Technological coalescence, recombinant innovation and future work

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Certification of Research

This is to certify that, except where specific reference is made, the work described in this thesis is the result of the candidate. Neither this thesis, nor any part of it, has been presented, or is currently submitted, in candidature for any degree at any other University.

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This has been an amazing journey and one that I have enjoyed immensely and has only been possible with the help of the truly talented and collaborative people I have been fortunate to cross paths with – Thank you!

Abstract

Workers are constantly reminded that computers, machines and technology such as artificial intelligence will replace them, jobs can be automated and humans replaced by machines. A dystopian view of the future world of work is portrayed. The pace of technological change is accelerating and workers are being left behind with the fear and expectation that they will be replaced. This research challenges the dystopian view that technology will replace humans in the workforce and that the end of work is near. It discredits the claim of technological substitution in the workplace and puts the human worker at the heart of future work.

This thesis followed a mixed method, empirical design that followed an abductive approach, through expert knowledge utilising a two round Delphi approach, triangulated with historical quantitative data and with semi-structured follow-up interviews. The methodological choices present a novel and original approach to exploratory study, building on the best practices of others to explore an area of economic and societal importance, exploring the impact of technological change on future high skilled professional work.

The original contribution to knowledge presented in this thesis is a human centric competency and contextualisation model. The model captures six significant areas of competency that represents a human comparative advantage that professional workers provide over emerging technological change. These areas are an ability to 'assess, create, relate, adapt, prioritise and filter.' These six areas enable complex contextualisation that technology cannot replicate and replace. This model informs policy owners and makers along with individual students and workers on the key competency areas that need to be taught, learnt and developed for future professional roles. In addition to the competency and contextualisation model this research delivers a recommended approach of workforce coalescence. Furthermore, this research acknowledges the need for ethical compliance and governance over the use and adoption of technology and identified this as an important emerging area of future human job growth, with new roles required in this field. The model of workforce coalescence emphasises the need for augmentation and integration with technological change, driven by human contextualisation and ethical adoption, further dispelling the myth of technological threat to workers and presenting a more complementary existence for economic and societal benefit. In an area that has been obfuscated by a varied array of interpretation and individual definition this thesis presents clarity on what constitutes technological change, establishing a baseline for future research and literature. It supports the seminal definitions of historical figures who coined terms such as Artificial Intelligence, reiterating and re-establishing the term as a science.

Contents

List of Tables

The first number denotes the chapter number of the table.

List of Figures

The first number denotes the chapter number of the figure.

Copyright Statement

1 Chapter 1 Introduction

1.1 Introduction

This chapter is structured across ten sub-sections, starting with an explanation of the background and context for the research, followed by an overview of the existing literature. The motivation for conducting this research along with the purpose of this research is provided, describing the challenge this research is addressing through the research aim and objectives, which are captured in a further sub-section. The research and analysis approach that were taken to achieve the research aim and objectives is described, followed by details of the original contribution to knowledge that this research thesis delivers. The remaining sub-sections provide a rundown of the thesis structure and a summary that closes this inaugural chapter.

Technological change disrupts the workforce (Alin, 2017; Jarrahi, 2018); The internet, digitalisation, automation, robotics, cloud computing, artificial intelligence, machine learning, the internet of things and blockchain are all areas of technological change which have created a skills bias (Deming, 2017; Benzell *et al.*, 2019) within the workforce, driving a demand for professional and higher skilled workers. This thesis explores the impact of technological change on future high skilled professional work. It explores the areas of; human comparative advantage; considers the potential future job roles alongside technological change and discovers the views of existing professional workers on future work. The exploration into the impact of technological change and future high skilled professional work is to investigate the considerations for education and corporate organisations to inform and prepare future training and readiness policies, programmes and courses.

1.2 Research Context

Industries are being affected by technological advancements that are being claimed as the Fourth Industrial Revolution (Schwab, 2017). The Fourth Industrial revolution focuses on the technological advancements in data and internet connectivity. Technological advancements from the 1970s onwards were hailed as the third Industrial revolution which introduced electronics, information technology (IT) and automation of production lines. During the eighties, nineties and into the new millennium technological change included exponential growth in computing power (Greenstein, 2015), along with the introduction of connectivity capabilities of the internet and the sharing ability of the world wide web (Berners-Lee *et al.*, 2010). The introduction in 2006 of cloud-based services in addition to the advancements in computing power triggered a revival in the field of Artificial Intelligence (AI) which was a historical area of innovation that had stalled (McWaters, 2018). The ability to collect data through remotely located sensors has driven a further specialism, the Internet of Things (IoT) and the growth in access to data has led to a focus on '*Big Data.*' This abundance of data has fuelled machine learning techniques which look to mimic or replicate human level intelligence under the science of AI (McCarthy and Hayes, 1969; Stone *et al.*, 2016). These areas of technological change have and are disrupting how people carry out their day-to-day work. Figure 1-1 captures some of the technological change that has been developed, launched or enhanced over the last fifty to sixty years and demonstrates the rate of innovation and change that technology has driven. These technological inventions and enhancements have disrupted how we live and work (Marnewick and Marnewick, 2019).

