collaboration	1	14	9	0
5-learning/development	3	4	9	0
6-digital identity/wellbeing	0	4	2	0

Table 5.6 Digital capabilities of Chartered Engineers (ENG0c/UK-SPEC)

5.1.4.1 ICT proficiency

ICT proficiency for engineers seems to involve general ICT skills, IT development, and project and risk management tools (ENG0b). Engineers use MS Office tools and Adobe suite (ENG6emp-Paul, ENG7emp-Craig), OneDrive and SharePoint alongside cloud computing facilities (ENG9emp-Adam). Consultant ENG6emp-Paul uses data collection devices and software, including thermal imaging cameras, vibration sensors/monitors, drones, oscilloscopes, etc. ENG9emp-Adam uses MS Project for resource allocation and budgeting.

5.1.4.2 Data, information and media literacy

5.1.4.2.1 Data literacy

Data literacy appears to be a core part of the engineering professional framework (ENG0c/ENG0b), involving risk management, health and safety risk analysis, or quality assessments. Both risk analysis and quality improvements are areas where engineers are likely to draw on large amounts of data and/or use digital tools to support these processes. For instance, ENG9emp-Adam uses MS Excel for stock-taking and data manipulation.

5.1.4.2.2 Information literacy

Generally, information literacy comes into focus when engineers explore current or new solutions to ensure they are economically, ecologically viable and safe, e.g. "understand and evaluate business, customer and user needs" or "understanding of the commercial, economic and social context of engineering processes" (ENG0b). Whilst information (and data) literacy appears to be a significant capability in the curriculum, the engineers interviewed discussed it less frequently. This could be because it is developed appropriately during university and thereby more taken-for-granted in professional life.

5.1.4.2.3 Media literacy

Engineers constantly work with 2D/3D images, animations and simulations when problem-solving or collaborating, which is probably why visual literacy is not explicitly articulated. In engineering, media literacy (the ability to work with and critique content in different media) overlaps with collaboration and problem-solving.

5.1.4.3 Digital problem-solving

Digital capabilities in problem-solving and creative production are explicitly or implicitly highlighted in numerous areas of competence, e.g. in the "ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques" (ENG0b) referring to 2D/3D-modelling software specific to engineering.

Engineers use a wide range of subject-specific software depending on their sub-disciplinary specialisms. As a structural engineer, ENG5emp-George uses REVIT (a BIM-software) and AutoCAD, while as an infrastructure engineering consultant ENG6emp-Paul uses WaterCAD, StormCAD, Hevacomp (for simuation and energy analysis) and BIM 5D (for modelling). Engineers also use product lifecycle management tools, e.g. SiemensNX and TeamsCenter (ENG8emp-Jack and ENG7emp-Craig) which have information about the components across the manufacturing, design, and supply-chain processes so that team members can build assemblies by reusing others' components. Paul uses QlikView, a plain-language tool that can interrogate the data reservoir and populate proprietary platforms so that SAP or other systems can interoperate with their 3D-models. Simulation, stress modelling and testing, e.g. finite elements analysis, are also key areas of engineering.

These findings lead to three observations. First, the co-existence of analysis/simulation and modelling in one digital artefact has transformed and blurred the boundaries of the skillset needed for engineers and technicians. Second, engineering practice is more than simply applying existing software: engineering itself is the source of producing new technologies through the ability to "use imagination, creativity and innovation to provide products and services which maintain and enhance the quality of the environment and community" (ENG0c). Such new innovations include 3D-printing and virtual- and augmented-reality applications in biomedical engineering. Third, the use of digital problem-solving and communication/communication tools appears to be influenced by sub-disciplinary practices and company size/type. The former cannot be underestimated as it also affects how engineers collaborate effectively with each other.

5.1.4.4 Digital communication/collaboration

In professional frameworks' competency statements, the digital aspects of communication/collaboration are not explicitly articulated, e.g. whether to include the ability to "communicate their work to technical and non-technical audiences" (ENG0b), or "agree objectives and work plans with teams and individuals" (ENG0c)..

5.1.4.4.1 Communication of content

Practising engineers have not added presentation tools beyond MS Office, including MS PowerPoint, although they highlighted that they are free to use other software.

5.1.4.4.2 Communication between teams and sites

Engineers consider various factors when choosing the most appropriate method of communication between teams and customers (face-to-face, telephone or digital). These include the size and location of the given company and its sites, the perceived formality of the conversation, client and team preferences, and intercultural norms. ENG8emp-Jack, for instance, uses telephone calls for quick, informal two-way discussions with his colleagues at another site. His second, more formal, choice is email, leaving a conversation trail while being effective and quick in reaching a wide audience when problems arise. Email generally seems to be a common mode of engineers' communication. For complex problems, Jack uses video-conferencing with screen-sharing.

Institutional culture is another factor in choosing communicative tools. Paul's team uses Appear.in for pre-planned video-conversations, as it is a web-based application that does not need proprietary software and is relatively safe to use in a context where project security is a primary concern. At Adam's military organisation, where he works as a civil engineer, third-party tools are not officially allowed. WhatsApp seems to be the only 'tolerated' tool, because of its end-to-end encryption, which Adam uses to keep in touch with a team of foremen under his leadership.

5.1.4.4.3 Asynchronous/synchronous collaboration

Engineers are engaged in synchronous and asynchronous collaboration involving artefacts and designs. For synchronous collaboration, ENG5emp-George expresses a clear preference for face-to-face collaboration: "if they're here, you'd get them, sit next to them and go through it" (ENG8emp-Jack). Jack perceives in-person conversations as necessary, because although digital artefacts and models encapsulate all design aspects, some tacit engineering knowledge will remain invisible to others (Polanyi, 1958). This is what George calls the 'myth' of 24/7 global engineering projects. It would be too risky for an engineer at-a-distance to progress a design without discussing it with the originator. However, speaking in person is not always possible, so engineers do rely on digital discussions of their artefacts. For such synchronous collaborations, Skype, Lync and other virtual conferencing platforms are used. ENG5emp-George uses See-and-Share, a remote image-sharing software enabling engineers to scribble over their designs and physically change their model using mouse movements as they discuss it over distances.

When asynchronously picking up someone else's components or providing feedback on the designs of others, engineers might:

- scribble over designs and return them by email (ENG5emp-George);
- use an existing component from a database or repository (ENG8emp-Jack);
- use an institutional file-sharing application (e.g. SharePoint) or shared drives (ENG5emp-George, ENG8emp-Jack), OneNote or OneDrive (ENG9emp-Adam);
- share servers where each job is in a folder with subfolders with differentiated access rights for clients and engineers (ENG5emp-George).

Digital participation seems to overlap with learning/development in terms of how engineers can benefit from communities of practice via networked learning (Wenger, Trayner, & de Laat, 2011), which I discuss in the next sub-section.

5.1.4.5 Digital learning/development

A few engineers cited attending courses or using their organisation's VLE in relation to their learning. The professional frameworks only implicitly involve digital aspects in terms of outcomes such as the ability to "plan self-learning and improve performance" (ENG0b). However, at least a couple of outcomes do refer to extending one's digital capabilities explicitly, such as "identify constraints and exploit opportunities for the development and transfer of technology within own chosen field" (ENG0c).

The engineers interviewed mentioned little about participating, facilitating and building digital networks, despite the fact that they are likely to draw on a number of employees, contractors, external professional contacts from past/present projects and other online communities in order to access, interpret and create new disciplinary knowledge (similar to Sally, a design engineer, as discussed in Littlejohn et al., 2012). Engineers' networks are likely to be multi- and inter-disciplinary to support their innovation (McNair et al., 2015) and challenge their "intellectual and ethical blindspots" (Calhoun, 2006, p.33).

5.1.4.6 Digital identity/wellbeing

The professional frameworks mainly focus on the areas of "professional and ethical conduct" (ENG0b, or "comply[ing] with the rules of professional initiative in and commitment to the affairs of your institution" (ENG0c). Although the frameworks do not explicitly mention digital platforms, these could be interpreted as covering one's online presence. Most practising engineers' approach to social media seems to be cautious and critical. LinkedIn is seen as the only professionally acceptable platform:

“if you said you want to meet on Facebook, a senior strategist will probably say no, and might just change their mind about you and no longer take you seriously as they did before” (ENG6emp-Paul). Young engineers seem more relaxed about using social media professionally, blurring the personal/professional boundaries. However, this may become problematic as they progress up the career ladder.

5.1.4.7 Overview of gaps

Engineers identified some curricular gaps, with the obvious constraint that their experience could be limited to their own educational experiences. I list these briefly (all from ENG8emp-Jack):

- **Failure mode effect analysis** – a structured way of analysing a design or a process such that engineers can determine what must fail for it not to work, “What if I left an O ring out, what if I left a bolt out, what would the affect be on the product?”
- More detailed **data gathering and presentation software** (which seems to confirm academics’ perceptions):

  > Most [students] know what Excel is, but they don’t really know how to do anything apart from put numbers into it and add them up. I’ve got a task at the moment that’s outputting 100,000 data points. That’s completely useless unless you know how to present it or how to pull information out of it.

- **Coding** using industry tools e.g. Minitab, “the other thing that doesn’t always get covered is some aspect of coding …even if you’re a mechanical designer, you’re going to need to understand how that’s going to work”.
- **Process control plans**:

  > …which are where you lay down, exactly step-by-step, …time and motion studies, where you look at exactly how long it’s going to take for you to move your arm from here to here and will you bang your head whilst you’re doing it.

5.1.5 Summary: engineering

Engineering students' digital capability development seems to be largely led by curriculum design. This is especially true in digital problem-solving and collaboration/communication, with a particular emphasis on exposing students to sophisticated, industry-standard software intended to design and solve engineering problems. Students are also well provided for in the area of information literacy, which recalls Beetham et al. (2009).

The findings demonstrate an overlap between communication and media literacy, as well as problem-solving. This is partly due to the multimodal nature of engineers' work with 2D/3D visual artefacts and simulations. This overlap poses the question to what extent the media literacy articulated in the DigiCap-Framework is the same as or different in engineering, where visual literacy seems to be so essential to engineering problem-solving. Perhaps, in addition to multimodal problem-solving, media literacy could involve the communication of engineering solutions and designs to different audiences, e.g. lay audiences, similar to the poster/wiki task in ENGm1.

Students taking part in Formula One teams seem to excel in media literacy, social media use and creative production of multimedia artefacts; they produce glossy brochures and websites. These are co-curricular activities particular to automotive engineering, which raises the question as to how the curriculum could include more of these opportunities to benefit all students in different sub-disciplines.

Although professionalism and ethical behaviour is one of the key competencies in HE engineering education and professional practice, digital identity management is not referred to explicitly in professional frameworks and learning outcomes, which suggests this as an area for consideration both for curricula and professional frameworks.

One of this study's research questions relates to the identification of capabilities which may not be articulated or planned for students, but which do emerge. Due to limited student data, my findings are tentative. However, apart from the potential gaps identified in sub-section 5.1.4.7, students do seem to be developing digital capabilities required of engineers. This could be explained by effective curriculum design, i.e. the strong vertical linkages between different levels of learning outcomes (subject/programme/module).

Students also develop more than discreet software skills, echoing Gilster's (1997) notion of digital literacy of "mastering ideas, not keystrokes" (p.15), in line with Nussbaum's (2011) idea of capabilities. A key aspect of engineers' digital capabilities appears to concern the link between preparing students for lifelong learning, self-efficacy, and confidence in using new technologies for disciplinary problem-solving, which also promotes their professional success (Becker et al., 2017).

5.2 Case 2: Management

I present management, the second case, in the same way as that for engineering.

5.2.1 Modules

Tables present each module's details, followed by a description of assessment tasks. At UniA, outcomes also include skills-mapping in accordance with their management graduate attributes. UniB has explicitly mapped digital/information literacy in each programme's outcomes.

5.2.1.1 Module 1: E-business models and strategies

MANm1 is a third-year module on e-business part-led by MAN1-Sam at UniA.

Module title	**E-business models and strategies**
Programme	BA Business Management
PBSR	Students may apply for some CIMA (Chartered Institute of Management Accountants) examination exemptions.
Year	3
Credit	15
Length	1 semester
Aims	To provide an introduction to the appraisal and formulation of e-business strategy and contemporary e-business models.
Learning outcomes and *skills (italics)*	• MAN1b-LO1 to understand the basics of business strategy • MAN1b-LO2 to understand the capabilities and therefore business capabilities and business strategies enabled by the Internet • MAN1b-LO3 to be able to analyse, understand and constructively criticise an existing e-business strategy

Module title	**E-business models and strategies**
	• MAN1b-LO4 to be able to formulate an e-business strategy to help in addressing the strengths, weaknesses, opportunities and threats faced by a business • MAN1b-LO5 to have well-founded views on the future development of e-business models • *MAN1b-SK1 problem-solving skills* • *MAN1b-SK2 commercial awareness* • *MAN1b-SK3 teamwork* • *MAN1b-SK4 organisational skills* • *MAN1b-SK5 communication skills* • *MAN1b-SK6 lifelong learning skills*
Assessment tasks/methods (ATs)	• AT1: Assignment 1 (50%): 2500 words • AT2: Assignment 2 (50%): 2500 words
TLAs	• Lectures*12. • Seminars*6.

Table 5.7 Unit of analysis 1: MANm1

In MANm1 students explore how digital technologies and developments have impacted on businesses and organisations. These include changes to business models, such as *intermediation* (insurance or holiday brokering sites which have stepped in to mediate between consumers and businesses) and *disintermediation* (e.g. Airbnb or Uber in which intermediaries have been cut out of the business chain). Students explore the unpredictability of such changes in order to prepare for dealing with their effects.

Students work in groups, but the assignments are individual. In AT1 students develop a ‘direct-to-consumer’ e-business strategy for a real client, Company P, potentially bypassing their main distribution channels. The strategy is written for a mixed technical and business audience comprising: 1) an analysis of academic literature to identify possible solutions; 2) an analysis of case studies on accessing consumers through e-business; and 3) details of the business plan for the solution. In AT2, students provide a critical comparison of the e-business strategies of two companies operating in the same industry (e.g., banks, supermarkets, smartphones).

5.2.1.2 Module 2: Risk management

MANm2 is a masters-level risk management module led by Rob at UniA.

Module title	**Risk Management**
Programme	MSc Programme and Project Management
PBSR	e.g. Association to Advance Collegiate Schools of Business (AACSB)
Year	Masters
Credit	15
Length	1 semester
Aims	To enable students to understand and apply appropriate techniques to plan, monitor and assess risk in projects. The module emphasises the requirements of risk management and planning as it relates to effective monitoring and control of projects.
Learning outcomes (*skills in italics*)	• MAN2b-LO1 Identify, assess and manage project risks • MAN2b-LO2 Develop an appropriate Work Breakdown Structure from established project requirements • MAN2b-LO3 Plan and evaluate capital and revenue expenditure as well as monitor and control the project budget • MAN2b-LO4 Develop the risk management plan • MAN2b-LO5 Analyse and refine project time and cost estimates to define project baseline, schedule and budget • MAN2b-LO6 Understand the importance of controlling project risk and implement project control systems to manage risk • MAN2b-LO7 Establish an effective communication system, which allows for improvements to communicate risk methods as the project progresses • MAN2b-LO8 Implement an effective risk control process, operating at appropriate, strategic points during the life of the project

Module title	**Risk Management**
	• MAN2b-LO9 Develop a documented, comprehensive project risk plan (including the controls and plans for communications, risk management, change control and risk modelling) • MAN2b-LO10 Develop evaluation strategies for project risk success • *MAN2b-SK1 Adaptability* • *MAN2b-SK2 Problem-solving skills* • *MAN2b-SK3 Numeracy* • *MAN2b-SK4 Commercial awareness* • *MAN2b-SK5 Teamwork* • *MAN2b-SK6 Organisational skills* • *MAN2b-SK7 Communication skills* • *MAN2b-SK8 IT skills* • *MAN2b-SK9 International awareness* • *MAN2b-SK10 Lifelong learning skills* • *MAN2b-SK11 Ethical awareness* • *MAN2b-SK12 Leadership*
Assessment	• AT1: coursework (20%) – 2000 words • AT2: coursework (20%) – 2000 words • AT3: written examination (60%)
TLAs	• Lectures*20; • Tutorials*12; • Computer laboratories*4.

Table 5.8 Unit of analysis 2: MANm2

The module introduces masters-level students to the concept of uncertainty and risk – an area they will encounter in any industry – and techniques to manage it. Students analyse a scenario of a failed real-world project based in building a hotel in the Bahamas, just before the 2008 economic crash. Students apply their critical thinking to the identification of different risk types (human, technological, political, etc.) and calculate their probability in a spreadsheet based on a quantitative risk-model prepared by MAN2-Rob.

The two coursework assessment tasks are: 1) completing an online simulation game (AT1) and; 2) writing an accompanying report on how they perform in the game

(AT2). Students have to tackle a simulated scenario, arranging a relief effort for a hurricane-hit village working with the village chief and other stakeholders. The simulation game is an individual task and students have to deliver a project within a finite budget and time period. The purpose of the simulation scenario is to help students apply risk theories as well as their model construction which they have been learning and practising. AT3 is an examination problem-solving question related to risk management. The module develops twelve subject-specific and generic skills (see Table 5.2).

5.2.1.3 Module 3: Marketing research

MANm3 is a first-year market research module led by MAN3-Laura at UniB.

Module title	**Marketing research**
Programme	BA Business & Marketing Management
PBSR	Institute of Direct Marketing (IDM), Certificate in Direct and Interactive Marketing
Year	1
Credit	15
Length	1 semester
Aims	This module explores the process of marketing research and its role in the achievement of organisational objectives. Students are introduced to the academic concepts underlying marketing research and develop practical research skills.
Learning outcomes (*mapped to digital/information literacy development)	• MAN3b-LO1 Contribute to the short- and long-term strategic competitive capabilities of organisations operating in diverse domestic, international and global markets by using marketing research to develop an understanding of the marketing environment • MAN3b-LO2* Select and critically apply appropriate research methods and tools of qualitative and quantitative data analysis, to a range of marketing problems and scenarios in diverse contexts across the globe

Module title	**Marketing research**
	• MAN3b-LO3* Express ideas and opinions, with confidence and clarity, to a variety of audiences for a variety of purposes • MAN3b-LO4 Work productively as part of a team • MAN3b-LO5* Develop skills in the appropriate use of IT tools and digital media for the purposes of information gathering, collation and analysis • MAN3b-LO6* Adopt IT tools and digital media as appropriate to aid the effective communication and presentation of ideas • MAN3b-LO7 Recognise the importance and influence of professional values, incorporating approaches to corporate citizenship. These values should pay due respect to legal, professional and ethical codes of practice, and with due regard for the well-being of society
Assessment	• AT1 - Individual report (80%) – 2,500 words • AT2 - Group presentation to client (20%)
TLAs	• Lectures*12 – core theoretical concepts • Seminars*12 – applying theoretical concepts through client project

Table 5.9 Unit of analysis 3: MANm3

In MANm3 students carry out market research for a real client, HealthyJuiceCompany (pseudonym), that wants to expand to the student market. After receiving the client brief, students work in groups and are supported through the marketing research process. Students investigate the market environment of HealthyJuiceCompany and explore UK student consumption patterns. They then establish a primary research proposal, which further explores potential opportunities for the company within the student market. Students develop their research design and data collection instruments via seminar guidance and formative feedback, carry out the research and analyse the results. Each student produces an individual research report (AT1), which provides the theoretical underpinning for the practical project. The other assessment task (AT2) is a group presentation to the client.

5.2.1.4 Module 4: Corporate communications

MANm4 is a third-year module on corporate communications led by MAN5-Patrick with MAN4-Lesley at UniA.

Module title	**Corporate communications**
Programme	BA Marketing
PBSR	AACSB (The Association to Advance Collegiate Schools of Business)
Year	3
Credit	15
Length	1 semester
Aims	The aims of the module are to: • increase awareness of the importance of language and communication in the business and management contexts; • develop an understanding of internal communication and external communication systems; • explore the importance of integrated communications; • broaden the understanding of communications within the theory of stakeholder management; • apply core communication, marketing and sociolinguistic theory to the business environment.
Learning outcomes (*skills in italics*)	• MAN4b-LO1 understand the function of corporate communications • MAN4b-LO2 demonstrate an appreciation of the key issues and problems associated with corporate communications • MAN4b-LO3 apply core communication, marketing and sociolinguistic theory to the business environment • MAN4b-LO4 explore methods of evaluating corporate communications • MAN4b-LO5 demonstrate an ability to analyse critically and to undertake independent research

Module title	**Corporate communications**
	• MAN4b-LO6 to be able to write concise reports and opinions • MAN4b-LO7 demonstrate an ability to discuss and present work orally and to communicate ideas effectively • MAN4b-LO8 demonstrate an ability to work as part of a team • MAN4b-LO9 demonstrate an ability to reflect on the learning experience and personal development • *MAN4b-SK1 Oral communication* • *MAN4b-SK2 Written communication* • *MAN4b-SK3 Teamwork* • *MAN4b-SK4 Lifelong learning* • *MAN4b-SK5 Numeracy* • *MAN4b-SK6 IT literacy* • *MAN4b-SK7 Commercial awareness* • *MAN4b-SK8 International awareness* • *MAN4b-SK9 Ability to work under pressure* • *MAN4b-SK10 Ethical awareness* • *MAN4b-SK11 Positive attitude*
Assessment	• AT1: group presentation (30%) • AT2: written report (60%) • AT3: self-reflection on personal development (10%)
TLAs	• Lectures*24 • Seminars and workshops*5 • VLE discussion questions

Table 5.10 Unit of analysis 4: MANm4

In MANm4, students develop an understanding of internal and external communication systems. The module uses case studies and scenario-based exercises to help students develop their critical analysis skills with videos, online activities, and a study-skills session on writing reports, as well as giving presentations and working as part of a team. Discussion questions might be posted on the VLE relating to current affairs and issues arising.

In the group presentation (AT1), students evaluate the communications of a public-sector or non-profit-making organisation and deliver their findings and critical analysis. The presentation covers a brief introduction to the organisation, a description and evaluation of the effectiveness of their internal/external communication systems, applying communication theory to the organisation in addition to recommendations and/or a communications plan. For the individual report (AT2), students execute the same task for a for-profit organisation. In the final assessment task (AT3), students reflect on their personal development via the range of graduate attributes specified at UniA's management school which they have developed over their programme and via co-/extra-curricular activities.

5.2.2 Curriculum

Having described the units of analysis, I now present how the six digital capability elements are planned into management curricula based on documentary analysis and interviews with academics.

5.2.2.1 ICT proficiency

ICT proficiency for students seems to involve basic ICT skills, such as using MS Office packages, e.g. "be able to write concise reports and opinions" (MAN4b-6). At UniA's Management School, 'IT awareness' is mapped as a graduate attribute (e.g. MAN4a-SK13). Some academics have recommended that students use third-party tools, e.g. LucidChart, to create diagrams (MAN2-Rob) or Slack for project management (MAN1-Sam).

5.2.2.2 Data, information and media literacy

5.2.2.2.1 Data literacy

Data literacy involves collecting and critically analysing data for the purpose of problem-solving and interpretation and communication. Whether it is analysing either market research data, organisational communication budgets or calculating risk probability, students need to draw on qualitative and quantitative data methods. This is articulated explicitly in the module and programme outcomes, e.g. "students will be able to understand how to communicate knowledge of Business Management concepts and techniques using a variety of quantitative and qualitative methods" (MAN1a-6) while associated graduate attributes include "numeracy" (e.g. MAN4a-SK14).

Most data that management students will come across are likely to be in digital form, handled in spreadsheets or other formats. Using different technologies for manipulating and representing data can be useful. For instance, online simulation games can help students put management theory into practice or, as shown in MANm2, schema building in MS Excel can be a powerful tool to help students apply theory and critical thinking to given problems.

One characteristic in management appears to be the overlap between data and information. As evidenced from the above programme outcome detailed in MANm1, qualitative and quantitative methods involve numeric and textual forms, where text can be both data and information.

5.2.2.2.2 Information literacy

Information literacy in management, which overlaps with data literacy, involves the resourceful collection of primary or secondary data from a wide range of sources (academic, case-based or online). Information literate students "demonstrate an ability to analyse critically and to undertake independent research" (MAN4b-LO5). This includes the critical analysis and interpretation of such communication for the purpose of communicating decision-making or engagement to relevant stakeholders. The curricular examples involve modules across all years, confirming the conclusion that digital scholarship should continue throughout university study (Beetham, McGill, & Littlejohn, 2009), thereby challenging and exposing students to ideas and sources beyond Google and Wikipedia (Brabazon, 2013). UniB's programme defines information literacy as "the ability to search for, retrieve and store information online, to evaluate online/digital information, and to cite such information correctly using the Harvard reference system" (MAN3a).

A number of the disciplinary learning outcomes that involve information literacy may, however, not always articulate the latter in an explicit fashion. For instance, demonstrating "an appreciation of the key issues and problems associated with corporate communications" (MAN4b-2) could not happen without information literacy. At the same time, information literacy features in a number of graduate attributes of UniA's management school's "self-guided research", critical "analytical skills", "commercial awareness" and "international awareness" (e.g. MAN4a). Similarly, it is also stipulated in the professional AACSB framework referenced in MANm4 (goal1) that there is a need to "develop an understanding of theory and practice in core business and management areas".

5.2.2.2.3 Media literacy

Learning outcomes such as "adopt IT tools and digital media as appropriate to aid the effective communication and presentation of ideas" (MAN3a-16) demonstrate that media literacy in management overlaps with digital communication/collaboration and information/data literacy insofar as this element refers to students' ability to communicate content effectively verbally or in writing (MAN4a-SK11/MAN4a-SK12). Academics highlight that management students need to balance when *to* and *not to* use digital resources in communicating with stakeholders, such as articulated in the stated need to "demonstrate an ability to discuss and present work orally and to communicate ideas effectively" (MAN4b-7). Critical use of media is essential in this discipline.

On the one hand, it appears that students' experiences of working with digital media, i.e. beyond spreadsheet manipulation, refers to either creating presentations or word-processed documents with diagrams. Thus, production of multimedia seems somewhat restricted, whereas media literacy and creative production in the DigiCap-Framework extends to producing audio, video, graphics and other formats (JISC, 2017d). This chimes with the Horizon study, which found that 63.4% of students have minimal or no training in multimedia production of content (Becker et al., 2017). On the other hand, the critical evaluation aspect of media literacy seems to be well covered in disciplinary tasks.

5.2.2.3 Digital problem-solving

Whether students are given a real-life challenge to find out about a particular market and make recommendations to clients or if they invent solutions for a particular organisation, problem-solving in management is more than likely to involve working with data and information in digital form. This is expressed, for instance, in the programme outcome: "use IT tools and digital media effectively, efficiently and flexibly for the purposes of information gathering, collation and analysis, with appropriate adaptation for the nature of the problem-solving task under consideration" (MAN3a-15).

Typically, students need to: locate information using marketing and other business databases; analyse and interpret data by using their critical capabilities; apply the relevant management theories; and communicate their findings to either their peers or the client. Students also need to be able to "evaluate the efficacy of different problem-solving techniques in a Business Management context" (MAN1a-7), enhance their reflective thinking (MAN4a-SK19) as demonstrated in the assessment criteria of “excellent selection and critical application of research methods and analytical tools; decisions well justified” (MAN3b-LO2). In conclusion, in management, problem-solving is equivalent to data/information literacy, hence digital scholarship activities are very characteristic of management curricula, similar to other disciplines (Becker et al., 2017). I discuss this disciplinary process as a signature digital capability in sub-section 6.1.2.2.3 in more detail.

5.2.2.4 Digital communication/collaboration

Digital collaboration/communication refers mainly to content communication and teamwork collaboration. The primary concern of students in choosing communication strategies depends on their appropriateness, such as “express[ing] ideas and opinions, with confidence and clarity, to a variety of audiences for a variety of purposes” (MAN3a-13), which may or may not be digital. I have already discussed the overlap between digital communication of content and media literacy, covering mainly written and verbal communication skills in management curricula (see sub-section 5.1.2.4.1).

In management, collaboration seems to be less prominent than in engineering. Even in group tasks, marks tend to be moderated to reflect individual achievement, although networking and “working productively as part of a team” (MAN3b-LO4) are clearly important aspects of the curriculum. As for collaborative digital tools, academics may recommend institutionally-provided tools, e.g. discussion boards or third-party tools. Most module leaders seem to let students make their own choices, with groups opting for WhatsApp, DropBox, Google Docs, etc.

UniB explicitly articulates digital capabilities relating to communication in MANm3’s programme outcomes:

> Communicating effectively online – Students will learn to use email effectively, for example, for exchanges with staff, external organisations and professional bodies. Students will also have the opportunity to participate in online discussion boards and other online community activities.
>
> Managing group interactions and collaborating digitally – [module] will provide students with an early opportunity to develop digital literacies via collaboration in virtual teams as part of an assessed online collaborative activity. (MAN3a)

5.2.2.5 Digital learning/development

Academics expect students to make use of the VLE's digital learning opportunities, e.g. submitting assignments online, accessing feedback or watching captured lectures. They also expect students to learn new software themselves from YouTube and elsewhere. A key feature in management seems to be the development of subject-specific and generic skills and, to this end, students need to be able to reflect on their own capabilities. Accordingly, students are asked to consider their use of digital tools. UniB has developed a smartphone app, SkillsApp (pseudonym), which guides students to record and reflect on the various skills they have acquired. This articulation supports students' confidence, strengthening the relationship between digital capability, confidence and self-efficacy (Becker et al., 2017). Students can then use these digital records in job applications. Critical reflection appears to emerge in most management programmes whether in relation to disciplinary concepts or skills, including the ability to "critically reflect on the use of management theory to understand management practice" (goal 3, AACSB referenced in MANm4) or "demonstrate a willingness to self-reflect, identifying gaps and weaknesses in [students'] understanding of Business Management issues" (MAN1a-8).

5.2.2.6 Digital identity/wellbeing

Digital identity is covered mainly from an employability angle in the management curriculum. The academics have a range of perceptions as to whether the curriculum is developing or constraining students' capacity to project a positive digital identity. MAN1-Sam advises students on how to portray themselves on social media, while students of MAN4-Lesley and MAN5-Patrick are educated about how companies look at their digital footprint or how they can develop a positive online identity on LinkedIn, which seems to be the most significant professional platform for management students and professionals. In MAN3-Laura's module, students are shown two student profiles to decide who they would employ. MAN2-Rob is aware that the Careers Service covers aspects of digital identity with students but in his view this is not covered in the curriculum. In this case, co- and extra-curricular activities complement curricular opportunities. As for professional bodies, the Chartered Management Institute has published a social media guideline for managers (CMI, 2014).

An issue related to digital identity is the ethical dimension of business and management, which is also a graduate attribute of management students. As MAN4-Lesley observes, modules and topics on business ethics cover case studies that incorporate digital examples of ethical conduct. A digital aspect tends to be implied here, rather than being an explicit learning outcome, e.g. "ensur[ing] individual integrity and professionalism by adhering to legal requirements and ethical standards" (MAN2a-7). In Laura's module, the outcomes also link to – albeit implicitly – the digital wellbeing of society, echoing Nussbaum's (2011) capability approach:

> Recognise the importance and influence of professional values, incorporating approaches to corporate citizenship. These values should pay due respect to legal, professional and ethical codes of practice, and with due regard for the well-being of society. MAN3b-7

In other units of analysis, aspects of digital wellbeing and online safety seem to fall outside the curriculum, although academics are aware of cases, e.g. sexual harassment via social media.

5.2.2.7 Overview

Exploring each capability element through an analysis of assessment tasks and criteria suggests that data and information literacy, which overlaps with digital problem-solving, and digital collaboration/communication (including media literacy, and shortened as coll/comm), appear to be the most significant digital capabilities in management curricula. As before, the darker the cell background, the more prominent the element; text in square brackets signals if the element was not relevant, not discussed, or only implied indirectly (see Table 5.11).

	MANm1: E-business models and strategies	**MANm2: Risk management (masters)**	**MANm3: Market research**	**MANm4: Corporate communications**
1-ICT	AT1/AT2 – written comm for report writing	AT1/AT2 – working with online simulation, report writing	AT1/AT2 – written comm /ICT in report writing & presentation	AT1 - presentation, AT2 - report writing, AT3 - reflective log completion
2a-DL	AT1/AT2 – analysing data of e-business strategies	AT1 - interpreting data in simulation game, AT2- analysing risk for a given project	AT1/AT2 data collection, analysis in marketing research project	AT1/AT2 data collection analysing two organisation's corporate comms
2b-IL	AT1/AT2 – analysing data relating to e-business strategies, info	AT1/2 – collecting information for risk analysis	AT1/AT2 data collection, analysis relating to market research project,	AT1/AT2 data collection to profit/non-profit organisations'

	MANm1: E-business models and strategies	MANm2: Risk management (masters)	MANm3: Market research	MANm4: Corporate communications
	searching in academic & technical literature and critical analysis.		commercial awareness of marketing environment	corporate comms; critical reflection
2c-ML	Using multimedia in written comm	Using media in written comm [& simulation game]	AT1/AT2 report writing, presentation.	AT1/AT2 report writing & presentation.
3-PS	AT1/AT2 – critical analysis of e-business strategies, solutions -also requiring commercial and international awareness	AT1 - simulation game, AT2 - coursework analysing risk for a given project [AT3 - written examination- not digital]	AT1/2 - qual/quant research methods & analysis	Critical reflection for both AT1/AT2
4-CC	[AT1/2 – group work but individual assessment]	[not explicitly, assessment is individual]	AT2 - presentation – engaged teams	AT1 - teamwork for presentation
5-L&D	[Reflection, organisational skills]		Students reflect on their skills using SkillsAPP, including DigiCap elements	Reflective log on graduate skills over 3 years incl DigiCap
6-DI	[not explicitly]	[not explicitly]	related to LO7	[includes learning about online identity]

Table 5.11 Mapping DigiCap-Framework elements in management modules

In many cases it is the assessment criteria (not the learning outcome) that articulate digital capabilities explicitly. For instance, capability in relation to digital problem-solving is stated as students being able to “select and critically apply appropriate research methods and tools of qualitative and quantitative data analysis, to a range of marketing problems and scenarios in diverse contexts across the globe” (MANm3 assessment criterion), similar to ENGm1.

5.2.3 Students

5.2.3.1 ICT proficiency

Management students are influenced by a number of factors when adopting basic IT applications, e.g. work placements, advice from academics, tool availability on their devices and their own study-practices. On the advice of her lecturer – an influential source for students (Beetham, McGill, & Littlejohn, 2009; Jones et al., 2010) – MANstd1-Eleanor started using Slack to keep in touch with him while on placement. Some students use cloud-computing for file management, e.g. DropBox or Google. MANstd-FG1-Lidia, however, distrusts these; she uses a memory stick to store everything. Academics' perception seems to be that students are generally ICT proficient.

5.2.3.2 Data, information and media literacy

5.2.3.2.1 Data literacy

A number of academics perceive students to lack the ability to work using spreadsheets:

> I have fifty years' worth of terrorism data for one of my risk projects. If I say, 'Here you go, run a pivot analysis and I only want all the incidents, cross-tabulated by country that were bombs,' I would still get [students] coming back to ask me 'How do I do that?' MAN2-Rob

Students have a similar view of their own skills: "you get more and more people, especially in our generation who don't know how to use Excel" (MANstd2-Eloise). This gap seems important given the prominence of data literacy as discussed earlier.

5.2.3.2.2 Information literacy

Students perceive that an information sourcing capability is well-provided for "at the beginning of every module, we get a library introduction where the lecturer will go through the best way to source data and information" (MANstd2-Eloise). They also receive support in effective searching strategies, such as using keywords or "filtering out irrelevant information" (MANstd4-Maria), as well as exploiting the range of available business information sources, search engines (e.g. Discover), and databases (Business Source Complete, etc.). As students progress, this range extends to more specialised business databases, such as Mintel and Marketline.

Academics and librarians seem to play a large part in educating students in critically evaluating the trustworthiness of sources. Such subject-specific support is clearly valuable: "If the university hadn't told us 'Oh, go use Mintel', I probably would have just gone on Google" (MANstd-FG1-Lidia). Students seem to become progressively more critical when evaluating sources: "You have to be quite careful if you're just looking on Google, because …everything that you see might not be true or it might not be relevant" (MANstd3-Charlotte).

At the same time, students discern their growing independence: "I'm happy to come here and chat to a librarian if I need any help, but, actually, being in third-year, it just comes with practise; just looking around Discover and finding what is available to you to use" (MANstd2-Eloise). In addition, some students find that in some instances Google Scholar can produce better search results than academic sources. This seems to go beyond Brabazon's (2013) fear of students' uncritical use of Google and Wikipedia, hinting at a higher level of critical capability in the way students can successfully weigh when/how to combine academic databases and Google Scholar to yield better results. In addition, Eleanor also skilfully utilises social media if the information is difficult to locate in the academic and business literature.

5.2.3.2.3 Media literacy

In addition to MS Excel, students' predominant experiences of developing media literacy and content communication in different digital forms appear to be restricted to creating presentations or word-processed documents with diagrams and charts. Students may vary the kind of presentation tools used – e.g. moving between Google Slides and MS PowerPoint – the former being better suited to synchronous collaborative work, especially if recommended by their tutors.