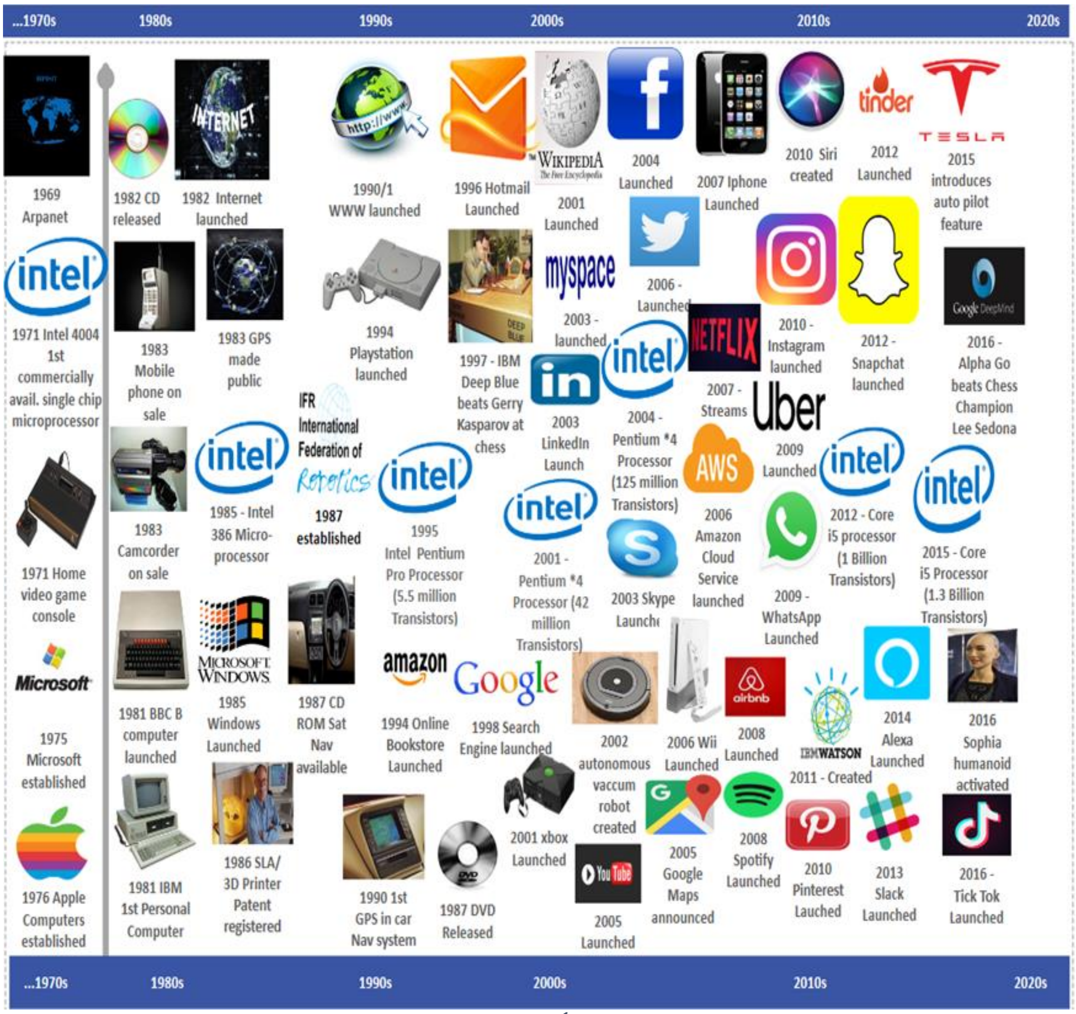

Figure 1-1 Chronological Technological Change[1]

Workforce disruption is not a new phenomenon, the earlier industrial revolutions, the first and second are historical milestones in relation to the change and societal impact that ensued. The introduction of mechanical equipment towards the end of the eighteenth century powered by water and steam signalled the first Industrial Revolution and significantly disrupted the cotton and agricultural industries. Weaving or loom machinery threatened the livelihoods of seamstresses and the Luddites notoriously demonstrated their outrage at the threat machinery poised to people's livelihoods. The term '*Luddite*' is now associated with someone who opposes technology or change (Jha, 2020).

[1] *The logos represented in this thesis do not endorse the products or services in any way and merely capture the technological timeframe of their creation to demonstrate technological evolution over time and publicly available logos have been utilised to depict the evolution of technological change.*

The second industrial revolution ninety years on from the first, in the 1870s also disrupted the workforce through the introduction of mass production lines and electricity. A consistent theme that emerged across all three of the previous industrial revolutions is the claim of a '*division of labour*,' which relates back to Adam Smith (1776), whose seminal literature '*A Wealth of Nations'* referred to the importance of taking advantage of the different skills workers have to drive efficiencies. Ricardo (1817) forty years later called this advantage, the '*Comparative advantage*.' At the beginning of the third Industrial revolution, Simon (1969) made a number of predictions for 1985 addressing a question that he had been posed, "The Corporation: Will it be managed by machines?" His predictions included an important claim that there is a fundamental difference between humans and computers highlighting that they have different cognitive comparative advantages.

Adam Smith (1776) described a division of labour, this was further supported by research conducted over two hundred years later by Levy and Murnane (2004). They examined the workforce impact during the third Industrial revolution, between 1969 and 1999. Levy and Murnane highlighted a '*displacement*' effect as a result of technological change. They articulated specific occupations in the US that had been displaced, focussing on wage inequality because of the job displacement. Significant research has built on the findings of Levy and Murnane (Autor, 1998; Goos,Manning and Salomons, 2009; Bogliacino,Lucchese and Pianta, 2012; Katz and Margo, 2014; Murphy and Oesch, 2017; Autor and Salomons, 2018; Acemoglu *et al.*, 2019; Autor *et al.*, 2020; Spencer and Slater, 2020; Spencer, 2020). The abundance of literature focused on the polarisation of work from a wages and skills perspective, with emphasis on the socio-economic inequality of the low skilled worker because of technological change. The literature acknowledged the demand for high skilled workers through a claim of '*Skills Biased Technical Change*' (SBTC) (Benzell *et al.*, 2019) however, there is a paucity relating to research in this area of high demand. Benzell et al. highlighted the requirement for governments and individuals to recognise the importance of understanding the need for workers to retrain and adopt new skills to address the challenge of SBTC. Understanding the skills and retraining requirements were stipulated as being a crucial factor in the evolution of the workforce.

1.3 Research Gaps

The existing literature captured six key perspectives which are highlighted below in bold in relation to the impact of technological change on the workforce.

- Technology creates a **displacement effect,** displacing workers from existing jobs, changing the work carried out at the activity and task level.
- Displacement presented a further claim of **job polarisation**, where technology substitutes the middle layer of work polarising workers to lower or higher skilled work.
- Job polarisation led to a claim of **Skills Bias Technical Change** (SBTC) towards higher skilled workers, creating an inequality for the lower skilled.
- Technology substitutes people's jobs, resulting in **technical unemployment.**
- Technology triggers **job creation**, either through more demand for existing jobs, supporting the view of polarisation, or net new roles.
- Technology drives a dual effect called **creative destruction** or a reinstatement effect. This is where technology replaces jobs and is then followed by a compensation effect where new jobs are created.

Literature to date has focused on the historical impact of technological change, looking backwards at what has already occurred and adopting quantitative research methods, to quantify the historical impact (Rumberger and Levin, 1985; Levy and Murnane, 2005; Autor, 2019). Furthermore, the literature has focused on the socio-economic inequalities as a result of technology, the unemployment, the inequality in wages of the lower skilled workers as a result of the hollowing out of the middle layer of work due to automation (Frey and Osborne, 2017).

A significant gap in the literature presented itself, in relation to the scarcity of literature on the potential job creation along with understanding the comparative advantage associated with the claimed SBTC job roles which require a higher skillset. A recent article (Archanskaia,Van Biesebroeck and Willmann, 2020) captured the need for acknowledgement from Government bodies in relation to the substitution of routine work which was carried out by humans and is now fulfilled by machines. This highlighted the need for further consideration to be given to how non-routine work complements the routine tasks carried out by machines. This reinforces the need for research in exploring the comparative advantage of humans alongside the comparative advantage of machines. This thesis addresses the gap in existing literature by exploring the impact of technological change on future high skilled professional work.

1.4 Personal Research motivation and rationale

Having spent twenty years working in the Information Technology (IT) sector within major global organisations I have observed an increase in demand for high skilled workers both within the organisations I have worked and across customer and partner organisations. Recruitment and training are constant activities and meeting the rising demand as technology matures is a growing challenge. Technology has the potential to bring huge societal benefit if deployed responsibly and ethically and to achieve this, organisations need to prepare and develop their staff and students through educational programmes and courses to be able to fulfil the future work demand. The lack of reliable literature that explores the potential positive impact on future professional work raises concerns and a fear of lost opportunity for many. This thesis and research study contributes to knowledge by addressing the gap in literature to help organisations and individuals prepare for a future which can provide significant job opportunities to complement and optimise the innovation being presented through the maturing technological change. As a mother of three children, I am motivated to contribute to knowledge and practice relating to the future workforce. As a professional leader, coach, and mentor to others I strive to encourage others to develop key skills and to invest in their personal development and growth. To be able to do this the required skills need to be understood and captured to inform educational and organisational training policies, strategies, plans, approaches, programmes, and courses.

1.5 Purpose Statement

The purpose of this thesis is to address the gaps in existing literature through exploration of the impact of technological change on future high skilled professional work in the developed world. To help inform educational and organisational training policies and plans to encourage workers into higher skilled jobs.