As for sourcing images for their presentations, students appear to limit themselves to using Google or companies' social media pages: "We easily found an article, but I think it's difficult to find a general article with images" (MANstd5-Odi). Video or audio recordings have rarely been mentioned in assessment tasks: "A lot of business management is essay writing and that's all just going to be done on Word" (MANstd2-Eloise). This might suggest that students' media literacy could be extended to incorporate working with a wider range of media such as graphics, audio and video, as confirmed by MANstd-FG1-Reem who would like training in image-editing tools.

5.2.3.3 Digital problem-solving

As discussed in sub-section 5.2.2.3, digital problem-solving in management encompasses data, information and media literacy together with content communication, so it is not discussed separately. Students' problem-solving skills equate with the way they tackle the challenge of sourcing requisite, reliable information. In addition, students often recount the challenges of finding information, whether this concerns innovative products, new market trends or organisations' internal corporate communication strategies. Taking the example of a first-year marketing assignment (MANstd-FG1), one group had to be inventive about sourcing information since no market research intelligence was available on vegan chocolate at the time.

5.2.3.4 Digital communication/collaboration

Content communication from a student capability perspective was discussed in sub-section 5.2.3.2.3, so this sub-section focuses on how students communicate and collaborate during teamwork.

Students appear to consider speed, visibility, reaction time, platform dependency, and access when it comes to choosing communication tools. Similar to engineering, WhatsApp seems to be management students' go-to tool for organising daily activities, even when team members flat-share: "I feel like it makes people more involved because if there's someone in the group who's slacking off, you can see if they're online" (MANstd-FG1-Lidia).

There is a potential tension here between prescribed/suggested digital tools and the freedom to let students decide which digital platform to use. Although WhatsApp is a default communication tool, MANstd1-Eleanor persuaded her team to use Slack to share resources within their group (recommended by her academic supervisor whilst on placement, as mentioned above), demonstrating academics' positive influence on students' technology adoption practices (Margaryan et al., 2011). In other cases, academics may require students to use a particular tool for a given task. Tay and Allen (2011), however, recommend that lecturers avoid prescribing particular technologies for students to focus on the learning process itself, which would enable students to discover and validate their choices. They also observe, however, that students might use tools with which they are familiar, similar to some risk-averse (Prescott, 2013) engineering students (see sub-section 5.1.3.7).

This tension could surface in a cultural dimension. Asian and Western students use different platforms (Choi & Im, 2012; Li & Chen, 2014). It was discussed above that intercultural groups chose a platform to which all their team had access. There may be occasions when students are unaware of the most appropriate tool for their task and context, or might not act in an inclusive way. This underlines the importance of students being exposed to, or asked to reflect on, technology choices, whether it is from an intercultural (Varga-Atkins, 2015), disciplinary, or any other perspective.

5.2.3.5 Digital learning/development

Reading, annotating and note-taking are management students' core learning tasks, in which they exhibit their most personal preferences. For instance, MANstd1-Eleanor prefers to read articles on paper, whilst others like to annotate PDFs (portable document format) on their laptop (e.g. MANstd5-Odi) for ecological and economic reasons as well as better accessibility and manageability.

Matching academic expectations, students' general approach is to use Google or YouTube to find advice on software functions or when struggling with a topic. MANstd4-Maria mainly uses her smartphone and laptop to organise herself: "The only thing I really write out are my deadlines," while Eloise uses online stickies to help remind herself of module deadlines (Figure 5.1).

Figure 5.1 Online stickies for managing deadlines (MANstd2-Eloise)

MANstd1-Eleanor plans her essays with a mind-mapping tool recommended by her lecturer (Figure 5.2) so that she can quickly re-order sections, insert new references and ideas and link points together.

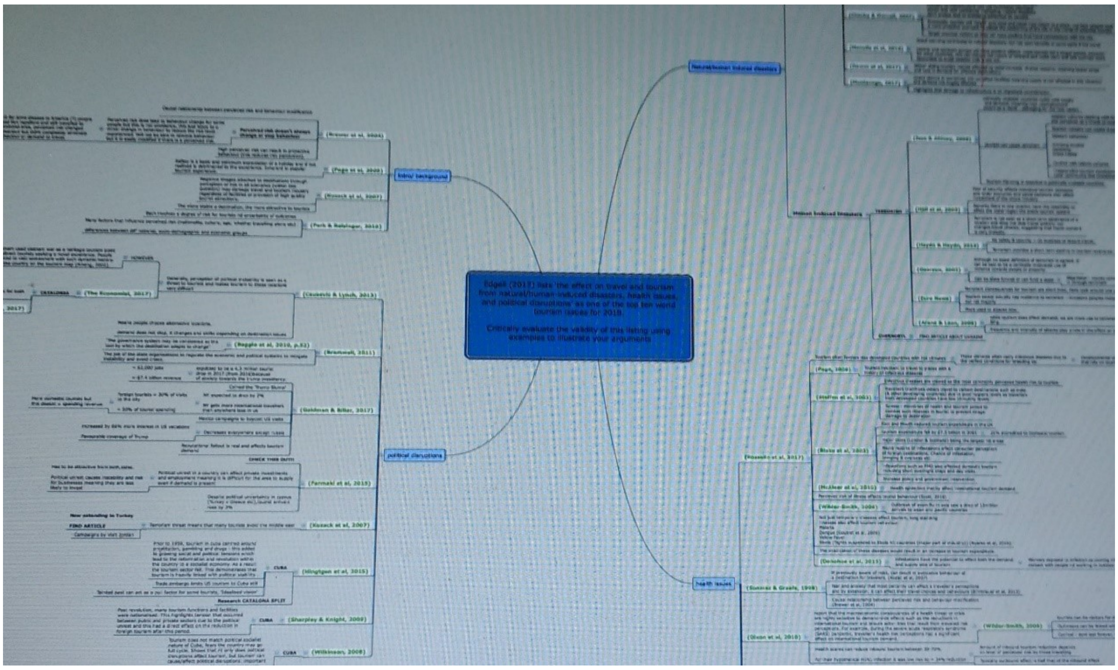

Figure 5.2. Mind-mapping tool used (MANstd1-Eleanor)

Despite these digital practices, Eleanor prefers to compile her references manually as "I think sometimes technology can de-skill you …you're trusting an application to do it for you, and I don't like that" (MANstd1-Eleanor), demonstrating sophisticated and critical technology use.

5.2.3.6 Digital identity/wellbeing

Broadly speaking, management students are present on digital platforms, e.g. Facebook, Instagram and Snapchat, though on the whole, they seem to be cautious social-media users. Some opt for separate professional and personal/private profiles for the "daft stuff they do" (MANstd-FG1-Ben) as they are aware that employers look at their social media profiles, and this is also the case for using private spaces for learning (Beetham, McGill, & Littlejohn, 2009). Some even know of employers who go behind privacy settings, so they are extra careful posting, even in their private profiles.

Students appear to be aware that being able to positively manage their online identity can "make you more employable" (MANstd-FG1-Reem). They view LinkedIn as a professional platform for current awareness and jobs: "I don't expect to see on [LinkedIn] anybody's personal information or what they've been up to on a weekend" (MANstd2-Eloise). One student who has written about her placement experience in a student-led marketing blog which MAN5-Patrick edits, managed to secure a post with an employer as a result of their blog contribution. This suggests that students are aware of how the purposeful use of social media can benefit them in their chosen profession.

5.2.4 Professionals in management

5.2.4.1 ICT proficiency

Managers seem to be using the same IT applications, e.g. MS Office, as those reported by students. MAN6emp-Dermot uses a customer-relationship management system to keep client records. Others use MS Project (Man8emp-Felix), MS Excel and OneNote (MAN11emp-Michael) for project management. Office365 for collaborative working is not yet widespread (MAN9emp-Lucas). HR and helpdesk systems are also used with file/content-management systems. Organisational practices seem to be the main influence in terms of application choice.

5.2.4.2 Data, information and media literacy

Managers work with data and information using the tools cited above, and more complex business analysis tools, such as Power BI, a business intelligence tool in Office365 for creating 4D-style pivot tables and smart analytics (MAN9-Lucas). MAN6-Dermot uses data mining software to identify customer behaviour trends while MAN8-Felix's cutting-edge scientific company generate their own market research data: "If we're looking at a medical product, we will go and talk to the clinicians who are leaders in their field", which is more effective and up-to-date than buying off-the-shelf market intelligence.

Managers report similarly limited media literacy practices as students do, using presentations and basic IT packages to create multimedia content, although even these 'simple' packages can be used in complex ways by embedding visualisations and time-lapse animations (MAN8emp-Felix). Meanwhile, marketing professionals are demonstrating more media literacy capability. MAN7emp-Don, who specialises in business-to-business marketing, is proficient in a range of multimedia packages, including various Adobe packages such as Creative Suite, Photoshop, Premiere Pro and After Effects. This matches a special industry need for high-resolution product images for websites, brochures and other marketing platforms.

5.2.4.3 Digital problem-solving

Findings seem to divide into three themes in relation to managers' digital problem-solving practices. First, the higher they are on the managerial ladder, the less likely they seem to use subject-specific software. Second, the disciplinary background of managers and their company's practices appear to be the two main factors in choosing digital tools. For instance, IT manager MAN6-Dermot uses specialist software-development tools. Originally a biochemist, SME director MAN8-Felix uses bespoke software for chemical modelling and other scientific apparatus and scanning software, while MAN9-Lucas, who nurtures an intra-organisational network of experts, uses Yammer, SharePoint and the corporate intranet. Third, the degree of digitisation changes from company to company. Most of the processes in Dermot's financial firm are handled electronically, while MAN11-Michael's waste management company had only just started digitising its paper records.

5.2.4.4 Digital communication/collaboration

Managers typically mention using email, web-conferencing systems (e.g. Skype, WebEx), or organisational tools (e.g. Lync or Yammer) to connect with clients and colleagues. Project manager MAN11emp-Michael uses telephone, email and, less frequently, video-conferencing. Despite's MAN8emp-Felix's preference for face-to-face communication, video-conferencing is important for daily interactions with biochemists and microbiologists as they need to see what they are talking about.

Employees in larger companies collaborate via institutional tools, e.g. SharePoint and OneDrive (MAN9emp-Lucas, MAN11emp-Michael). In addition, in Lucas's company, communities of practice use corporate intranet pages and knowledge-bases for sharing. Social media has not been mentioned as a source of organisational learning, such as the use of weblogs for internal communications reported by Efimova and Grudin (2008).

MAN10emp-Rebecca, a self-employed co-owner of a marketing company, reports different practices. Much of her initial client communication takes place on social media platforms, mainly via Facebook, but Instagram, Twitter and LinkedIn are also used for self-promotion. Rebecca works from home and makes 5 to 6 Skype calls a day to check in with her business partner: "We just both sit, both work and both [click on] Skype to video conference to each other".

When choosing collaborative tools, managers are influenced by client preferences and technological know-how, company size, software availability (and price), and intercultural considerations. University education, therefore, needs to prepare students so they can respond to and be reflective about their technology choices in these different contexts (Remneland-Wikhamn, 2017).

5.2.4.5 Digital learning/development

With respect to undertaking digital learning opportunities, managers partake in online tutorials and courses run by their organisation. Just as is the case for students, professionals also benefit from learning via online modules and courses (MAN6emp-Dermot; MAN9emp-Lucas). Lucas's company has a VLE with a course catalogue promoting topics for employees across the globe. Another source of professional learning is participation in 'networked learning' (Wenger et al., 2011) in communities of practice (Wenger, 1999), which in large organisations tend to be digitally mediated. In Lucas's company a network of technical experts uses Yammer to "stay in touch and share information".

However, informal learning at the point of need appears to be the trend rather than undertaking formal instruction, which has been made possible by digital tools being more intuitive compared to 10-20 years ago (MAN8emp-Felix). MAN7emp-Don emphasises that training is still needed in relation to complex and specialised software. Self-learning is especially important for MAN10emp-Rebecca to maintain her cutting-edge marketing business. In terms of developing her own digital know-how, Rebecca's general approach is trial and error. Most recently, it took her half a day to learn a new feature of their preferred website-design tool.

5.2.4.6 Digital identity

Managers make careful decisions regarding the digital platforms they use as an individual or a company, which depends on their company type and disciplinary area. IT manager MAN6emp-Dermot emphasises that social media use is inappropriate in his line of work due to client confidentiality. Innovative businesses are also less keen on broadcasting their current projects for fear of competition. Much of Felix's company's innovation projects are confidential; social media is not seen "as a professional medium".

In MAN7emp-Don's case there seems to be a difference between his individual/professional approach to social media and his company's. The latter does not have direct customers, therefore social media is less critical for their clients who are businesses themselves. The company has accounts on LinkedIn and Facebook, with some subdivisions having additional profiles. Subdivisions' platform choice depends on their customer base, e.g. dentistry/healthcare prefers Facebook, whilst others lean toward LinkedIn.

MAN9emp-Lucas's global company uses Yammer for their intra-company communication platform and is present on various platforms, e.g. YouTube, Facebook and Twitter. As a professional, Lucas uses Twitter for current awareness and to promote the company's graduate outreach programmes, with LinkedIn deployed for keeping in touch with former colleagues; he avoids Facebook. In large companies, dedicated social media roles introduce an additional corporate tier.

If online platforms are more ancillary to many managers' work, this is not the case for MAN10emp-Rebecca. Her marketing business could not live without social media which connects her with new clients and helps her nurture existing customer relationships with cake makers and local artists who are small businesses themselves. These social media interactions have mutual benefits for Rebecca and her clients who:

> become massive supporters of our little business. When we launch a new website or we launch a new bit of a brand, they will like things, they will share things for us. We turn our customers into little promoters.

5.2.5 Summary: management

Management students' development of digital capabilities is also largely led by curriculum design. Many of these are related to the subject-specific and graduate-attribute skills articulated at programme- and module-level, although in many cases the digital aspects of these are implied rather than explicit. That said, by the very nature of digital signature pedagogies, many of the information- and data-related processes are digital as this is the medium in which information and data exist. Findings also show that a number of digital capability elements overlap in management practice, e.g. information/data literacy, problem-solving and communication.

Media literacy seems limited to producing and communicating findings, typically charts and diagrams, with limited opportunities for students to produce multimedia outputs. Digital learning/development is another capability area which does not seem to be explicitly articulated in management curricula in programme- or module-level outcomes, but where students can demonstrate quite sophisticated and critical digital scholarship practices, encouraged by their tutors (Margaryan et al., 2011) and supported by librarians. Digital identity and social media use appears to be more emphasised in management, especially in marketing. It is also the case that interviewed managers' digital practices seem to be more influenced by the type of company they work for, more so than their discipline in general.

In terms of gaps in the curriculum, three areas have emerged:

- **Students' MS Excel skills – to teach or not to teach?** (data literacy). A number of academics and students perceive students to be lacking spreadsheet skills despite the fact that most data/information is likely to be handled in this form. The question arises, if MS Excel is vital, whose responsibility is it to educate students? In MAN1-Sam's view, students should self-learn hands-on skills from YouTube videos or extra-curricular provision, as he sees the university "as trying to educate [students] in a wider understanding," in analytical strategies linked to theory, which chimes with Gilster's (1997) notion mentioned earlier. From others' perspectives, students should acquire a strong foundation in their first year which is then nurtured developmentally via assignments. Even others observe that spreadsheet skills are best acquired in a work-based setting dealing with real problems.

- **Beyond Microsoft Office** (media literacy and content communication). Students' experiences of working with digital media appear limited to either creating presentations or word-processed reports and essays with diagrams. Video or audio recordings have rarely been mentioned as assessment tasks. This suggests, in line with the LLiDA study (Beetham, McGill, & Littlejohn, 2009), that media literacy involving multimedia production and communication could be one potential enhancement.

- **Hands-on digital marketing/social media skills** – especially in marketing, students and employers feel that digital marketing, given its prominence, should be introduced earlier in the curriculum, namely in Year 1. Marketing professionals in particular believe that graduates should possess more hands-on skills and experience in content marketing on digital platforms than currently provided.

5.3 Summary of findings

I have explored three perspectives concerning how digital capabilities and practices are conceptualised and experienced in engineering and management curricula. With regards to the DigiCap-Framework, I can conclude that in both cases, certain digital capability elements seem to overlap either fully or partially with others, and also that particular elements seem to be more prominent in engineering or in management. In engineering, digital problem-solving and collaboration/communication, followed by data and information literacy, appear to be the most important capabilities. In management, data and information literacy as well as problem-solving overlap with each other, and, together with digital content communication, form this discipline's characteristic capabilities. I will endeavour to demonstrate in the next chapter that these characteristics of digital capabilities are not accidental but are aligned strongly with the respective discipline's signature pedagogies, confirming that this two-lens conceptual framework has proved relevant.

6 Chapter 6 Discussion

Thus far, I have presented findings from a digital capability perspective. In order to explore the disciplinary characteristics of digital capabilities in HE curricula, I need to return to my conceptual framework and signature pedagogies. A central finding is that the two disciplines' digital capabilities are aligned with their signature pedagogy. To demonstrate how I have arrived at this conclusion, I first summarise engineering and management's signature pedagogies, followed by what I have identified as their signature digital capabilities.

6.1 Signature pedagogies

Academics and employers were asked (Appendix A) to provide a definition of a 'good engineer/manager' in order to gain insight into the "types of teaching that organize the fundamental ways in which future practitioners are educated" (Shulman, 2005b, p. 52) while also characterising a 'digitally capable engineer/manager'.

As discussed in sub-section 4.8.1.2, I wrote poems to capture (Bazeley, 2013) my salient findings with respect to engineering and management's signature pedagogies and their approach to digital capabilities (Figure 6.1 and Figure 6.2). The following sections, referring back to the poems, outline engineering's three levels of signature pedagogies: values and beliefs (implicit), then epistemic characteristics, engineering's disciplinary know-how (deep structure) and module-level teaching approaches and learning activities (surface-level) (see sub-section 3.3.2).

6.1.1 Engineering

We open boxes. Pull things apart.
Bikes, trimmers, spark plugs, cars.
We simulate and model with graphs
Solve problems with applied maths.

We collaborate from day one,
On all things complex and human.
we draw on global resources,
join forces,
Just like in the real world.

Although, CREO, CAD, Rivet are core.
You don't need to be the master-of-all.
After baptism by a 5-day Wildfire,
Fight your way through the digital mire,
Armed only with wit and the need to enquire.
Just like in the real world.