The identified gaps in literature relate to the following areas that have not been explored or captured in the existing literature:

- What impact is projected for the future high skilled professional work alongside the technological change.
- Skills biased technological change is cited in the literature, however what this looks like is not captured. It is unclear whether there are skills that high skilled professional workers could have an advantage over technology and should focus on developing.
- Are there specific skills or competency areas to integrate and complement the maturing technology that workers, organisations and education programmes should be focusing on.
- The area of job creation does technological change create or drive a demand for new job roles or for existing roles to be updated to align with the technological change.
- Aspects Existing literature suggests there is a negative perception relating to technological change and future work. It is unclear whether this view is shared amongst existing professional workers who are working in high skilled areas.
- What considerations should educational and corporate organisations be adopting when planning and scoping training and readiness courses for students and workers to meet future high skilled workforce demands?

Technology has substituted the middle layer of work, driving workers to lower skilled and lower paid work along with driving a demand for higher skilled workers. To meet the demand of higher skilled work, training and development programmes are required to encourage and support displaced as well as new workers into the higher skilled and paid roles.

For education and corporate establishments to be able to update their training policies, approaches, plans, programmes and courses, insight is required into the types of skills and work that individuals need to develop and learn. My analysis has identified that there is a gap in the existing literature where studies have omitted to offer meaningful and informed insight to meet the demands to help inform organisations to meet the demand for future higher skilled workers and a skills gap has emerged alongside the emerging technological change.

1.6 Research Aim and Objectives

The identified gap in literature supported the need for further research in relation to technological change and the higher skilled workforce. The gap reinforced the contribution to original knowledge that this thesis provides by answering the following research aim:

Research Aim

To explore the impact of technological change on future high skilled professional work.

Four research objectives underpinned this research aim and provided specific areas of exploration that had not been addressed through the existing literature. The objectives acted as a research navigation tool, guiding this research keeping it on course and ensuring the research aim was at the heart and centre of the study. These objectives were pivotal in this research aim being achieved.

Research objective 1

To explore the human centric skills, the skills that are not easily replaced or substituted by technology

Research Objective one acknowledges that organisations need to be able to inform and build educational and organisational policies. These policies would inform training plans and programmes. Clarity was required on the types of skills that technology may struggle with or is not best placed to carry out. The significance of this objective is to understand the skills that present a human comparative advantage over the technology. This knowledge enables organisations to build training courses and programmes so that individual students and workers can learn or develop the required skills and competencies for higher skilled work.

Research objective 2

To explore the potential future high skilled occupations

Research objective 2, addresses the gap in literature relating to job creation. Existing literature acknowledged that technological change does create jobs, highlighting demand for high skilled work. However, the existing literature does not articulate what jobs could be created within the high-skilled area of work. The significance of this objective is the identification of key high skilled roles that informs educational and organisation policies, which in turn feeds the training programmes and courses to enable the training and development of individuals, into such roles to meet future workforce demands.

Research objective 3

To explore the views of future high skilled work from existing professional workers

Research objective three is to validate the negative views presented in the existing literature (Kurzweil, 2005; Ford, 2015; Bostrom, 2017; Frey and Osborne, 2017;

Huang and Rust, 2018; Susskind, 2020) that the end of work is near and that technology will substitute work. The key focus of existing claims and findings relate to unemployment and inequality. This objective through adopting an original and novel methodological approach, sought the opinion of existing high skilled professional workers, to verify and subjectively gain insight into existing perceptions and views on future high skilled work alongside technological change. The relevance of this objective is that it provides a counterclaim and an informed balanced view to help organisations build communication policies and plans to workers and students on the views of future high skilled work. Balancing the existing negative views that are widely captured which could discourage workers from retraining or following work within a high skilled area.

Research objective 4

To explore the key considerations for organisations, workers and students in relation to future high skilled work

The last research objective, number four evaluates the findings from the previous three objectives and captured the important considerations in relation to future high skilled work. The significance of this objective is that it contributes to knowledge by making recommendations to organisations, workers and students in relation to the skills and occupational training requirements that education and corporate organisations need to be establishing to meet the demands of the future high skilled workforce. Without these considerations training courses and programmes would remain the same and the skills shortage will grow. Insufficient supply of workers could have a detrimental impact on the productivity capability of businesses that underpin the economic position as captured in the UK Government Industrial Strategy document (Department for Business, 2017).

This section has explained the research objectives of this thesis that have enabled the research aim to be achieved. The next section will explain how this research was conducted, describing the research and analysis approach.

1.7 Research and Analysis Approach

This research followed an empirical mixed method approach, exploring expert opinion across developed markets through a two round Delphi study, with a phase of triangulation with government quantitative and qualitative data. A further phase of semi-structured follow-up interviews were used to validate respondent themes from the Delphi data.

The mixed method data analysis approach adopted a quantitative statistical approach applying Kendall's coefficient of concordance (w) to evaluate the level of agreement across the expert panel, which resulted in a level of agreement being recorded (Schmidt, 1997; Saunders,Lewis and Thornhill, 2012). Qualitative data, returned through the Delphi rounds and from the interview transcripts were analysed through the application of thematic analysis (Clarke,Braun and Lane, 2014) a six stage method that enabled the exploration of themes from qualitative data.