Figure 6.1 Poem: engineering

6.1.1.1 Implicit level: values and beliefs

The engineering poem's first two stanzas (shown left in the following text) (from Figure 6.1) illustrate the values and beliefs underpinning engineering (shown right) below:

'We open boxes. Pull things apart/Bikes, trimmers, spark plugs, cars.'	Opening boxes and taking things apart express engineers' inquisitiveness and "curiosity about the world" (ENG6emp-Paul). ENG7emp-Craig captures the essence of a true engineer: "I really want to make things, I really want to build things, I really want to investigate this world that isn't, that's made by man". This professional drive is expressed by ENG2-Mike who talks about "living and breathing" a project (as opposed to a '9-5 job'), because you (the engineer) are excited about it and want to make it work.
'We simulate and model with graphs/Solve problems with applied maths.'	Engineers are problem solvers who apply the principles of science and mathematics. In ENG6emp-Paul's words, "an engineering project is the ways and means by which some other end is achieved". In problem-solving, modelling and simulation have emerged as a signature engineering trait which I discuss in sub-section 6.2.1.1.
'We collaborate from day one/On all things complex and human.'	Collaborative working is a core part of engineering and engineering education (Kahn et al., 2013), which is also essentially interdisciplinary (McNair et al., 2015). In addition, engineers need to operate within a "matrix of social and environmental responsibility" (Shulman, 2005d, p.11) or as expressed in the subject benchmarks, "engineering drives technological, economic and social progress" (QAA, 2015b, sec. 6) by solving economic, social, health or environmental challenges. These human challenges tend to be open-ended or 'messy' with no definite solutions (ENG6emp-Paul). Project briefs can be as short as "save us some electricity" with students being "given instructions on the engineering tasks that they have to do, but how they do it is not our business" (ENG2-Mike). Building up students' resilience

	in terms of “cop[ing] with the unknown” (ENG3-Gill) is another aspect of their education. This is what Shulman terms ‘pedagogies of uncertainty’ (2005a), i.e. when educators need to prepare students to face open problems.
‘we draw on global resources/join forces’	Solving open-ended problems requires engineers to be creative and collaborate with allied disciplines in an increasingly global, intercultural setting (Walker & McLean, 2015): > We will take the information from [the architect’s] design, build our own analysis model, do the structural analysis, then the mechanical engineers will take the same architectural information, do their own analysis, and electrical engineers will do the same and so on. *ENG5emp-George* Accordingly, at university, “a lot of our assessments and design type of activities are a single output from a team” (ENG1-Thomas). Engineers also need to understand how businesses work so that they are “able to collaborate with them rather than seeing them as a disturbance and a nuisance in their daily lives” (ENG3-Gill), such as with people working in architecture, marketing or sales. At the same time, self-reliance is seen as a fundamental characteristic of a successful engineer (ENG4-Dylan).
‘Just like in the real world.’	‘Real world’ refers to the aforementioned concern with real problems. It also refers to students’ excitement when exposed to industry-wide software which they will use in the workplace for ‘real’.

Engineering is value-driven according to participant accounts. Similarly, in McLean and Walker’s study on ‘public-good’ professionals (2012), engineers convey a sense of confidence in being resilient problem-solvers and agents of change, with integrity, efficiency and honesty (Walker & McLean, 2015) in the spirit of education for sustainable development (Mikateko, 2018).

6.1.1.2 Deep structure: science, mathematics and realisation and CDIO

The most pertinent work on engineering's signature pedagogies is by Lucas and Hanson (2016) who identify six engineering habits of the mind: systems-thinking, adapting, problem-finding, creative problem-solving, visualising, and improving. They posit that the engineering design process and learning from professionals are two specific hallmarks for cultivating engineering habits of the mind.

Engineering is "the application of science to solve a problem" (ENG8emp-Jack), relying on three core knowledge-processes: scientific principles, mathematics, and realisation. "Realisation encapsulates the whole range of creative abilities which distinguish the engineer from the scientist; to conceive, make and actually bring to fruition something which has never existed before" (QAA, 2015b, p.6).

Realisation is what makes engineering distinct from 'pure' sciences, such as mathematics or physics. Engineers are pragmatists. Whereas physicists may be concerned with putting "a hole in something that's at 53.136 degrees", engineers "will do it at 50 degrees and then compensate for it in another way" (ENG8-Jack). Engineers tend to draw on quantitative methodologies using primary/secondary sources, test, experiment, observe, analyse and interpret.

Beyond valuing logical thinking, efficiency and pragmatism, engineers are also driven by human concerns, such as cost-effectiveness (McLean & Walker, 2012), making it much more of an "art"' in which two modes of thinking are balanced: "using creativity to invent new ways of doing things and using logic to make things work" (Lucas & Hanson, 2016, p.7).

CDIO (Conceive-Design-Implement-Operate) is an increasingly pervasive signature pedagogy in engineering education (Kahn et al., 2013), which sets engineering fundamentals in the context of real-world systems and products (Crawley et al., 2014), and which has been adopted at various UK universities (including UniA) in different engineering programmes, including aerospace, applied physics, electrical as well as mechanical engineering.

6.1.1.3 Surface level: strong alignment

The following teaching and learning activities characterise engineering:

- **design and/or team projects** – students design a product or process, solving open-ended challenges, paying attention to economic and social aspects;
- **capstone projects** – usually final-year longer-term, investigative projects, which assess students' demonstration of their acquired knowledge and skills both as a team and individually (Lee & Loton, 2017);
- **project- and problem-based learning** – student-centred learning tasks based around open-ended problems;
- **lectures** – explaining theories and mathematics- and science-based knowledge;
- **3D-modelling, simulations** and **real-life experiments** – laboratory/computer laboratory work for design, modelling and validation;
- **portfolio design** – students gathering a portfolio of evidence of their achievements to present to employers.

Although some of these feature in other disciplines, the combination of long-term, team-based, open-ended projects is a "mode of teaching …that I don't think you see anywhere else in the university" (ENG2-Mike). Dym et al. (2005) identify design thinking and project-based learning as two signature pedagogies in engineering. Another distinct feature is that students are "thrown into teamwork from day 1" (ENG1-Thomas).

To conclude, in engineering the three aspects of signature pedagogies – implicit beliefs and values (such as team work, real-life problem solving), deep structure (approaches to knowledge-processes) and learning and teaching-level activities – show strong alignment. This is also the case in management.

6.1.2 Management

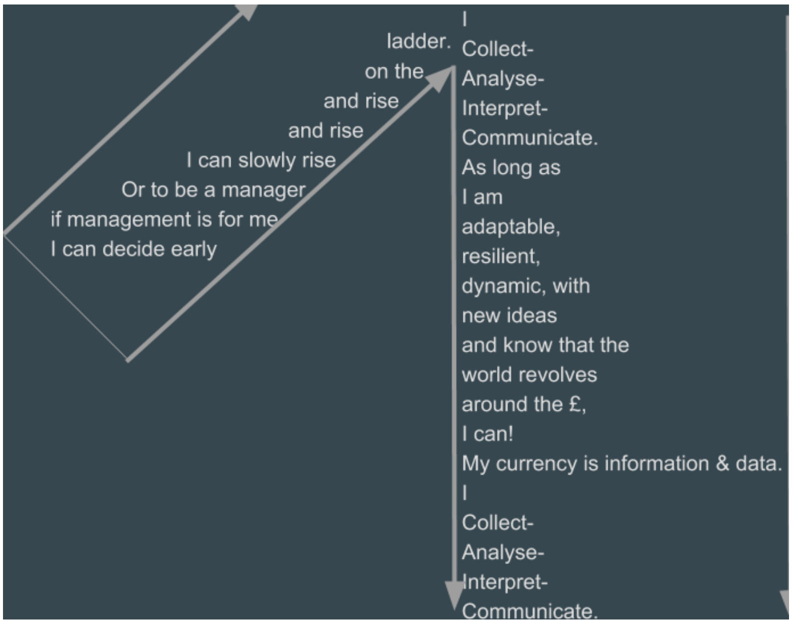

Figure 6.2 Poem: management (left bottom upwards to top and then down)

According to the QAA subject benchmark, the purpose of business and management HE programmes is threefold: 1) an increase in the “understanding of organisations, their management, the economy and the business environment; 2) preparation for and development of a career in business and management; and 3) enhancement of a wide range of skills and attributes which equip graduates to become effective global citizens” (QAA, 2015a, p.6; hereafter MAN0). According to these benchmarks, the pedagogical nature of management programmes, whether “heavily practice-based or more conventionally academic” (MAN0), appears to be dependent on the nature of the awarding HEI.

This study’s participants highlighted two characteristics of management. Firstly, that management is as an umbrella term for very different sub-disciplines. As MAN2-Rob observes, “we’re partly social science, we’re partly mathematics, [and] we’re partly behavioural, it's very hard to basically stand in a room and say ‘this is my pedagogical framework’” (MAN2-Rob). Secondly, managers either arrive from a graduate route, or “come up through the ranks” in their own specialist area (MAN11emp-Michael); none of the six managers interviewed had an undergraduate degree in management (see sub-section 4.7.2).

6.1.2.1 Implicit level: values and beliefs

Lines from the poem illustrate (Figure 6.2) some of the values and beliefs underpinning management as a discipline:

"As long as I am	A salient finding, in contrast with the collaborative nature of engineering, is that management seems more focused on individual achievement, expressed in the graphic poem in which words are aligned to form a number 1 (Figure 6.2). This is evidenced in the "careful consideration …given to the extent of group work in a programme and the attribution of group versus individual marks" (MAN0, section 4.7), although teamwork is in demand by employers. UniA, for instance, uses peer assessment in many tasks, with the option to receive an individual grade. At UniB, group work can count towards a maximum of 20% of a module's mark.
adaptable,	'Good' managers are expected to be adaptable and flexible. Bager-Elsborg (2017) has also found that business as a discipline values change, as it needs to respond to a changing business environment: "a good manager today needs to be able to cope with change, and change quickly …see where the technology is going, where should the business be going" (MAN6emp-Dermot).
resilient,	In addition, 'good' managers need to be resilient if "things going wrong and being able to crack on again" (MAN1-Sam), and not getting "flummoxed [if] no project goes to plan" (MAN9-Lucas). In this regard, MAN3-Laura supports students by "managing their disappointment if they're not getting the grades that they were hoping they would get, and to keep trying and action planning" (MAN3-Laura).
dynamic with new ideas	"The world of business is not for the faint of heart, and for those who want to get to the top of the ladder …intellect is not enough …you also have to stand out from the crowd" (MAN2-Rob). Good management professionals are dynamic with a "hunger" for the "next big idea", says Rob. For MAN10emp-Rebecca, a good marketing professional is

	enthusiastic and constantly open to learning new ideas. This is vital for those working for small entrepreneurial companies: "Everything we do is about embracing change and looking for new ideas" (MAN8emp-Felix).
and know that the world revolves around the £ *['pound'],*	Commercial and strategic awareness is another implicit signature trait of managers. According to MAN2-Rob, 'reading' is what distinguishes a multimillion-dollar entrepreneur who has never set foot in a business school from management graduates. By 'reading', Rob means that "they're strategically and situationally aware of their environment because they think critically about everything around them". This competitive aspect is linked to "understand[ing] that the world revolves around money and budget" (MAN5-Patrick).
I can"	Although management seems more focused on the individual, managers can only succeed through effective social interactions and by being able to communicate their ideas: "How you connect with customers, how you connect with suppliers, how you build partnerships and relationships, it's a heavy part of being in business and being a manager in business" (MAN1-Sam). Most organisations work with international stakeholders, thus professionalism, ethical and intercultural awareness in global and local contexts are important values for management professionals (also highlighted in the QAA benchmark, MAN0).

6.1.2.2 Deep structure: application of theory

In terms of management studies' disciplinary know-how, my findings do reflect the benchmark standards, which posit that management graduates should:

- have a wide knowledge and understanding of the broad range of areas of business and management and the detailed relationships between these and their **application to practice**;
- consistently demonstrate a command of **subject-specific skills** as well as proficiency in **generic skills and attributes**;

- have **a view of business and management** which is influenced by a wide range of learning sources, based on a proactive and **independent** approach to learning;
- be distinguished from the threshold category by their enhanced capacity to develop and **apply their own perspectives** to their studies, to deal with uncertainty and complexity, to explore alternative solutions, to demonstrate **critical** evaluation and to **integrate theory and practice** in a wide range of situations. (MAN0, 5.5)

I discuss these here individually.

6.1.2.2.1 Management theory and application

If engineers apply scientific principles to design and implementation, managers apply business and management theories to practice (MAN0). For instance, in corporate communications, students could be analysing related theoretical components: "Is it the brand? Is it the public relations?", then identify commercial practice that "either supports that theory or [another] theory that allows you to critique that commercial practice" (MAN5-Patrick). One way of supporting students in applying theory is by inviting guest lecturers to talk about their business and real-life case studies (MAN4-Lesley), also highlighted by Bager-Elsborg (2017).

6.1.2.2.2 Subject-specific and generic skills

Management degrees require students to develop relevant subject-specific and generic skills. The former involves people management, problem-solving, critical analysis, research, commercial acumen, innovation, creativity, enterprise, numeracy and networking, while the latter implies collaborative working, cultural awareness, communication skills, conceptual and critical thinking, analysis, synthesis, evaluation, self-management and self-reflection (MAN0). The reason for 'transferable' or 'generic' skills being prominent in management could be explained by the fact that as a discipline it focuses on both the content and process of learning, which involves students appreciating how they learn (Reynolds, 1997). This is also reflected in the graduate attributes of UniA's management school's programmes and modules.

6.1.2.2.3 Collect-Analyse-Interpret-Communicate (CAIC) as signature pedagogy

Management has a number of varied sub-disciplines that belong to the sciences or social sciences (from accounting/finance through to economics and human resources, respectively). Despite this variety, MAN1-Sam identifies the discipline's overarching deep structural process. This process comprises four distinct stages that a good manager will follow: "Collect-Analyse-Interpret-Communicate" (CAIC) which includes "[1] the ability to collect data and get hold it; [2] the ability to analyse it; [3] interpret what comes out of the analysis; and then [4] communicate what they have found to a particular type of audience" (MAN1-Sam). For the remainder of the thesis, I will use Sam's term, CAIC, to describe management's overarching signature pedagogy – akin to CDIO in engineering – while also referring to the following stages:

- **Collect**: collecting evidence, e.g. gathering data/information from databases or the internet, with students conducting their own primary data collection (e.g. interviews, surveys or focus groups) and drawing on/enhancing their self-guided research skills;
- **Analyse:** drawing on their analytical skills and theoretical knowledge, students analyse the quantitative/qualitative data. Numeracy is essential (see MANm1/MANm2): "I'm saying the world revolves around data and numbers, and if you don't build that capability in as a first order, those students are not going to be as market ready as you think they are" (MAN2-Rob), while students also need to be able to analyse "how the market segments for you, …you need to be able to understand how statistics work in a business environment" (MAN1-Sam);
- **Interpret**: after analysis comes the 'so-what?' question, i.e. the narrative that emerges from the data with a particular set of recommendations (MAN1-Sam). Sam exposes management students to a wide range of analytical approaches so that they can make connections and arrive at interpretations;
- **Communicate**: findings need to be communicated to relevant audiences for their decision making, which can mean anything from a presentation to a verbal report or essay. In line with preparing graduates for life beyond academia, students are exposed to authentic scenarios, "so they understand the difference in communicating with a technical audience, a senior manager audience, a customer-based audience" (MAN1-Sam).

Rob concludes that the real skill is creating the story around the data, with the key component being critical thinking. Making sense of data is a human process which requires strong analytical skills; computers cannot replace this.

6.1.2.3 Surface-level: reflecting epistemological variety

The broad range of management-related learning and teaching activities reflects the epistemological variety of its sub-disciplines. That said, teaching/learning activities exhibit vertical alignment to the discipline's implicit values and deep structures.

Management is an applied discipline; it balances theory with application. Accordingly, teaching methods include a mix of lectures (which are ideal for presenting, discussing and debating theories), and other formats, which engage students in applying theory, e.g. tutorials, seminars, practicals, laboratory work or case studies. This mixture also enables the acquisition of **subject-specific and generic skills.** Simulation can be used as one method of practising theories in life-like contexts, e.g. teams participating in game-based decision-making (MANm3). Assessment tasks tend to include examinations, coursework/reports, group work, presentations and learning logs. The involvement of real businesses and problems via live projects and authentic assessments are signature management features, ensuring opportunities for theory application in a business or organisational context.

Academics pay a lot of attention to using current examples to illustrate theories, thereby underlining to students the relevance and importance of **commercial and strategic awareness**. Those working in business need to be aware of what is happening in the world and how it may affect their business. Instilling this aspect in students' thinking manifests itself in lecturers adapting their teaching to the interests of students, making theory and content topical and current through scenarios and cases (Bager-Elsborg, 2017). MAN5-Patrick, for instance, posts links to current news items related to the topic under discussion to encourage students' inquisitiveness.

The use of **CAIC** can be more granular; students could cover its four stages across a whole semester or in one teaching session. Finally, there are other typical teaching methods in business and management, including placements and internships, study trips, business mentoring and business start-ups. Some of these may be co-curricular, such as MAN5-Patrick's project for first-year students who want to gain more marketing experience, based on *The Apprentice* television programme.

6.1.3 Summary

6.1.3.1 Overview

My findings on disciplinary features concur with Trowler's (2014a) revised metaphor of 'tribes and territories'. Trowler suggests that disciplines act more as family resemblances; they show similarity and variability. There is no ever-present essential core at all times, but rather, different aspects come forward at different times. Although engineering is a science-based discipline, it can display characteristics from the arts and social sciences (e.g. creativity and concern for sustainability or the public good (Mikateko, 2018; Walker & McLean, 2015)). Management's sub-disciplines also traverse the entire spectrum from the sciences to social sciences. Nevertheless, it has been possible to outline signature pedagogies in each case.

In engineering these are summarised as (see Figure 6.3):

1. Engineers are collaborative problem-solvers who are resilient, creative, and act with integrity, values which also manifest themselves in the discipline's deep structure;
2. Engineers apply science and mathematics to real-world, open-ended problems in teams, whether economic, social, environmental, or local/global;
3. **CDIO** is one overarching signature pedagogy, a worldwide educational framework that sets engineering fundamentals in the context of real-world systems and products (Crawley et al., 2014).

Management's signature pedagogies are (Figure 6.3):

1. The implicit values and attributes of good managers are adaptability, resilience, dynamism, cultural/commercial awareness and good networking; the focus is on individual achievement;
2. The deep structure of management seems to be a combination of three aspects: developing students' understanding of the link between management theory and application, their commercial and strategic awareness and a mix of subject-specific and generic/transferable skills;
3. Despite the fact that management is an umbrella term for epistemologically distinct sub-disciplines, **CAIC** (Collect-Analyse-Interpret-Communicate) can be seen as its overarching signature pedagogy.

The three levels of each discipline are summarised in Figure 6.3.

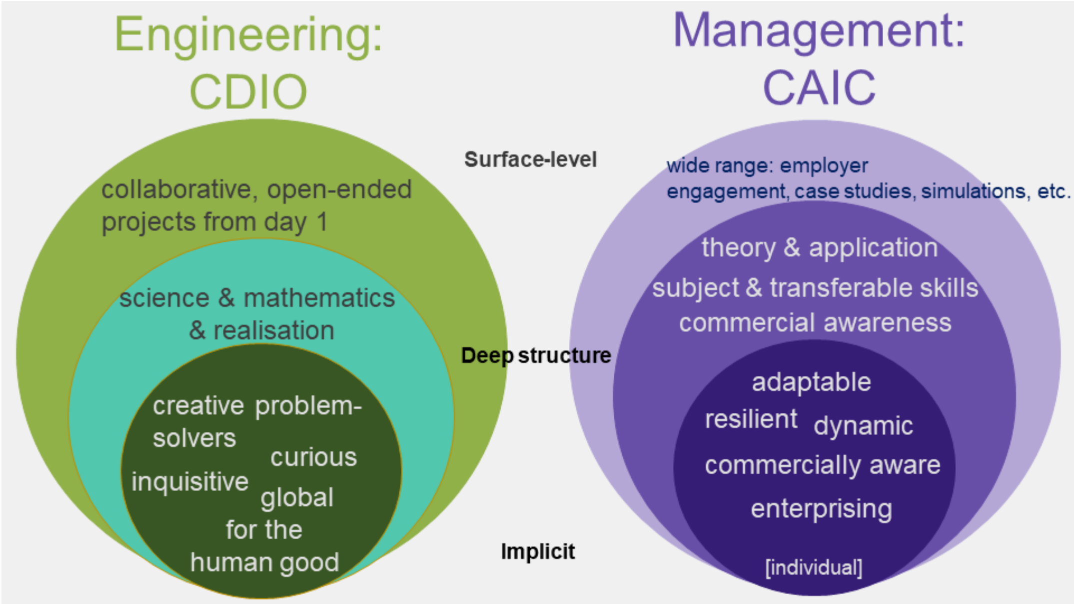

Figure 6.3 Signature pedagogies: engineering and management

6.1.3.2 Similarities

With respect to similarities, both disciplines are concerned with the application of theory (Biglan, 1973) and each have an overarching signature pedagogy. Although CDIO is well-known in engineering education (Crawley et al., 2014), this study suggests CAIC as a signature management pedagogy, which has not previously been highlighted. In both cases, the levels demonstrate strong linkages: implicit beliefs and values are manifest in the discipline's deep structure and surface-level activities (Figure 6.3). There is also vertical alignment between learning outcomes of modules, programmes and subject benchmarks/professional frameworks (Jackson, 2002).

6.1.3.3 Differences

Taking each level in turn, one major difference between engineering and management is the value placed on teamwork. Whilst this is a core value in engineering, management's values, entrepreneurialism, commercial awareness and adaptability appears to foreground individual achievement instead. In curriculum design, this translates into group/collaborative versus individual assessments, respectively. With regards to deep structure, engineers employ scientific and mathematical principles and mainly numeric and visual/3D data, whereas management is concerned with evidence-based decision-making (which may or may not be numerical). Sub-sections 6.1.1.3 and 6.1.2.3 detail the different surface-level learning activities in engineering and management, respectively.

There are three additional differences. First, the professional competency framework of chartered/incorporated engineers has a stronger influence on engineering programmes, and less so in management, unless considering its specific sub-disciplines, e.g. marketing. This finding is tentative due to the limited cross-institutional data available. Second, in management, the profile of the awarding institution – whether research-intensive or teaching-focussed – might have a greater influence on the degree's pedagogical nature (MAN0), whereas HE engineering degrees tend to be more similar due to their potentially stronger professional/regulatory requirements. Third, the career pathways differ. Engineers typically join the profession after completing their tertiary education, whereas managers either arrive from a graduate route or "come up in the ranks" (MAN11emp-Michael). Finally, a somewhat unforeseen but logical finding shows that engineering and management can overlap, insofar as, due to their highly team-based nature, engineers progress quickly to managerial roles.

6.2 Signature digital capabilities

I set out to explore how the six digital capability elements are conceptualised in two applied disciplines. I expected that certain elements might be more prominent than others and in different ways (Beetham, 2017a). But I did not know how – or if – there might be a link between these and the nature of the given disciplines. What I have subsequently found in the eight modules examined is that disciplinary digital practices seem to align with their signature pedagogies.

Engineers are collaborative, problem-solvers drawing on scientific and mathematical knowledge. Accordingly, collaboration/communication, problem-solving and information/data literacy are engineering's most characteristic digital capability elements. In contrast, managers focus on the analysis and interpretation of information/data for communication and decision-making; their work tends to be a more individual endeavour. Consequently, digitally-capable managers' practices feature a combination of information/data literacy, digital problem-solving and communication of content, including media literacy. I have termed these as 'signature digital capabilities', partly to reflect their prominence within the DigiCap-Framework and also to suggest that these digital practices intertwine with their respective discipline's signature pedagogies (see Figure 6.4).

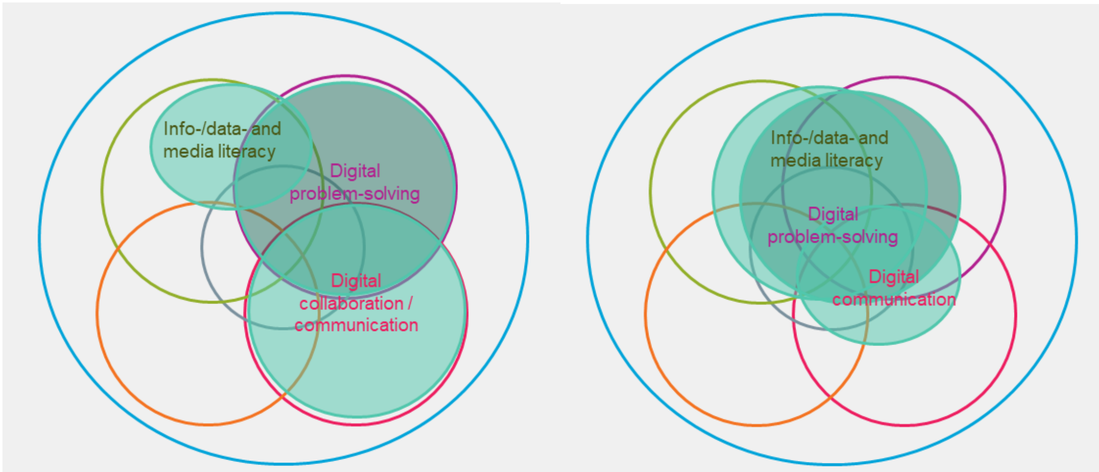

Figure 6.4 Signature digital capabilities: engineering (left) and management (right)

In both cases, observations can be visualised as shown in Figure 6.4, based on the analysis of assessment tasks in Tables Table 5.5 and Table 5.11 alongside the detailed analysis of the six capability elements (e.g. use of similar technologies in the respective elements). These show that: 1) digital capabilities are of different prominence (signalled by 'darker' shading in Figure 6.4); and 2) the elements overlap, confirming that DigiCap-Framework's visualisation as concentric circles is appropriate in this context also, although the degree of overlap is more irregular than suggested by the original representation. I now turn to discussing these signature digital capabilities in engineering.

6.2.1 Engineering

To unpick the ‘signature’ nature of these digital capabilities means returning to Shulman’s concept of signature pedagogies, which are composed of the habitual, pervasive and routine practices of professionals (Shulman, 2005b, 2005c). In each discipline, I have selected three of the most prominent signature digital capabilities, i.e. those given most weight in the explored modules’ assessment criteria, learning outcomes and teaching/learning activities, due to limited space. I discuss these in relation to engineering as: 1) simulation and modelling; 2) open-ended collaborative design projects; and 3) engineers as public-good technology innovators, referring to signature pedagogy’s levels – implicit values, deep and surface – followed by curriculum design considerations.

6.2.1.1 ‘We simulate and model with graphs’

Fifteen years after Shulman coined the term signature pedagogies (2005b), the technological landscape is significantly different, with the widespread use of ‘big data’, mobile technology and social media in every facet of life (Passey et al., 2018). In engineering, evidence of the transformative impact of technologies on disciplinary practices are demonstrated by simulation and modelling having emerged as a signature pedagogy (Warren, 2011), together with a change in capabilities required in the profession. This also confirms Shulman’s (2005b) call for a continuous revisiting of signature pedagogies.

Although ENG7emp-Craig observes that engineering has drawn on computational tools for the last 30 years, other participants emphasised the shift from hand-sketching and physical manufacturing to 3D-CAD modelling, simulation and rapid prototyping as transformational. In the past, engineers built physical prototypes and tested them in laboratories or real conditions, whereas now “we try to make it clear to prospective students that their life is not going to be in a workshop using machinery, it will be a lot of simulations, sitting at computers” (ENG1-Thomas). Virtual epistemic processes have largely replaced the testing of physical prototypes using highly specialised industry-standard simulation software such as CAD and finite-elements analysis tools, applying forces to things to “predict what’s going to happen in the real world when you get components” (ENG8emp-Jack). Whereas drawing and analysis used to be done separately from the model itself, engineers can now receive information in software, e.g. Revit, conduct their analysis, and finally send the results back to Revit, which is also where the 2D/3D-models are produced (ENG5emp-George).

These practices show that using technology is far from instrumental and cannot be separated from engineering know-how. This can be illustrated by referencing the second-year module discussed earlier (ENGm4), which aims to develop students' practical skills and understanding of product visualisation and simulation techniques. Students learn how to model in 3D and use virtual reality, visualisation and simulation tools such as Photoshop, CorelDraw Fluent, Pro/Mechanica, Dyna3D, Cobra, VRML, Moldflow and 3DS Max. At the same time, students also learn about associated scientific principles, materials and operations. As ENG6emp-Paul says, if an engineer can be replaced by a piece of software, then it is not real engineering.

Visualisation and modelling software have become problem-solving instruments *and* epistemological sites for developing scientific understanding. These are inseparable. Virtual modelling skills need to be underpinned by sound engineering knowledge. Epistemologically, the 3D-model becomes the "master-model" (ENG4-Dylan) from which all the analyses derive: "If you looked at the 3D-model of our car, you probably would be quite stunned at the level of detail on it. They have wires, nuts, bolts, everything" (ENG4-Dylan). The virtual model becomes hyper-real.

Digitisation has transformational agency in engineering. As Dylan puts it, "We are no longer restricted by size when we model in the digital space". This signals a mutually dependent connection between epistemic and digital capabilities, which is explicitly articulated in the programme outcome to "recognise and understand the capabilities and limitations of computer-based methods for engineering problem-solving" (ENG4a-2.4). Modelling capability in terms of software skills can impact on students' ability to carry out their design concept or, vice versa, their design concept may be limited by their 3D-modelling skills or software functionality:

> Just like modelling with your hands, if you are good with your hands, then you end up with a fantastic model. *ENG4-Dylan*

As modelling has become everyday practice, it has affected graduates' skill requirements. Previously, engineers sketched for technicians on paper, which were then prototyped/manufactured in a laboratory for testing. Today, because all this takes place virtually, modelling has become part of the graduate skillset: "We are determined to give the students the core skill of being able to model in 3D in a boundary representation modelling" (ENG4-Dylan). Similar debates about the impact of technologies concern the effect of artificial intelligence and automation on employment (Schneider, Bakhsi, & Armstrong, 2017), or the disappearance of mid-skilled in favour of high- and low-skilled jobs (Curwen, 2017).

The picture painted of simulation and modelling so far is of a single engineer in front of the computer. In reality, just like in ENGm2's observed session, it is more likely that a group of students are huddled around a screen discussing and collaborating on the different components of their designs. Modelling comprises the design of multi-components and their assembly is a team effort, as discussed next.

6.2.1.2 Collaborative design projects from day 1

Open-ended collaborative design projects, a central feature in CDIO (see sub-section 6.1.1.2), are engineering's signature pedagogies: "We have to get our students from day 1 to be comfortable working in lots of different levels of other people in a practical way" (ENG1-Thomas). Indeed, many of UniA's modules feature such projects, from designing slot cars to humanitarian drones. Although this approach does not explicitly articulate digital capabilities, an earlier description of the design process in sub-section 5.1.2 has demonstrated how each stage calls on digital capabilities, from researching existing solutions (information literacy), designing, modelling and testing virtual prototypes (digital problem-solving and data literacy), and digital modes of collaborating and communicating with team members, lecturers and people from other professions. Fung (2016) cites similar engineering projects with students designing 'smart' clothing to monitor a marathon runner's wellbeing (p.3), which draws on a number of digital capability elements.

There are a number of signature pedagogy elements to unpick here. 'Open-ended' refers to what Shulman calls 'pedagogies of uncertainty' (Shulman, 2005a), to educate future professionals to be able to act in scenarios where they may not have all information and knowledge available. Relating this to digital capability, they also need to prepare students to be self-reliant and confident in using unfamiliar technologies and able to search for information, other designs and regulations.

'Collaborative' refers to the fact that many of these complex challenges are the result of team effort. Findings (see sub-section 5.1.2.4) have shown the many ways digital collaboration/communication happens in the curriculum and in professional practice. Academics provide institutional technologies for collaboration and sharing (e.g. VLE tools or shared drives and file exchange). However, instead of explicit instruction, staff tend to either model ways of collaborating or offer support to students. Some also let student groups choose collaboration tools according to their preferences. One surprising finding is that, given its prominence, digital collaboration is not explicitly articulated in engineering's professional framework (ENG0c).

6.2.1.3 Engineers as public-good innovators of technology

Another digital signature trait of engineering is its distinct relationship with technology. Whilst the DigiCap-Framework mainly conceives of professionals as ‘consumers’ or ‘producers’ of digital content, to use Warren’s (2011) terms, my findings suggest that engineers are also ‘innovators’ of technology. This characteristic is a signature trait articulated in its professional competency framework:

> A2. Engage in the creative and innovative *development* of engineering *technology* and continuous improvement systems. ENG0c

This feature carries through to programme-level outcomes, such as “understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, application and *development of technology*, etc.)”. This places engineering in a mutual relationship with the field of technology: the outcome of engineering problem-solving can be a digital technology or, vice versa, technologies can support the engineering problem-solving process.

I argue that although to some extent this innovation aspect is referred to in the DigiCap-Framework under the digital problem-solving element – namely, the ability to either “develop new digital tools/processes” or “to code and to design apps/applications, games, virtual environments and interfaces” – to some extent the nature of the framework limits the conceptualisation of engineers as innovators of technology. The University of Bath conducted one of the few disciplinary mapping activities (Anagnostopoulou, 2013) – using DigiCap-Framework’s earlier version – but the resulting statements show engineering students being mainly ‘consumers’ of technology (Warren, 2011), as opposed to ‘producers’ or ‘innovators’.[3]

In addition, I concur with Downey who suggests that portraying engineers as “mathematical problem-solver[s] who provide technical support to those in leadership positions” (2008, p.431) as limiting. What this portrayal misses is an important signature value: engineers’ concerns with solving complex, human problems (see sub-section 6.1.1.1). This signature trait highlights that engineers’ agency goes (and should go) beyond the role of consumers and producers of technology to innovating and creating new technologies and processes for the benefit of humankind (Walker & McLean, 2015). Examples include innovations in

[3] See http://digilitpride.wordpress.com/digital-literacy-statements/ or, for engineering, http://www.bath.ac.uk/lmf/download/55728

health, such as body implants engineered via 3D-printing (ENGemp8-Jack), or as shown by the visit to the Virtual Engineering Centre, an individual child's heart modelled in VR for magnification by the surgeon prior to operation.

6.2.1.4 Curricular considerations

One of the purposes of this thesis was to consider effective curriculum design in order to develop digitally capable engineers and managers. Having outlined the above signature digital capabilities of engineering, I reflect on what considerations have arisen for curriculum design.

As most disciplinary problem-solving practices (simulation/modelling) are digitally mediated, the approach of university educators is to ensure students acquire the principles underpinning the use of subject-specific software, rather than training students in the use of a specific tool. Based on staff, student and professional perspectives, this approach seems to be effective. Findings show that students *are* developing capabilities in digital-problem solving, though one area of weakness seems to be students' data literacy, e.g. their capacity to use spreadsheets or to write programming code.

This study confirms that embedded curricular design via authentic, disciplinary tasks seems valuable for the development of digital capabilities (Littlejohn et al., 2012). Using CDIO as a pedagogical framework ensures that students are exposed to digital tasks and tools as they progress through the stages of conceive-design-implement-operate. Echoing Sharpe (2014), academics seem to agree that students find choosing and using digital tools unproblematic when it comes to team collaboration.

What students need support with is communicating professionally in an industry context. Explicit instruction is not always necessary on using digital communication tools as students can pick up teams' or institutions' professional norms of communication through disciplinary assessment tasks. Communicative practices can also be modelled by academics, confirming the important influence of the institution and lecturers on students' adoption of digital technologies (Beetham, McGill, & Littlejohn, 2009; Jones, 2011). Academics felt that this combined approach, treating collaboration as a core activity from day 1 and supporting students' communication/collaboration digitally via modelling and scaffolding/support, is effective for developing their engineering know-how.

Company and sub-disciplinary differences as factors influencing professional digital practices are worth noting. In relation to engineering curricula, this entails preparing students for these different scenarios to ensure that students gain both confidence in using industry-wide software while also developing their adaptability in case they end up working with unfamiliar software. Rather than teaching students one particular software, it seems that a more effective approach is to immerse them in collaborative tasks and give them the relevant tools with appropriate guidance and modelling to nurture their confidence. This in turn develops students' self-reliance and cultivates their attitude to lifelong learning (Becker et al., 2017**).** Jones and Bloxham (2001) also found that students' confidence increased after engaging in networked learning, despite their previous lack of digital capabilities.

Some tension exists between curricular requirements and students' freedom in choosing technologies for their task. As shown in sub-section 5.1.3.7, risk-averse or pragmatic students (Prescott, 2013) might opt for familiar software, unless a particular software is required for the task. This means that given freedom, they might remain unchallenged in terms of adopting new digital practices, or being required to use a particular software might impede their development of using critical judgement when adopting new technologies.

6.2.2 Management

The three prominent signature digital capabilities in management that are discussed are: 1) digitally-mediated CAIC; 2) using technologies to connect theory to practice, and 3) self-reflexivity and social media in marketing.

6.2.2.1 Digitally-mediated CAIC

Digitally-mediated CAIC (Collect-Analyse-Interpret-Communicate) is management's overarching signature digital capability, where information and data literacy overlap with digital problem-solving and content communication (including media literacy). This is best illustrated by a programme learning outcome, namely to "use IT tools and digital media effectively, efficiently and flexibly for the purposes of information gathering, collation and analysis, with appropriate adaptation for the nature of the problem-solving task under consideration" (MAN3a-15).

MANm1 is a useful illustration of the way CAIC is enhanced digitally in each phase. Students in this module develop a 'direct-to-consumer' e-business strategy, by-passing Company P's current business-to-business distribution channels. In addition, students write a business plan for a mixed technical and business audience drawing on digital capabilities in each respective phase.

In the **Collect** phase, students work on searching and retrieving academic and case-based literature relating to companies' e-business strategies from different sources (numeric and textual data, information, diagrams, etc.), including websites, databases and social media. Module leaders educate students to move from Google to reliable sources and to appreciate empirical data.