The approach contributed to original methodological knowledge building on the proven Delphi approach (Dalkey and Helmer, 1963; Linstone and Turoff, 1975; Gary and Von Der Gracht, 2015; Bloem da Silveira Junior *et al.*, 2017; Bokrantz *et al.*, 2017; White, 2017; Forbes *et al.*, 2018; Khallaf,Naderpajouh and Hastak, 2018; Khan and Bhatti, 2018; Samuel *et al.*, 2018; Strohmeier, 2018; Kawamoto *et al.*, 2019; Yeoh, 2019) through using novel digital channels to increase expert participation and achieved high response rates across both rounds. The methodological approach further demonstrated originality through triangulating government data to validate findings and via a further phase of validation and respondent verification through follow up interviews, which also utilised digital tooling to record and transcribe the interviews.

This section has described how this research was conducted; Chapter 4 of this thesis provides further detail on the method and approach adopted. The next section will outline the contribution to knowledge that this thesis presents.

1.8 Contribution

This thesis provides an original contribution to knowledge by exploring a gap in existing literature on the impact of technological change on future high skilled work. This research revealed key human centric skills that fall into two areas, worker characteristics and worker requirements. A novel and unexpected finding from this research revealed that experts believed that a worker's characteristics (how people approached work, their abilities, styles and values) were more important than the worker requirements (specific skills and knowledge). This weighted belief towards the importance of how people approach work over the specific skills required to carry out a job is significant as it challenges educational and training considerations for the future. One interpretation is that organisations need to encourage workers to be more flexible in how they approach change, encouraging and developing work styles that are creative and promote abilities such as idea generation, reasoning, empathy, emotional intelligence, social influence such as leadership and interpersonal orientation. This research acknowledges that key skills such as complex problem solving, specialist skills both technical and non-technical are still important to high skilled work. However, this research identifies the importance of how workers adapt to change and the need for flexibility as being a stronger factor. This research reveals key competence areas for high skilled workers, the top four were:

1. An ability to change and learn.
2. Analytical, interpretation, problem solving and critical thinking.

3. Creativity, Innovation and curiosity.
4. Empathy and Emotional Intelligence (EQ)

This research recommends that organisations, both educational and corporate need to accommodate and develop the four competences alongside the more traditional worker requirements. The worker requirements were captured in this research as role specific knowledge and skills, these included STEM subjects, technical skills and system skills training.

This research made a theoretical contribution capturing a clear comparative advantage that high skilled human workers have over technology. The comparative advantage areas are captured in the four skill competencies articulated above. The interpretation that was made is that these four are key human advantage competencies are areas that technological change would struggle to replace. Furthermore, the four competencies are required to augment technology to help optimise value and business benefit.

This research provided theoretical contribution to knowledge by capturing an area of human comparative advantage over technology. Presenting competency areas that drive an ability for humans to contextualise situations. This is a significant differentiator for high skilled human workers. Pilots, doctors, nurses, teachers, engineers, scientists, all professional workers evaluate multiple variables as a result of the innate human competency model; this is achieved through contextualisation which enables prioritisation of appropriate action at that specific time. This is a limitation of technology and as a result should be captured as a significant human comparative advantage that organisations should harness and promote within worker evaluations. This thesis captures a theoretical human competency contextualisation model that helps organisations and individuals visualise the required human competencies. This thesis captures how the skills augment to form the additional human centric skill of contextualisation which underpins workplace and societal prioritisation of actions.

This thesis provides a practical contribution to education and organisational policies and plans along with future communication considerations by presenting a model of coalescence. This model articulates the required human competency areas alongside technological change, it also acknowledges a further requirement for future technological adoption which creates additional human high skilled work, the need for ethical compliance and governance.

In addition to the human centric competencies, this thesis contributes to original knowledge by consolidating and presenting the areas that constitute technological change, providing practical contribution to individual students and workers along with policy makers and readiness planners by providing a more contemporary and practical definition of what is included in the term technological change. Figure 1-2 outlines the technological change topics presented in this thesis and are described in more detail in section 2.5.

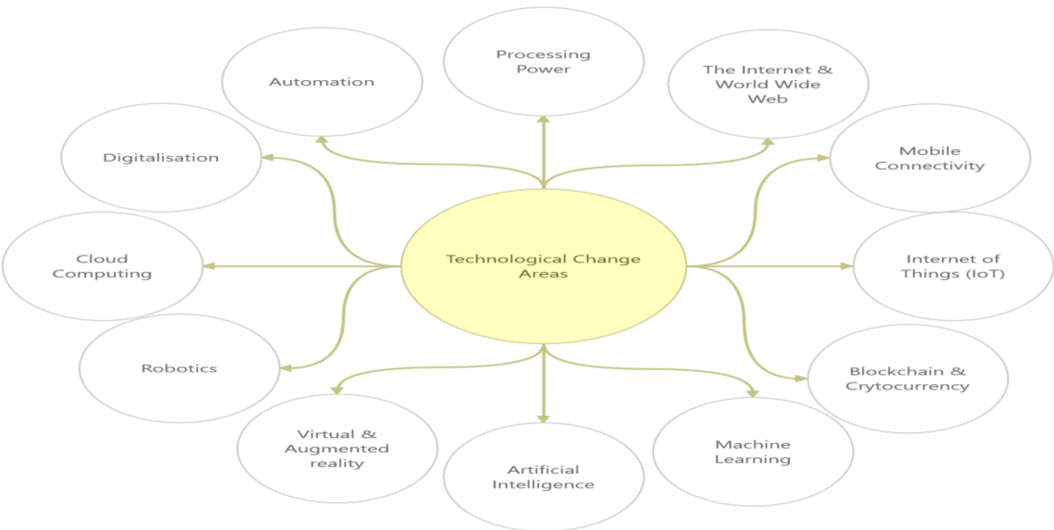

Figure 1-2 Areas of Technological Change

1.9 Thesis Structure

This thesis has been structured over eight chapters. This section will explain the chapter layout and the purpose of the eight chapters and how they flow through this thesis. Figure 1-3 provides a diagrammatic map of the eight chapters.

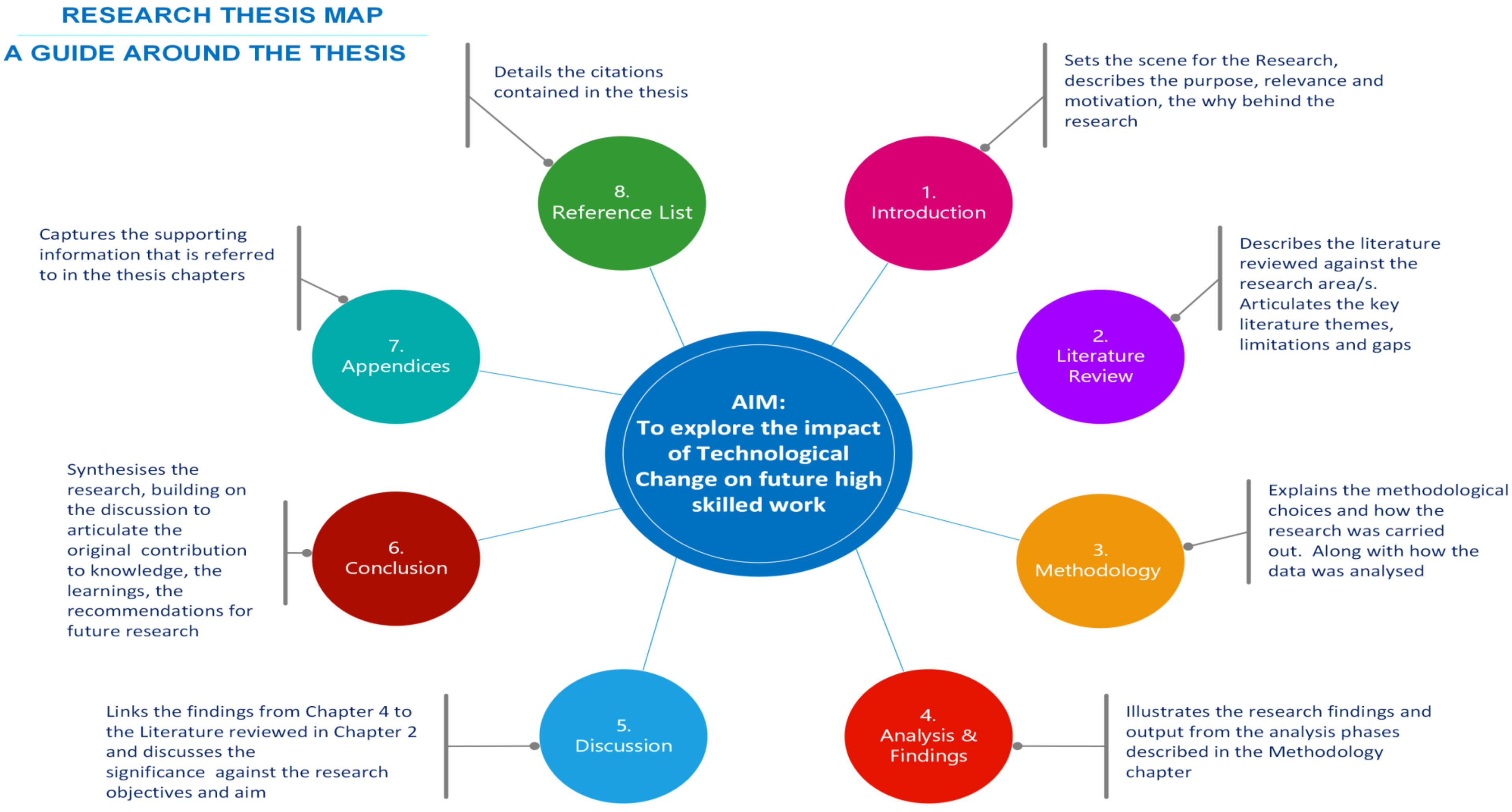

Figure 1-3 Thesis Map

Chapter 1 – This is this chapter, the **Introduction**. Its purpose is to introduce the research topic and provide context, describing the relevance of the research, along with the motivation and contribution it provides.