In the **Analysis** phase, students critically analyse their data, thus developing their information, data and media literacy. At this point, MAN1-Sam calls students' attention to the trustworthiness of data:

> [Students] would go on the web and say "This lawyer said yes" and we say "Well, have they proven it"? "Well, he said yes", "Well, so what, has he proven it?" And a lot of what we are doing is drilling them in being able to discriminate what data is used in what situations and, therefore, what techniques and tools they can use to get to the data.

An academic's role is to expose students to different analytical strategies, thereby enabling students to make connections between theory and practice, another signature pedagogy at deep structural level. For instance, Sam shows students how to conduct a SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis of the e-business strategies identified. This requires critical thinking and commercial awareness, i.e. what is happening in the world socially, politically, environmentally and how this may impact on businesses. Sam shows students that working with digital tools (e.g. MS Excel or Wordle) can enhance this cognitive process by "cutting and segmenting of data, clustering it to identify themes or spot connections" (MAN1-Sam), eventually yielding new insights.

In the **Interpret** phase, students identify solutions relating to a direct-to-consumer e-business strategy by deploying their critical analysis. Students' ideas need to be original and convincing, in line with the discipline's implicit values and the module's outcome, namely, "to be able to analyse, understand and constructively criticise an existing e-business strategy" (MAN1b-3).

Finally, in the **Communication** phase, students detail their business strategy in report form, integrating digital media, e.g. diagrams, charts. The media literacy aspect links to content communication as well as data and information literacy insofar as students are to communicate a narrative. This is expressed in one of the programme outcomes, whereby students are to "adopt IT tools and digital media as appropriate to aid the effective communication and presentation of ideas" (MAN3a-16); but the solution may not always be digital, MAN4-Lesley adds.

The digital capabilities inherent in CAIC are also characteristics of inquiry-based learning (Fung, 2016). Bruce and Casey (2012) describe critical inquiry as a "pedagogical sweet-spot" for developing digital literacy (p.192), where digital problem-solving overlap with data and information literacy. To what extent it then constitutes a signature capability – i.e. specific to management as a profession – is debatable. Students might undertake an inquiry-based learning activity in any other discipline, researching other disciplinary issues. That said, CAIC fulfils a number of Shulman's signature pedagogy criteria. It appears to be routine and pervasive in management and requires students to be participative (Hyland & Kilcommins, 2009).

Another way to ensure that the approach develops 'habits of the heart', i.e. cultivates management's implicit values, e.g. commercial/strategic awareness, is to involve real clients, organisations and scenarios through authentic assessment (Ashford-Rowe et al., 2014; Gulikers et al., 2004). In each module explored, students make recommendations for actions on the part of organisations or clients which leads to students' choices, actions and professional responsibility (Shulman, 2005c).

Management students' digital capabilities related to CAIC are developed incrementally over their course. This is an area that is perceived by students as well-provided for via academics and librarians, suggesting that university provision is appropriate, as observed in previous studies (Becker et al., 2017; Beetham, McGill, & Littlejohn, 2009). Perhaps one area of development could be media literacy, i.e. extending students' creative production and critical analysis skills to multimedia, which can enhance and expand the practice of inquiry by facilitating different modes of engagement (Bruce & Casey, 2012).

With respect to managers' digital practices, their information/data literacy practices seem less prominent, which might be because working with information and data is so ubiquitous in their everyday that they are not articulated. However, one insight into managers' problem-solving strategies showed that when struggling to obtain relevant information, managers gather their own data from experts in current, innovative fields of interest, instead of waiting on market research.

6.2.2.2 Using technologies to connect theory to practice

Connecting theory to practice has been identified as another potential signature management pedagogy. With respect to signature digital capabilities, technologies – such as a simulation game or schema-building in spreadsheets – can help students acquire managers' "habits of the mind" (Shulman, 2005a), i.e. deep structural aspects of a given discipline. This is well illustrated by MANm2, a Masters-level module, which introduces students to the concepts of uncertainty and risk, something they would encounter as managers in any area.

In MANm2's assessed online simulation game, each student manages a relief effort for a village hit by a hurricane within a limited budget and a finite amount of time by working with the village chief and other stakeholders. As the student makes various decisions, such as buying relief tents, unexpected events (e.g. a storm) impact on their remaining resources. Students who are able to apply risk assessment theories well are more likely to succeed at the game. While Remneland-Wikhamn critiques university management education in relation to the limited opportunities it offers students to enact management practice (2017), virtual simulation appears to be a perfect vehicle for addressing this critique.

In the other task, students act as project managers of a hotel construction at the time of the 2008-crash in the Bahamas. Students are asked to identify and record different risk types (human, technological, political, etc.) and calculate their probability in a spreadsheet using a quantitative schema prepared by MAN2-Rob. The 'schema' is derived from theory. For managers, working with data in spreadsheets are problem-solving sites. Knowing what calculations to put in Excel, and whether to represent the data with a graph or bar chart, all "comes back to the whole concept of critical thinking" (MAN2-Rob). Digital technologies can play a large part in helping students to develop their capacity to apply theory, articulated as the ability to "demonstrate self-direction and originality in tackling and solving problems as well as synthesising theoretical and practical management perspectives to foster a professional approach to project management" (MAN2a-9).

At the same time, Rob emphasises the importance of critical thinking for managers over functional IT skills such as managing data and information, confirming Gilster's argument that digital literacy involves "mastering ideas, not keystrokes" (1997, p.15). Rob calls for students to "give me the story" behind the data. He intends to prepare students for their future profession as managers, when they will be required to act on their findings, thereby subtly educating them to develop a “sense of normative purpose and professional identity” (Wilkerson, 2010, p.8).

6.2.2.3 ‘Everybody is a consumer’: self-reflexivity and social media in marketing

As mentioned above, since Shulman (2005b) coined signature pedagogies, social media has transformed our society. In management’s sub-discipline, marketing, a new signature pedagogy seems to have emerged at the intersection of digital problem-solving and digital identity. I illustrate this by drawing on two modules.

In MANm4, third-year marketing students develop an understanding of internal and external communications, including public relations, marketing, political communication and the media. The module makes extensive use of case studies and scenario-based exercises. In the first assessment, students evaluate the communications of a public-sector or non-profit-making organisation, and deliver a group presentation of their critical analysis of its corporate communications function. The final assessment is an individual report; students carry out the same task for a for-profit organisation with recommendations regarding how it might improve its communications.

Corporate communications involve a range of external and internal channels and, naturally, some of these will be social media platforms. Students contrast businesses’ social media activity with competitors’ online presence through analysis and critical evaluation. What is significant about the pedagogical approach of a similar marketing module, MANm3, is that

> …everybody is a consumer, and everybody has been marketed to or is marketed to constantly, so we can always, if we’re trying to explain a concept, we can just spin it round and imagine you[rself as a consumer]. When we’re talking about how do you use social media for a business purpose, we say, well, how would that make you feel? *MAN3-Laura*

This self-reflexivity utilised in the analysis of social media seems to be marketing’s signature pedagogy, which requires students to “understand the challenges of new technologies for marketing and how consumers engage and interact with that technology” (MAN4a-5). The combination of self-reflexivity and social media can be exploited in different ways. Firstly, social media acts as a personal/professional identity space for students (as students). Secondly, it can also be an information source for commercial awareness (students as researchers of digital platforms for content). Thirdly, exploring social media is also an epistemic site for developing students’ understanding of the way organisations use these platforms from a customer perspective. Students channel their self-reflexivity (students-imagine-themselves-as-consumers). Fourthly, social media can also act as a rich terrain from which to explore "ethical questions about how businesses use the data that derives from social media platforms" (MAN3-Laura).

This signature trait is also evident in marketing students' experiences:

> …often you use it [social media] just in your free time just to catch up with your friends, but actually, when you look at it from more of a business perspective, it's really interesting, actually, what Facebook does for us as a consumer. *MANstd2-Eloise*

To discover social media's underlying marketing purpose appears to be a threshold concept (Meyer & Land, 2002) for some students: "I think as a consumer, you're unaware that this is an actual business function, and they're directly marketing to you in your own personal space" (MANstd1-Eleanor). Once recognised, students consider their own behaviour, usage patterns and experiences of social media platforms in order to support their critical analysis of organisational communications. MANstd5-Odi's group, for instance, noticed that UNICEF (United Nations International Children's Emergency Fund) had millions of Facebook followers, and only a few hundred thousand on YouTube, making recommendations that UNICEF cross-link their platforms to increase their YouTube traffic, which is something Odi would do in his social media use.

Hands-on social media experience is a coveted digital capability for graduates hoping to land a marketing role, "it makes you more employable" (MANstd-FG1-Reem). MANstd-FG1-Lidia was impressed by a guest speaker, who, despite having underperformed academically, was in demand by employers because of his fashion blogging and social media experience. Having managed the company's social media accounts during her work placement, MANstd3-Charlotte now feels confident in handling corporate digital platforms. MAN10-Rebecca, owner of a small marketing business, similarly believes that the capabilities required of graduates starting as marketing assistants are practical, hands-on content-marketing skills, alongside an awareness of how businesses and brands can use social media to their advantage.

6.2.2.4 Curricular considerations

Effective curriculum design should incorporate digital capabilities into authentic learning tasks (Beetham, McGill, & Littlejohn, 2009) and opportunities for lecturers to discuss, debate and jointly reflect on the use of digital technologies with students (Jeffrey et al., 2011). This is based on the general observation, confirming previous studies, that lecturers and librarians, as well as peers, have an influence on most students' adoption of digital practices (Margaryan et al., 2011), e.g. Eleanor using a digital mind-mapping tool recommended by her lecturer (Figure 5.2).

Management students are developing the signature digital capabilities identified, i.e. data and information literacy (equivalent to digital problem-solving) and content communication (media literacy). However, some potential curricular gaps have been discussed above, yielding the following observations that might enhance management's curriculum design for digital capability development.

The debate as to whose remit it is to train students in data management and manipulation is inconclusive. The tension between the need to train students in functional spreadsheet skills versus the wider critical and analytical strategies related to management theories and schema-building remains. The tendency seems to be for the university to be responsible for the development of the latter, whilst the consensus regarding the former seems to be to leave it to students' own initiative.

Despite the ever-growing need for the capacity to work with multimedia, students seem to have few opportunities to develop their capabilities for creative media production, echoing a recent study indicating that 51.4% of students report training in the use of digital artefacts to communicate ideas, including information concerning usage rights (Becker et al., 2017). Given the prominence of multimedia in today's society, this percentage seems low. More varied assessment types requiring management students to produce and communicate their findings could enhance their media literacy, e.g. via generating digital artefacts, crafting their own narrative, and participating in the collective web (Becker et al., 2017). Finally, some students and professionals observed that digital marketing and practical social media skills could be introduced earlier in the curriculum than currently provided, as they are professional skills in demand.

6.3 Cross-case comparison of digital capability development

Having highlighted some signature digital capabilities above, this section compares the two disciplines' approaches to digital capability development.

6.3.1 Digital capability elements

I have discussed the prominent digital capability elements, which I consider to be aspects of the discipline's signature pedagogies, in both disciplines above. I also highlighted those DigiCap-Framework elements which could be enhanced according to the discipline's signature pedagogies.

In engineering these included:

- *Media literacy* – opportunities to communicate engineering concepts to external (non-disciplinary) audiences in different media;
- *Digital problem-solving* – offering more varied programming code languages, e.g. Python and specific processes identified in sub-section 5.1.4.7;
- *Digital communication/collaboration* – modelling and support for participation in professional networks;
- *Digital identity* – extending co-curricular opportunities for social media engagement in the curriculum to all students; extending opportunities to develop critical use of social media/digital platforms.

As for management, these elements were as follows:

- *Data literacy* – spreadsheet, data management and manipulation skills;
- *Media literacy* – creative production and communication of content/findings in multimedia formats;
- *Digital identity* – hands-on social media skills.

More general observations about the approach to digital capability development are outlined in the next sections, which discuss the similarities and differences between the two disciplines.

6.3.2 Similarities

Four similarities in the way digital capabilities are developed in engineering and management curricula are highlighted below.

6.3.2.1 From signature pedagogies to disciplinary digital capabilities

Modular and programme-level mapping of digital capabilities have shown that the most-focussed of the digital capability elements reflect the discipline’s signature pedagogies. For instance, a core signature trait of engineering is that it is a collaborative, problem-solving discipline, and accordingly, the digital capability elements that seem to be prominent at modular level are digital problem-solving, digital communication/collaboration and, to a lesser extent, information-, media- and data-literacy.

In contrast, management is focused on individual achievement and its disciplinary problem-solving is underpinned by CAIC as a signature pedagogy. Accordingly, the prominent digital capability areas are information- and data-literacy (which overlap with digital problem-solving) and content communication (overlapping with media literacy). Despite these differences, the commonality is that digital capabilities follow the discipline’s signature pedagogies at modular-, programme- and subject-level.

These signature pedagogies affect the way digital capability elements overlap. For instance, in engineering digital problem-solving overlaps with data literacy, while in management, digital problem-solving does so with data and information literacy. The given discipline’s modality also has a bearing on the capability element of information/data/media literacy. For instance, 2D/3D visuals are so endemic in engineering that working with them is not explicitly articulated in learning outcomes, while in management, the boundary between data and information is blurred. All this has an impact on how media literacy is articulated.

It is also the case that professionals’ digital practices are influenced by a number of factors such as company size, type, technical infrastructure, the nature of the task and sub-disciplines. In addition, even within a discipline, professionals might approach problems from different knowledge domains (Dionne, 2018). An engineer might draw on creativity (arts) or scientific problem-solving (sciences) to solve social or environmental problems (social sciences/sciences). In agreement with Trowler (2014a), curriculum design needs to acknowledge this complexity, going beyond disciplinary essentialism. Moreover, digital practices might in themselves produce such new (inter)disciplinary practices and cultures (Oliver, 2012).

In both cases, recently emerging signature pedagogies have been identified, confirming the position that signature pedagogies need to be revisited regularly (Lucas & Hanson, 2016) by taking into account disciplinary innovations and technological changes. At the same time, professional frameworks and HE curricula need to observe the resulting shift in the capabilities and skillsets required.

6.3.2.2 'Mastering ideas, not keystrokes'

Another similarity between engineering and management concerns the way Gilster's (1997) notion of digital capability, "mastering ideas, not keystrokes" (p.15) is applicable in both disciplines, albeit in slightly different ways. In engineering, students are exposed to a range of specialised software (see sub-sections 5.1.3.3 and 5.1.4.3), which then results in an approach that attempts to prepare students for lifelong learning and the continuous updating of their software skills underpinned by sound engineering knowledge. In management, even if students were 'savvy spreadsheet-users', without a capacity for critical analysis of data, this skill would be superfluous.

6.3.2.3 Implicit/explicit articulations of digital capabilities

Another similarity between engineering and management is that digital capability development tends to be articulated implicitly, rather than explicitly, in learning or skill outcomes of module and programme specifications. For instance, the outcome, the "ability to organise and analyse information, and to present it in a clear, logical and concise manner" (ENG3a-3.4b) does not reference digital tools or capabilities; however, presentations are likely to involve some digitally-produced artefacts. This implied nature could partly be to do with disciplinary practices being foregrounded over digital capabilities.

Some exceptions in engineering include explicit mentions in learning outcomes (e.g. 'simulation', 'modelling' or the "ability to utilise a broad range of appropriate information technology skills", ENG3a-LO3.4a). Indeed, another way for outcomes to be explicit is when there is an institutional requirement to do so, e.g. at UniB:

> …includes the ability to search for, retrieve and store information online, to evaluate online/digital information, and to cite such information correctly using the Harvard reference system. *MAN3a*

This, in turn, in a module outcome becomes the ability to:

> …develop skills in the appropriate use of IT tools and digital media for the purposes of information gathering, collation and analysis. *MAN3b-5*

This is further mapped in MANm3's assessment criteria for distinction as "very effective use of IT tools and digital media to collect, organise, analyse and present data, where appropriate [with] Harvard referencing accurately applied".

In management at UniA, the articulation of digital capabilities is somewhere in between: despite each module or programme being mapped against a set of management graduate skills, including 'IT awareness', many digital capabilities are more likely to remain *implied* in skills and outcomes.

6.3.2.4 Signature assessments or assessment criteria – better indicators?

The above feature poses a challenge for the dominant curriculum design principle, constructive alignment (Biggs, 1996) between learning outcomes, teaching/learning activities, and assessment criteria. If digital capabilities remain unarticulated in outcomes, it makes alignment harder to implement. Findings have shown that assessment criteria can better indicate the development of digital capability. This concurs with Strivens (2017) who suggests that instead of signature pedagogies, 'signature assessments' might be more appropriate as a concept to establish the distinctness in educating professionals in different disciplines.

Nevertheless, tensions remain between constructive alignment and digital capabilities. If digital capabilities are implied/unarticulated in learning outcomes, it makes it difficult to ensure constructive alignment between outcomes, activities and assessment criteria. In addition, from a capability approach perspective, curriculum and pedagogy need to be designed in a way that "offers students the freedom to become and to choose" (Walker & McLean, 2015, p.80). Relating this to digital capability, this could entail academics offering students the opportunity to complete learning tasks chosen from a repertoire of technologies, making their own decisions as to which digital tool to use. However, enabling this learning context freedom might be difficult as constructive alignment needs to 'lock down' course objectives well before the learning event takes place. This tension has been also observed by Remneland-Wikham (2017) in the context of action learning. In this case, active participation and reflection were approaches that helped support students' self-awareness and confidence. Accordingly, in order to enhance students' digital capability, it seems important to provide opportunities for them to articulate, reflect and act on their own digital capabilities (Bruce & Casey, 2012), which would also address the potential issue of over-confidence discussed earlier (Jeffrey et al., 2011).

6.3.3 Differences

6.3.3.1 Programme-level approach: spiral versus patchwork

With respect to the two disciplines' approach to digital capabilities, one difference concerns their programme-level approach. In engineering, this is encapsulated by the poem's lines, "After baptism by a 5-day Wildfire/Fight your way through the digital mire/Armed only with wit and the need to enquire". At UniA, apart from a full week's training (a "baptism by Wildfire", with Wildfire the name of ProEngineer, a 3D-CAD software), students do not receive specific software training over the rest of their course. Graduate assistants and lecturers are on hand to help them through difficulties, but students are left to either work things out themselves or call on their peers for support. Academic support promotes students' self-reliance (as mentioned in section 6.2.1.4).

In contrast, instead of engineering's incremental spiral, digital capability development in management programmes could be visualised as more of a patchwork. Although skills-development (including IT awareness) is designed at programme-level, individual modules focus on different capabilities and may be unrelated to those in other modules. This feature might reflect the hierarchical/cumulative (engineering) and horizontal/segmented (management) curriculum structures identified by Maton (2009).