Chapter 2 - The Literature Review. This is broken down into nine sub-sections that explore and examine the existing literature in relation to the research aim. The chapter helps inform this research evaluating the view of others and validating the existing perspectives and claims to substantiate that there is a gap in existing knowledge that needs to be addressed and that further contribution to knowledge is merited.

Chapter 3 – Methodology Chapter. This Chapter is structured through thirteen sub-sections which capture the philosophical considerations, the research approach along with the research methods and analysis techniques applied. The chapter also shares the ethical considerations and research limitations along with the research timeline. This chapter explains how this research was conducted.

Chapter 4 – Analysis and Findings. This chapter captures the output of this research following the collection of data through the Delphi, triangulation, and interview phases and after the analysis phase had been completed. Chapter 3 explained how this research had been conducted and this chapter focuses on the data that had been collated.

Chapter 5 – Discussion. Following on from the analysis and findings chapter, this chapter interprets and discusses the implications of the findings in line with the literature that was reviewed in chapter two. The chapter provides meaning to the analysis and findings whilst also acknowledging the existing literature and knowledge that exists, highlighting where the findings agree, complement, or contradict the views and claims of others. The discussion chapter is broken down into seven sections that link back to the research aim and objectives to synthesise the findings against existing literature.

Chapter 6 – Conclusion. This section has nine sections and describes the relevance, impact, and consequences of the research. It is the finale of this thesis and encapsulates the contribution from the research. This chapter articulates the original contribution this thesis makes along with considerations for further research and reflections by the researcher.

Chapter 7 – Reference List. Contains a detailed list of the references, in a Harvard referencing format of all the citations contained within this thesis.

Chapter 8 – Appendices. Contains the supporting documentation that is referred to in this thesis.

1.10 Introduction Summary

This chapter has introduced the research area, explained the research contribution to knowledge and provided context along with the purpose of this research contained within this thesis. It has articulated the existing literature perspectives and claims and highlighted the research gaps that were addressed through the research aim and objectives. An introduction was provided into the research methods and approach and the structure of this thesis defined along with a diagrammatical map. The next chapter evaluates the existing literature in relation to the research aim, to explore the impact of technological change on future high skilled work and begins with a chapter overview.

2 Chapter 2 Literature Review

2.1 Chapter Overview

This chapter sets out a discussion on the existing literature relating to the impact of technological change on future work. The literature is being reviewed to understand and illustrate the key theories, previous research and published opinions and deliberations that have been captured to date, in relation to the research aim, '*To explore the impact of technological change on future high skilled professional work.*' The chapter is organised into nine sub sections, starting with an overview of how the literature review was carried out and details on the types, numbers and journal ratings associated with the findings. The review approach section also includes a summary of the key literature topics. The latter sub-sections are structured by chronology, capturing the historical and current opinion, perspectives, theories and debates on technological change and future work. Following the chronology there is a summary of the key claims and evaluation of the gaps in relation to the research aim and confirmation of the research objectives.

2.2 Literature review approach

A structured literature review was conducted, using an initial key word search in google scholar and the university FindIt tool. Figure 2-1 captures the key word combinations and the number of items returned. The search results were then reviewed and added to a citation and database tool, EndNote. This was done from the beginning of this research journey to help organise the literature and provide a simple search facility against literature that had already been found and reviewed. Building on the initial search by keyword the literature review was expanded by applying a '*snowball*' approach (Webster and Watson, 2002; Jalali and Wohlin, 2012), identifying key authors and cited articles from the initial items found through the key word searches. This snowball approach extended the evaluation and literature analysis further to enable submergence into the research topics. This supports the view that this is an emerging area of interest. The need for further research and papers is supported by Spencer and Slater (2020) and others (Kadir,Broberg and da Conceição, 2019; Kadir and Broberg, 2020) who highlight the lack of literature in emerging areas of technical change such as IOT and Industry 4.0 related technology.

This approach was followed until a point of data saturation. Boell and Cecez-Kecmanovic (2014, p.272) referred to saturation as being identified when you experience, "*diminishing novelty when reading additional literature and only marginal improvements in understanding the research problem.*" Another benchmark for determining saturation is where articles start to re-present themselves and no new literature, claims or theories are discovered through newly discovered publications. Saturation was achieved, articles started to reappear in searches and articles that were being reviewed. Saturation was also demonstrated by no new theories or debates being discovered, along with the repetition of authors and articles, no new claims emerged, the literature reinforced the focus of literature already identified.