6.3.3.2 Influence of professional frameworks

The second disciplinary difference concerns professional frameworks. Engineering curricula are greatly influenced by the UK-SPEC (ENG0) defining Incorporated/ Chartered Engineering competencies. This is less so in general programmes, such as business and management, where there is weaker alignment to specific professional frameworks. However, in management sub-disciplines such as accounting or marketing, a stronger influence of professional framework is discernible, and future research could explore if this also means a stronger influence on the way digital capabilities are conceptualised in management's sub-disciplines' HE curriculum.

6.3.3.3 Range of subject-specific software

Finally, there is a difference between the range of subject-specific software that engineers and managers use in their professional practice, with engineers drawing on a wider range of specialised software. This results in a different curricular approach. Engineering graduates need to be “able to work with simulation software and communicate digitally with confidence, with almost no training, no support” (ENG1-Thomas). Students also need to acquire software basics, so once they know how to operate one programme, they can self-teach themselves. This is because engineers constantly need to update their skills due to changes in technology as well as variation from organisation to organisation (ENG3-Gill). Management graduates may not encounter the same wide range of complex subject-specific software in their professional practice as engineers do. For them, the key is to develop critical thinking and critical use of technologies for evidence-based decision-making.

7 Chapter 7: Conclusion and recommendations

In this conclusion I summarise my findings in relation to the research questions, highlight the study's contribution to knowledge, discuss its implications and limitations, and suggest areas for further research.

7.1 Addressing the research questions

Underpinned by a human capabilities approach, my conceptual framework combined JISC's DigiCap-Framework and Shulman's signature pedagogies. The overarching research question was "How are digital capabilities conceptualised in two different disciplines, namely engineering and management?" I used a case study methodology drawing on programme design documents and participant accounts (staff, students and professionals) to analyse professionals' digital practices. Such detailed mapping in a specific disciplinary context has not been documented before, which was an original aspect of this study. My findings highlighted the distinct ways in which the six digital capability elements are manifested in the two disciplines in HE curricula, in alignment with the professions' signature pedagogies. The study identified similarities and differences between engineering and management in their approach to developing students' digital capabilities. The next sections summarise what was found about the way digital capabilities are conceptualised in these disciplines, which has not been reported in previous studies.

7.1.1 Curricular conceptualisations of digital capabilities

The first research question (RQ1) involved a curricular perspective: *How are digital capabilities conceptualised/planned in the curriculum at modular level in different disciplinary contexts (e.g. in engineering and management)?* This question was explored through the following sub-questions:

- RQ1.1 What digital capabilities are planned by academic staff to be developed as intended learning outcomes (ILOs), teaching and learning activities and assessment tasks?
- RQ1.2 How do these modular articulations fit in with programme and institutional levels of learning outcomes, and subject benchmarks?

After offering insights into the digital activities, assessments and digital capability outcomes of engineering and management students, and the digital practices of engineers and managers, I concluded that in both cases the most prominent digital capability elements reflect the discipline's signature pedagogies. For instance, engineering has teamwork at its core value, and accordingly, digital collaboration/communication are one of its most prominent capabilities in HE curricula. This confirms that identifying signature pedagogies seems to be a useful starting point to explore disciplinary conceptualisations of digital capabilities.

Another similarity between engineering and management is that digital capability development tends to be articulated implicitly in learning outcomes at each design level (subject, programme and module). The exception to this is when a university has decided to adopt digital literacy as a graduate attribute so that each of their programmes is required to articulate digital capability-related learning outcomes. In either case, digital capabilities appear to be most traceable in assessment criteria (see sub-section 6.3.2.4). I therefore suggest that for digital capabilities, 'signature assessments' may prove a more useful concept than 'signature pedagogies' (J. Strivens, personal communication, 14 May, 2017).

With respect to differences in the two disciplines' approach to digital capabilities, engineering curricula could be conceptualised as an incremental spiral from a programme-level perspective, focusing on students' increasing self-reliance when it comes to learning subject-specific software. In management, however, this could be visualised as a patchwork, with different capabilities developed discretely and in tandem. This difference in curricular conceptualisations of digital capabilities may also be linked to the discipline's knowledge structures (Maton, 2009).

Engineering students are exposed to a larger variety of software than management students; exposure is also further dependent on engineers' sub-disciplinary specialism. In contrast, management students hone their critical thinking, and are thereby immersed in data and information in different digital forms. In both cases, Gilster's (1997) notion of "mastering ideas, not keystrokes" is pertinent as an approach to digital capability. Another difference is that professional frameworks have more influence in engineering than in management programmes.

Typically, managers use technologies as 'consumers' or 'producers' of content (Warren, 2011), whilst engineering's relationship with technology is more symbiotic. Technology can be both an instrument and a product of engineering problem-solving. Engineers are 'innovators' of technology (Warren, 2011), tackling human problems. However, there are examples of this in business too, as demonstrated by the e-business module that explores how technologies have transformed and disrupted existing business models and processes. Management as a discipline can also be seen as 'innovator/disruptor'.

7.1.2 Student perspectives of digital capabilities

The second research question (RQ2) was, "*How is the development of digital capabilities enacted and experienced by engineering and management students?*" This was broken down into sub-questions to engage with different perspectives:

- RQ2.1 What are academics' perceptions of the digital capabilities being developed by engineering and management students as they enact the planned curriculum?
- RQ2.2 What are engineering and management students' perceptions of developing the planned ILOs with respect to digital capabilities? Are they developing what is planned for?

Although it was only possible to draw on limited data from students directly, it was possible to triangulate data by merging academic (RQ2.1) and student (RQ2.2) perspectives. Academics' views coalesced with students' own accounts of the latter's digital practices. Overall, students at UniA and UniB were shown to be developing the digital capabilities planned or intended for them in their curricula. Confirming previous research (e.g. Jones, 2011), curricular tasks, academics, peers and librarians/support staff have a role in nurturing students' digital capabilities since they have been shown to promote overwriting students' risk-averse or pragmatic attitudes to adopting new technologies.

There seems to be some tension between students expecting software training from the university and academics' intention to develop students' independence in acquiring their digital know-how. The preference of the latter seems to be to prepare tomorrow's professionals as lifelong self-learners who are confident, self-efficacious adopters of technology, which means that students are able to identify their own gaps and bridge them on their own where necessary, as opposed to providing hands-on sessions for students with functional software skills.

The third sub-question relating to the student perspective of digital capabilities aimed to find out:

- RQ2.3 Are engineering and management students developing any digital capabilities not articulated or planned for?

In both cases, within limited data available for engineering and management students (especially pursuing mechanical engineering or marketing), students' unintended learning was related to digital know-how, including media literacy, which mostly emerged as a result of co-curricular activities. In engineering, Formula-One team members in particular were reported to have developed sophisticated media skills, even surpassing those of academics due to sponsorship's influential role in the automotive industry. Extending such practices across the curricula could be one potential area that might enhance students' digital capability development, for instance by engaging them in tasks which require creating multimodal artefacts to communicate their designs.

Another area in which the students' consulted engaged in digital practices was learning and CPD. Both of these feature strongly in engineering professional frameworks and in programmes, but their digital aspects remain unarticulated. Some students demonstrated sophisticated digital study practices, which were not directly recognised in assessments or, at times, even by the students themselves. The same was the case regarding professionalism and ethical behaviour. Digital aspects of these, such as managing one's professional profiles or ethical online behaviour, are not explicitly referred to in professional frameworks and the curriculum. HE curricula could be enhanced to develop students' digital identity by exposing students to critiquing online interactions of professionals or engaging them in tasks which requires them paying attention to aspects of online professional identity. These, albeit limited, findings suggest that a critical perspective and reflective approach could usefully contribute to developing the digital practices of students and tomorrow's professionals and whether professional bodies need to account for these digital aspects of learning explicitly in their competency frameworks.

7.1.3 Professionals' digital practices

The third, and final, research question (RQ3) concerned digital workplace practices, *"To what extent do the curricular conceptualisations of digital capabilities indicate a match that of the digital capabilities practised by engineering and management employees/professionals?"* This was broken down into:

- RQ3.1 What are the possible digital practices of employees/professionals of the same discipline (e.g. in management and engineering)?
- RQ3.2 Are there digital capabilities that engineering and management students possibly need to be developing whilst at university that they are not currently developing?

In both cases, organisational profile appeared to be one of the influencing factors of professionals' signature digital practices, including the use of social media. In engineering, high-performance, industry-standard software is more likely to be used at global companies, with SMEs working with more affordable versions, as observed by ENG5emp-George.

The curriculum design implication is that HE needs to prepare students for these different contexts to: 1) ensure that students both gain confidence in using industry-wide software; and 2) also develop their adaptability when faced with unfamiliar software. Rather than teaching undergraduates particular software skills, academics expose students to authentic tasks, giving them the appropriate tools with guidance while modelling the requisite online behaviour to nurture their confidence and self-reliance:

> We never teach software, we show [students] software; they learn it themselves. We nurture it, we make sure there's enough opportunities that they're required to use it, make sure the tools are available, and make sure there's someone to catch them when they fall. *ENG2-Mike*

In both disciplines, information and data literacy appear to be more prominently discussed by students than in professional practice. This could be because once acquired, it becomes so ubiquitous and embedded in professionals' daily work that it remains unmentioned. If so, this would confirm the university's role and success in supporting students' information and data literacy.

With respect to professional engineers' signature digital practices, a major influencing factor is their sub-discipline, as evident from their use of specialist 3D-CAD tools. Disciplinary background also influences managers' digital practices. At the same time, the higher they are on the managerial ladder, the less likely they seem to employ subject-specific software. All this implies that for a full picture of disciplinary digital practices, both a bird's eye view of the discipline and a microscopic view of its sub-disciplines might be necessary.

7.2 Implications for practice

The study was borne out of my motivation to investigate disciplinary practices in detail so that I would be in a better position to support staff with respect to the digital capabilities required of future professionals. A particular aim was to identify effective strategies for supporting staff in their curriculum (re)design. The next section offers such recommendations; first within the two disciplines, then more generally for anyone involved in curriculum design, including programme teams and central staff, such as educational developers and learning technologists.

7.2.1 Programme teams in engineering and management

Earlier, I summarised a few potential gaps in HE curricula based on a comparison between curricular provision and professionals' digital practices. In engineering, this includes failure-mode effect analysis, skills in data manipulation, programming and process control plans. In management, these include spreadsheet, hands-on digital marketing and creative media production skills.

In both disciplines, information literacy is a vital capability to develop during university study, which is evident from the explored modules' learning/teaching activities and assessments. In management, there could be more scope for utilising simulations and sophisticated data tools. The general expectation of professionals and academics appears to focus on developing lifelong learners who are able to analyse problems, search for solutions and learn skills independently. Enquiry-based learning tasks are particular "sweet-spots" for developing digital capabilities, as suggested by Bruce and Casey (2012).

Media literacy is perhaps the least-developed capability, which could be enhanced through authentic assessment (see e.g. James & Casidy, 2018) via students critiquing and/or producing digital artefacts to communicate their solutions. The nature of 'media' seems relative to the discipline. Engineers routinely work with diagrams and 3D-models, whereas managers do less so. In either case, media literacy involves communicating findings effectively to a range of audiences in different forms.

Students displayed a variety of digital preferences and practices. Academics and the curriculum have an influence when it comes to students using digital learning tools. This implies that university staff could pay attention to pointing students to particular digital tools and techniques for their independent study, thereby increasing their repertoire and critical attitude. Alternatively, academics could model digital study practices, e.g. from essay-planning through to referencing professional communications by utilising digital tools.

As for digital identity and wellbeing, social media use was little in evidence, mainly in certain sub-disciplines and in co-curricular activities. Further research could explore the importance of social media in automotive engineering in contrast to other engineering sub-disciplines. For instance, are there other areas of engineering where digital identity may be more/less important? And to what extent does recruitment drive social media use in HE? With regards to engineering practice, it would be worth exploring younger engineers' social media use, and to what extent their use blurs professional/personal boundaries.

7.2.2 General considerations for curriculum design

This study has confirmed that students' digital capability development is most evident in authentic learning tasks in digitally-mediated contexts (Littlejohn, Beetham, & McGill, 2012). This is when students focus on subject-specific tasks, motivated by their enthusiasm for their subject. Digital tools can either act as a means to an end or serve as epistemological sites for solving challenges. My study has also shown that embedding digital capabilities in programmes needs to be continually re-evaluated to keep up with changing disciplinary practices.

A further implication for curriculum design concerns the importance of critical reflection. Some students demonstrate sophisticated and critical uses of technology, but may not themselves be aware of it, or vice versa. This suggests that supporting students to articulate and reflect on their capabilities is as important as developing them, which in turn, also contributes to enhancing their digital confidence and critical use of technology.

One tension for curriculum design lies in the question as to whether to offer students a choice of which technology they should use for a particular task. The right balance needs to be decided on: (1) should students be pushed towards a particular technology, so that even the risk-averse expand their repertoire; or, (2) should students be allowed to choose according to their preferences so that they develop the ability to critically evaluate and decide on the most appropriate one for the given task? In either scenario, it seems more important that students are given opportunities to critically reflect on and articulate their own digital capabilities as well as support in order to develop their confidence and disciplinary know-how (Anyangwe [n.d.], quoting Beetham, 2012).

This study has found that digital capabilities are rarely identified explicitly in learning outcomes (Beetham et al., 2009); thus, I concur with Hughes and Barrie (2010) who argue that the strongest graduate attribute, achievement, can be ensured by embedding these explicitly in assessments. Therefore, incorporating digital capability development in assessment criteria with opportunities for critical reflection appears to be an effective combination. Fielding et al. (2017), for instance, suggest that institutions develop the use of HEAR (Higher Education Achievement Report, a report that all UK students can receive on their curricular and co-/extra-curricular achievements upon graduation) to build digital capability outcomes into the curriculum, thereby recording and recognising student attainment.

Another curriculum design approach follows Gilster's (1997) principle of "mastering ideas, not keystrokes". This means that rather than teaching students hands-on skills (keystrokes), the role of the university should be to embed digital activities in subject-specific tasks (mastering ideas). In addition, the university's additional role is to instil adaptability and self-reliance in students, so when faced with unfamiliar digital applications, they are able to recognise their shortcomings, plan accordingly, and use their own initiative to learn independently. This is coupled with the recognition that disciplinary knowledge is constantly changing as a result of the field's digital transformations.

Wang (2015) sees curriculum mapping rhizomatically, which is an apt and eloquent visual metaphor for digital capabilities. As opposed to a map which guides someone to an unfamiliar (but fixed) destination, a rhizomatic map

> …has multiple entryways, but no fixed terminal. Instead of being reached or at somewhere, its value is revealed in being able to connect, from any existing position. This is a map that goes along with adventure in self-exploration. (Wang, 2015, p.1556)

Finally, many of the innovations observed during this study occurred as a result of interdisciplinary collaborations (Calhoun, 2006; McNair, Davitt, & Batten, 2015). For the HE curriculum, this means that interdisciplinary learning opportunities are likely to be, to use Bruce and Casey's (2012) term again, "pedagogical sweet-spots" for digital capability development. Further research could explore the way digital capabilities are developed in interdisciplinary contexts at the intersection of two or more disciplines.

7.2.3 Policy-makers

This thesis's findings point to the potential need for updating professional frameworks and subject benchmarks from a digital capability perspective. The analysis has shown that, with some exceptions, digital capabilities tend to be *implied*, rather than explicitly articulated in competencies and outcomes. This seems appropriate in most cases, although also resulting in a potential tension regarding constructive alignment (discussed later in sub-section 7.3.3). The areas in which digital capabilities could be further identified concern media literacy, digital problem-solving and digital identity/wellbeing. It is in these areas that digital technologies have impacted on epistemological practices of the disciplines. It may be useful to re-consider if such digital practices are covered in the current professional frameworks, or whether there are any which need to be explicitly articulated. Another option could be for the competency frameworks and benchmarks to offer a mapping against the DigiCap-Framework model by way of articulating the discipline's digital capabilities. Examples of this certainly exist in other areas, such as in nursing (NHS Health Education England, 2017).

7.3 Implications for theory

The major theoretical contribution of this study has been to offer a way to explore digital capabilities in disciplinary contexts. Other studies have either applied the DigiCap-Framework (Anagnostopoulou, 2013) or signature pedagogies. An original feature of this study is its combination of these two perspectives. As demonstrated in Chapter 3, literature at the intersecting domains of curriculum design, professional education, signature pedagogies, and digital capabilities is minimal. Whilst the DigiCap-Framework was able to illuminate digital learning activities in particular domains of practice, it is the combined conceptual framework which helped identify the distinct or signature digital capabilities in engineering and management. A further contribution of this study has been the identification of an overarching signature pedagogy of management, CAIC (collect-analyse-interpret-communicate), which, apart from in its sub-discipline accounting (Wilkerson, 2010), has not been accomplished previously.

7.3.1 Signature pedagogies

I would like to underline five implications arising from applying the concept of signature pedagogies to digital capabilities in curriculum design.

Firstly, it has been demonstrated that even within a span of 10-15 years, both engineering and marketing's signature pedagogies have undergone significant changes. This study concurs with Shulman (2005b), who posits that as technologies are constantly transforming professional practice, programme and curriculum design teams need to constantly revisit signature pedagogies.

Secondly, another theoretical implication concerns the need to extend signature pedagogies to 'signature assessments'. Assessment tasks and criteria are identified as better indicators for curriculum mapping, which, according to Kahn (2003), provide a more fine-grained approach. Thirdly, the notion of 'signature assessments' leads to the identification of a thus-far unobserved link between signature pedagogies and authentic assessments, as discussed in sub-section 6.2.2.1. Maton (2009) has similarly observed that authentic learning can support learning in professional education. Articulating this link between signature digital capabilities and authentic assessments is a further theoretical contribution of this study.

Fourthly, the study's conceptual framework offers advantages over another relatively widespread model applied in technology-enhanced learning, the TPACK model. TPACK actually originates from Shulman's (1986) ideas about combining disciplinary content-knowledge and pedagogical-knowledge in teacher education programmes (PCK as pedagogical-content-knowledge), which led to his ideas on signature pedagogies. Mishra and Koehler (2006) extended Shulman's PCK-model with the knowledge domain of technology, resulting in TPACK (Technological-Pedagogical-And-Content-Knowledge). Whereas TPACK articulates the skills needed for curriculum design/ers in a digital environment in a non-discipline-specific context, the conceptual framework adopted in this thesis is intended to explore disciplinary practices in depth.

Fifthly, I highlight one concern in using Shulman's theory. It was at times difficult to distinguish between the three levels of signature pedagogies (implicit, deep or surface) when categorising digital practices. For instance, commercial awareness can be either seen as an implicit value of management professionals, or as a deep-structural element. This difficulty could either occur because Shulman's theory is not granular enough, or because the vertical alignment between these levels was too strong.

7.3.2 The Digital Capability Framework

As for the other lens of my conceptual framework, I found working with JISC's Digital Capability Framework straightforward, thereby confirming the usefulness of its six articulated elements for teasing out the range of participants' disciplinary digital practices. However, taking a cue from Higgins' (2016) critique in relation to the Professional Capabilities Framework, which explores whether the framework used in social work curriculum redesign has managed to transform social work practice or not, the same question could be posed as to what extent the Digital Capability Framework could drive curriculum transformation and change?

One restriction of the DigiCap-Framework concerned the way it perceives professions' relationship with technology. As discussed in sub-section 3.3.4, the Framework suited Warren's (2011) 'consumer' and 'producer' categories, but it was not able to easily accommodate my findings insofar as engineers are not just innovators, but also creators of technology. This creator role is particularly important from a human capabilities perspective, since “new technology has huge potential to transform our lives for the better” (Hardoon, 2017, p.8), which Passey et al. (2018) explore in the wider context of digital agency. I would argue that creators of technology have a role in paying attention to its humane aspects, contributing to reducing inequality and promoting wellbeing, just as Bali (2017) highlights the lack of humane aspects in the computer science curriculum. Could the Framework articulate and visually represent this extra dimension?

Staying with the theme of visual representation, my study highlights a tension, one which is perhaps inherent in other visualisations. On the one hand, representing theoretical frameworks diagrammatically has the advantage of communicating complex concepts succinctly. My findings confirm that the DigiCap-Framework’s diagrammatic representation as intersecting circles is appropriate in this context: it communicates the overlap between its six elements. On the other hand, such representations are naturally a simplification, which might yield unintended interpretations (see in sub-section 2.3.1, and also Lemov, 2017), which could “inadvertently deskill educators from critically reading some of the deeper forces at work” (Brown 2017c, n.p.). For instance, the DigiCap-Framework suggests that the elements are of equal importance, which was shown not to be the case (see Figure 6.4). The implication of this is that when adopting a framework, one needs to critique its visualisation (if present) as part of the process of constructing one’s own version of it.

7.3.3 Curriculum design

The purpose of using this study’s conceptual framework was to explore effective curriculum design in order to develop digital capabilities. As highlighted in Chapter 3, constructive alignment was used to analyse digital capability development in modules, programmes and subject benchmarks. In Chapter 6, I highlighted the tension between mapping digital capabilities and constructive alignment as a curriculum design principle. Firstly, if digital capabilities are implied/unarticulated in outcomes, it becomes difficult to ensure constructive alignment with activities and assessment criteria. Secondly, as Remneland-Wikhamn (2017) warns, pre-determining every intended learning outcome might hinder “creativity, curiousity, individual initiatives and the serendipity of learning from emerging moments” (p.10). This particularly resonates with digital capabilities. Future research could explore, similar to Ferreira and Mendelowitz (2009), if, from a digital capability perspective, extended models of constructive alignment might be more appropriate or whether a different curriculum design approach might be needed altogether.

7.4 Contribution to knowledge

Having considered this study's implications from the perspectives of theory and practice, I now summarise its original contribution in these two respects. I highlight firstly the originality of my combined conceptual framework and, as a result, secondly, the mapping process of disciplinary digital capabilities derived from this framework, which can be used by educational practitioners.

7.4.1 Theoretical contribution: combined conceptual framework

Shulman's signature pedagogies and JISC's DigiCap-Framework enabled me to build a picture of disciplinary digital practices. I reflected on and critiqued both Shulman's concept on signature pedagogies and the more practice-oriented DigiCap-framework. But, it was the appropriateness of the *combined* nature of my conceptual framework that I wanted to explore in this study, i.e. whether this combination was suited to identify and explore digital capabilities in two particular disciplines.

It was the combination of these two elements which brought insights. I demonstrated in Chapters 5 and 6 how these two lenses (signature pedagogies and the DigiCap-Framework) could be used in a way that help highlight what disciplinary digital practices are foregrounded and practised in engineering and management. For instance, applying the DigiCap-framework on its own could offer description as to different digital practices in different disciplines, but it was mapping these against its signature pedagogies which yielded the insight into the nature of prioritisation of certain digital capabilities (how and why). I showed that this combined framework could be used both in a HE curricular and a workplace context. As a result of this combined conceptual framework, the interview process that I developed to help me identify and describe digital capabilities within engineering and management, can be transferred and applied into other disciplinary contexts (which I detail next).

7.4.2 Contribution to practice: mapping process of disciplinary digital capabilities

The research process itself is an outcome of this study. From the outset, knowing that the study would be limited to two subjects, I paid careful attention to the process and its potential transferability to other disciplines. I now outline the stages of this process and offer some ideas on when and why practitioners might use it.

The process is based on what I found to be the most useful interview questions derived from my combined conceptual framework (for the interview guide, see Appendix A), which led to insights about the disciplinary conceptualisations of digital capabilities. Practitioners – lecturers, curriculum designers, learning technologists, or anyone embarking on reviewing existing or designing new curricula from a digital capability perspective – might undertake a mapping process in collaboration with academic, student and professional participants as follows:

1. Elicit the signature pedagogies of the discipline (implicit, deep and surface) – e.g. ask questions such as:

   What are the characteristics of a good X (where X= a discipline) student?

   What do you think are distinct teaching methods in X (which you might not see anywhere else on campus)?

2. Explore the way digital technologies have transformed or disrupted the discipline (and/or interdisciplinary aspects), e.g. ask questions such as:

   Can you recall any significant digital development that has transformed or disrupted the field of X in recent years?

   What are your discipline's threshold concepts from a digital perspective?

These questions are particularly useful in providing an understanding of evolving digital practices (the former question was added on the basis of Sinclair, 2013; the latter question was added as a result of my findings).

3. Elicit characteristics of a 'digitally capable professional in [X]', where X is the discipline, as well as general approaches to digital capability development, e.g. ask questions such as:

   Can you describe a digitally capable professional in X?

4. Analyse module outcomes, skills, assessments (criteria) and learning/teaching tasks using JISC's DigiCap-Framework together with the associated programme and subject benchmarks. Identify progression and vertical links, e.g. ask questions such as:

   What tasks or activities have digital aspects in this module/programme? E.g. critical use of information and data, online collaboration, communication, research online, use of digital tools, resources for learning, positive digital identity management, etc.

   Assessment: Do the module's/programme's (formative, summative) assessments contain any digital aspects? Any digital artefacts produced?

> Learning outcomes and perceptions of student learning: Do the module's/programme's learning outcomes contain or relate to any digital aspects? Whether explicitly/implicitly?

5. Identify overlaps (horizontal links between DigiCap-elements), gaps and unarticulated capabilities, and where students may be recognising, reflecting on and articulating capabilities developed, e.g. ask questions such as:

> Which digital capabilities do students of your discipline need to acquire for the workplace/as engineering or management professionals? Is there a difference in the above elements between the HE and the workplace setting?
>
> What digital capabilities are actually being developed by students (expected and unexpected learning outcomes)?
>
> How (and where) do students recognise and reflect on their digital capabilities developed?
>
> How do your students' digital capabilities develop progressively (e.g. from first to final year)?

6. Identify emerging and existing signature digital capabilities, e.g. ask questions such as:

> As a result of significant digital developments that have transformed or disrupted your field of X in recent years, what emerging/new digital capabilities you think your students need to develop? And why/how might these be important in your field?

Naturally, the above steps might be adapted according to context. I have used aspects of this process in a number of staff workshops. Further testing and refining this process, building up disciplinary examples as stimulus material as well as using toolkits, such as radar diagrams (e.g. as in Osborne, Dunne, & Farrand, 2013) which help the mapping process could be the subject of further research and development.

7.5 Methodological implications and limitations

I have already addressed some of the limitations arising from the qualitative nature of this study in section 4.10. The main limitation concerns the volume of cases (two), number of units of analysis (four per discipline) and sources consulted. Had I taken on any more, the volume of data produced would have been unmanageable. The range of professionals consulted was also limited by: type (small, medium, or large business); sector (private, public and voluntary); and industry. In different work contexts digital resources and infrastructure vary, even from one organisation to another. This area potentially warrants further research. This relates to intentions also - not looking for generalisation and representation but for rich depiction of digital practices and how professionals make decisions as to what technologies to use in their work. Student data via focus groups, interviews and observations were also limited in scope (one module chosen per case) and temporality (consulted at one discrete point in their study), confirming Passey's (2017) observation that many educational studies lack a longitudinal angle. A longitudinal study following students' progression from university into employment would have been ideal but was not feasible in this case. However, the strength, and an original aspect of this thesis, is that it offers triangulation between staff, student and employer perspectives (similar to Hill et al., 2016).

The study's methodological contribution was to confirm the usefulness of poems as a way of synthesising findings (Bazeley, 2013). The underpinning multimodal logic (converting one mode into another) helped with gaining extra meaning (Jewitt, 2009). I had previously utilised images and metaphors to make sense of my research data (Powell & Varga-Atkins, 2013; Tunde Varga-Atkins & O'Brien, 2009). The advantage of poems is that whilst metaphors are useful for capturing one salient message (Nossiter & Biberman, 1990), poems operate at a multitude of levels. The carefully and meticulously crafted words, lines, stanzas, rhythm, and even the graphic layout, can all add extra layers of meaning (Cahnmann, 2003), all of which were particularly useful for communicating the complexity of digital capabilities.

I would also like to briefly reflect on interviewing. My post-interview journal reflections and previous experiences kept reminding me not to take interviewing for granted as a method. An interview is a socially constructed collaborative space between the interviewee and interviewer (Holstein & Gubrium, 2004). Interviewing is a science and an art at the same time. I believe that if two different interviewers were to conduct the same interview, the resulting narrative could be somewhat different. This is not to account for subjective elements, e.g. rapport or an interviewer's personality, but for the fact that interviewers are continually making decisions via active listening and elicitation techniques. What this implies is calling on interviewers to continuously reflect on their decision-making processes.

7.6 Epilogue: from Daniel to William Blake

By way of closing, I would like to take stock of my wider doctoral journey. I set out at the beginning in the hope that I would gain insights about two disciplines' digital practices and ways in which the university can successfully prepare tomorrow's digitally capable professionals. I also hoped that the process of the inquiry, i.e. my conceptual framework and research methodology, would be transferrable to other disciplinary contexts. As demonstrated above, I have achieved both aims. What for me was particularly stimulating in this journey was learning about the ways in which digital technologies have transformed and disrupted disciplinary knowledge-construction processes. This is where I felt the energy of students and professionals, and where I connected with them the most. I wish to visually capture this professional excitement, the same way Johnston (2018) uses 'Research as Art' to show people how to communicate their research in a photograph.

This photograph for me would be of William Blake's art. I opened my thesis with Daniel Blake to illustrate how his character intertwines the employability and human capabilities agendas. In one scene, Daniel paints graffiti, "I, Daniel Blake", as a way of rebelling against the system oppressing his freedom. Daniel is a clear allusion to William Blake, the romantic radical poet, whose art was concerned with the conflict between authority and freedom (Stevens, 2000):

> I must create a system or be enslaved by another man's;
> I will not reason and compare: my business is to create. (1804)

Blake, the artist, epitomises my study in a number of ways. The extract above resonates with my adopted definition of digital capabilities as enablers for thriving as a professional. Without professional agency, Hudson (2009) cautions, university educators' professional identity might be eroded, resulting in bureaucrats fulfilling central learning technology policies. For professionals, reward comes from taking an active part in innovation and scholarship (see Beetham, McGill, & Littlejohn, 2009). In my study, academics, professionals and students were not trying to satisfy a skills agenda. They were passionate about their subject in the same way William Blake was passionate about artistic creation. My take-away message is that this passion is also the means through which to kindle professionals' interest in digital capabilities.

As well as being a poet and an artist, Blake was also an engineer (who would perhaps have been horrified by my suggestion). Despite his negative perception of science, evidenced in his portrayal of Newton (Figure 7.1), Blake's artistic aspirations paved the way to his invention of a new, radical printing method, relief etching, to create unique pieces of art. His 'engineering' invention was a new 'technology', using acid-resistant copper-plates with brushes as if he was painting on paper, without being restricted to reproducing others' artwork (Viscomi, 2012). Blake's story is a perfect example of how innovations, albeit non-digital at this stage, are foremost in the profession (his art). It also captures the spirit of engineering as technology-creator, discussed earlier.

Figure 7.1 Newton by William Blake, 1795-c.1805 (credit: Tate, CC-BY-NC-ND, 3.0 unported)

However, once technology is available, it can dramatically transform professional practice. Viscomi (2012) argues that Blake's intention was to create a new method in order to be able to create his pictorial artwork, but once he saw that he was able to use brush-stokes for writing text on the plates, he came up with a new art form, the illuminated poem (Figure 7.2). Viscomi stresses that Blake's artistic innovation happened as a result of his technological invention, not vice versa as is commonly believed. This reflects exactly the signature digital capabilities, simulation and modelling in engineering, which are the results of technology transforming knowledge-practices.

Figure 7.2 William Blake, Songs of Innocence and of Experience *(1789), source: Wikipedia*

Blake, the poet, artist and – to my eyes – reluctant engineer, also embodies my final message. No profession is simply about science, the humanities, or social science. All share habits of the hand, mind and, most importantly, heart (Shulman, 2005a). This passion can surpass any disciplinary boundaries. It can be either the source or creative force behind technological transformation driving innovation. As a learning technology developer, harnessing this passion should be my starting point in order to support the digital capabilities of tomorrow's professionals.

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Appendix A – Interview guide: staff

Project title: Digital capabilities in curriculum design
Name of Researcher: Tünde Varga-Atkins

Prior to the interview:

- Module code?
- Schedule: Semester 1 or 2 or both?
- Module and programme specification documents, handbook?

Interview topic guide

Digital capabilities, digital literacies, digital/ICT skills will be used as interchangeable terms in the interview. Soft and hard skills related to ICT/digital capabilities are both included (e.g. not just functional and operational use of digital tools but also the etiquette and knowledge about how to use these tools in particular contexts and practices – not just how to use an email tool, what buttons to press, but the wider societal norms and etiquette of writing emails).

1. **About your discipline**
    - Can you – just very briefly – state your role and disciplinary background?
    - What do you think are the characteristics of a good Engineering/ Management student?
    - What do you think are distinct teaching methods in Engineering/ Management? *[as compared with other disciplines' teaching methods]*
    - Can you recall any significant digital development that has transformed or disrupted the field of Engineering/Management in recent years?

2. **Learning a bit about your module**
    - Can you describe the module, its aims, outcomes and assessment, and your role in the module?
    - Can you describe the nature of employer input in this module?
    - What wider contextual aspects, if any, have you drawn on whilst designing this module?
    - Can you talk a bit about students on this module with respect to their ICT/digital skills or capabilities? E.g. their prior digital experiences & expectations, or your observations of students' skills.

3. **Teasing out the digital, Part I – your module**
    - **Tasks, activities**: What tasks or activities have digital aspects in this module? E.g. critical use of information and data, online collaboration, communication, research online, use of digital tools, resources for learning, positive digital identity management, etc.

- **Assessment**: Do the module's (formative, summative) assessments contain any digital aspects? Any digital **artefacts** produced?
- **Learning outcomes & perceptions of student learning**: Do the module's learning outcomes contain or relate to any digital aspects? Whether explicitly/implicitly?

4. **Teasing out the digital, Part II – general perceptions**
    - Taking each of **the six elements of digital capabilities** [see below, overleaf – (1) ICT proficiency, (2) information/data/media literacies, (3) digital creation and innovation, (4) digital communication/collaboration/participation, (5) digital learning, (6) digital wellbeing and identity], please consider how it relates to Engineering/Management:
        - **How important** is each area in your discipline to develop in students? Is such development happening in the **curriculum**? If yes, can you give **examples**?
        - Does this **change as students progress** in the curriculum (Y1-3, PG)
        - What digital capabilities are **actually being** developed by students **(**expected and unexpected learning outcomes)?
        - Are there any students who are **disadvantaged** in any way in terms of digital capabilities either at joining, during or leaving the university?

5. **HE vs workplace setting**
    - Which digital capabilities do students of your discipline need to acquire for the workplace / as engineering or management professionals? Is there a difference in the above elements between the HE and the workplace setting?
    - *Or vice versa – any way the workplace needs to adopt to the digital capabilities of today's young workers?*
    - Anything from the employer involvement that has shaped the module?

6. **Summary** ***(and future – if time)***
    - In your view, what are the characteristics of a digitally capable (or skilled) Engineering/Management student (or professional)?
    - *What are your future plans for this module/programme?*
    - *If you had a magic wand, what would you want it to do for the university to help support the digital capabilities agenda in Engineering/Management?*

Six elements - Building digital capabilities in the curriculum

1.ICT proficiency

Are there opportunities for students to:

- Adopt new devices, applications and software? Troubleshoot failures? Design new solutions?
- Choose (and adopt) appropriate devices, applications and software relevant to their task?

2.Information, data and media literacies (critical use)

Are there opportunities for students to:

- Find, evaluate, manage, curate, organise and share digital information? Learn about copyright and creative commons?
- Collate, manage, access and use digital data e.g. in spreadsheets, databases or in other formats? [also: personal data security, legal, ethical aspects, algorithms]
- Critically receive and respond to messages in a range of digital media? [text, graphical, video, animation, audio; re-edit, curate digital information]
- Able to critically evaluate media messages in terms of provenance and purpose?

3.Digital creation, problem-solving and innovation (creative production)

Are there opportunities for students to:

- Using technology in innovative and creative ways?
- Design or create new digital artefacts and materials? E.g. digital writing, audio, video, presentations, apps, webpages, wikis etc.
- Use digital evidence to solve problems or answer questions? E.g. collect digital evidence/info, or evaluate/share the quality of digital info.
- Adopt and develop new practices with technology? E.g. for innovation, enterprise or project management.

4.Digital communication, collaboration and participation (participation)

Are there opportunities for students to:

- Communicate effectively in digital media – forums, social media, online video/audio – to different purposes and audiences? (Could include: to respect each other, to maintain privacy, an/or to deal with false or damaging digital communications.)
- Participate in digital teams and working groups through effective collaboration; produce shared materials, productivity tools; work across linguistic, cultural and social boundaries?
- Participate in, facilitate and build digital networks? (Could include: connecting with others in the same area, sharing/amplifying messages in networks, to behave safely and ethically in these environments.)

5. Digital learning and development

Are there opportunities for students to:

- Identify and use digital learning resources?
- Discuss their learning with others digitally?
- Use digital tools to organise, plan and reflect on their learning? E.g. blogs, portfolios, mindmaps
- Record, reflect on or showcase (their) learning events?
- Understand their own (digital) learning needs and challenges of learning online?

6. Digital identity and well-being

Are there opportunities for students to:

- Develop and project a positive digital identity(ies) and reputation across a range of platforms (personal and organisational)? Build and maintain profiles? Review the impact of online activity? Curate personal materials?
- Understand the risks and benefits involved in digital participation?
- Look after personal health, safety, relationships and work-life balance in digital settings? E.g. digital tools for personal goals (health/fitness), participant in social/community activities, act safely and responsibly in online environments, resolve conflict?
- Manage digital workload, overload and distraction? Switch-off when needed?