As anticipated the initial search results returned very high numbers (millions). The search parameters were updated to help identify a more manageable number to review. Figure 2-1 captures the key word searches and the volumes returned. The initial word search choices returned high numbers of articles that were not practical to fully review, such as over six million against the '*Future of Work*,' even sorting on relevance the search returned high numbers of items, with books featuring more than articles. A learning from the key word search was to be specific in the terminology and use inverted commas to help focus the results on the areas of interest. Table 2-1 captures the learning of starting broad with key words and the need to focus on the multiple areas within this research aim. These included, '*technical change + humans + future skills'* or '*technical change + humans + future* *jobs,'* these returned more manageable and relevant results and helped initiate the snowball approach.

Search Key Word/s	Google Scholar Search Return		
	Open search no date range*	Initial Data Range 2012 - 201	Data Refresh Range 2018 - 202
Future of Work	6,020,000	2,100,000	661,000
Technical Change	6,650,000	2,380,000	429,000
Technological Change	4,110,000	1,680,000	208,000
Automation	4,560,000	1,470,000	106,000
2050 + Work	1,230,000	374,000	84,100
Industry 4.0 + Future work	1,180,000	139,000	75,000
Comparative Advantage + Work	4,030,000	1,640,000	72,100
Future skills	4,870,000	743,000	51,000
Future forecasting + work	2,800,000	541,000	40,900
Future Professions	1,810,000	210,000	36,100
Future Work Force	5,490,000	493,000	30,000
2030 + Work	1,120,000	247,000	30,000
Future jobs + technical change	1,730,000	258,000	28,700
2025 + Work	800,000	151,000	27,500
Future Workforce + technical change	1,150,000	130,000	24,200
Professions + Future	1,810,000	207,000	23,000
Technological Unemployment	1,980,000	74,700	22,500
"Technology" + "humans" + "Jobs"	407,000	64,600	21,860
Comparative Advantage + Jobs	842,000	114,000	20,900
2040 + Work	693,000	132,000	20,900
Automation + Jobs	524,000	54,900	20,600
"Automation" + "Jobs"	575,000	49,700	20,400
Job Displacement	817,000	74,500	20,000
Creative Destruction + Technology	621,000	54,400	20,000
Creative Destruction + Technical Change	467,000	46,500	19,900
Artificial Intelligence + Jobs	274,000	36,500	19,500
Job polarization	421,000	41,000	18,600
Comparative Advantage + Employment	2,730,000	69,800	18,400
Future skills + Industry 4.0	260,000	33,000	18,400
Industrial Revolution 4.0 + future work	124,000	21,500	17,600
"Comparative Advantage" + "Employment"	256,000	24,800	17,400
Worker Displacement	304,000	27,200	17,200
Future Workforce + technological change	1,020,000	18,500	17,000
Technology Foresight	282,000	38,900	17,000
"Comparative Advantage" + "Work"	461,000	38,800	16,400
"Future forecasting" + "work"	461,000	38,800	16,400
Future jobs + technology	4,330,000	17,900	15,300
"Comparative Advantage" + "Jobs"	121,000	18,500	12,600
Job polarisation	70,100	16,500	9,170
"evolution of technology"	36,400	15,900	7,810
"Industry 4.0" + "Future work"	8,960	2,100	6,710
"Creative Destruction" + "Technical Change"	14,300	5,080	2,010
"Job creation" + "technical change"	11,700	3,690	1,680
"jobs of the future"	6,790	2,630	1,280
Future work + "technical change"	7,960	2,450	1,180
"jobs of the future" + "technology"	5,590	2,190	1,130
Future employment + "AI"	625,000	1,670	1,090
"Automation" + "Future Jobs"	2,990	918	922
"workplace" + "technology" + "human" + "coalescence"	3,960	1,340	787
"Technology" + "humans" + "Future Jobs"	2,970	1,120	770
"Future employment" + "Artificial Intelligence"	1,870	581	715
"Job creation" + "emerging technology"	2,690	1,160	557
"convergence" + "technical change" + "future work"	2,040	627	423
"Future skills" + "Industry 4.0"	352	59	277
"human" + "technology" + "workplace integration"	1,080	412	216
"Future employment" + "technology"	49,400	289	154
"business and employment" "artificial intelligence"	285	89	154
"human" + "technology" + "job integration"	582	180	54
"socio-technical theory" + "Future work"	275	119	45
"Technical Change" + "humans" + "Future Jobs"	117	40	42
"technological augmentation" + "Jobs"	164	66	35
"Technical Change" + "humans" + "Future skills"	70	15	28
***refreshed March 27th 2020**			

Figure 2-1 Literature Review key word search

The broader key word searches were filtered more by date to help reduce the initial high numbers and the first few pages of results reviewed, if the abstract and conclusion contained pertinent scope the full article was reviewed and the author citations noted and then looked up in Google Scholar and or FindIt as part of the snowballing approach previously set out in this section.

There was an increase in articles being published since 2018 in relation to this research aim and associated topics, namely the following two key word searches: '*technical change + humans + future skills'* or '*technical change + humans + future jobs,'*

Figure 2-2 captures the six key word search combinations that returned an increase on items published after 2017. Noting that 2018 to 2020 captures a much smaller timeframe, fifteen months, whereas the 2012 to 2017 range captures a five-year window of published literature.

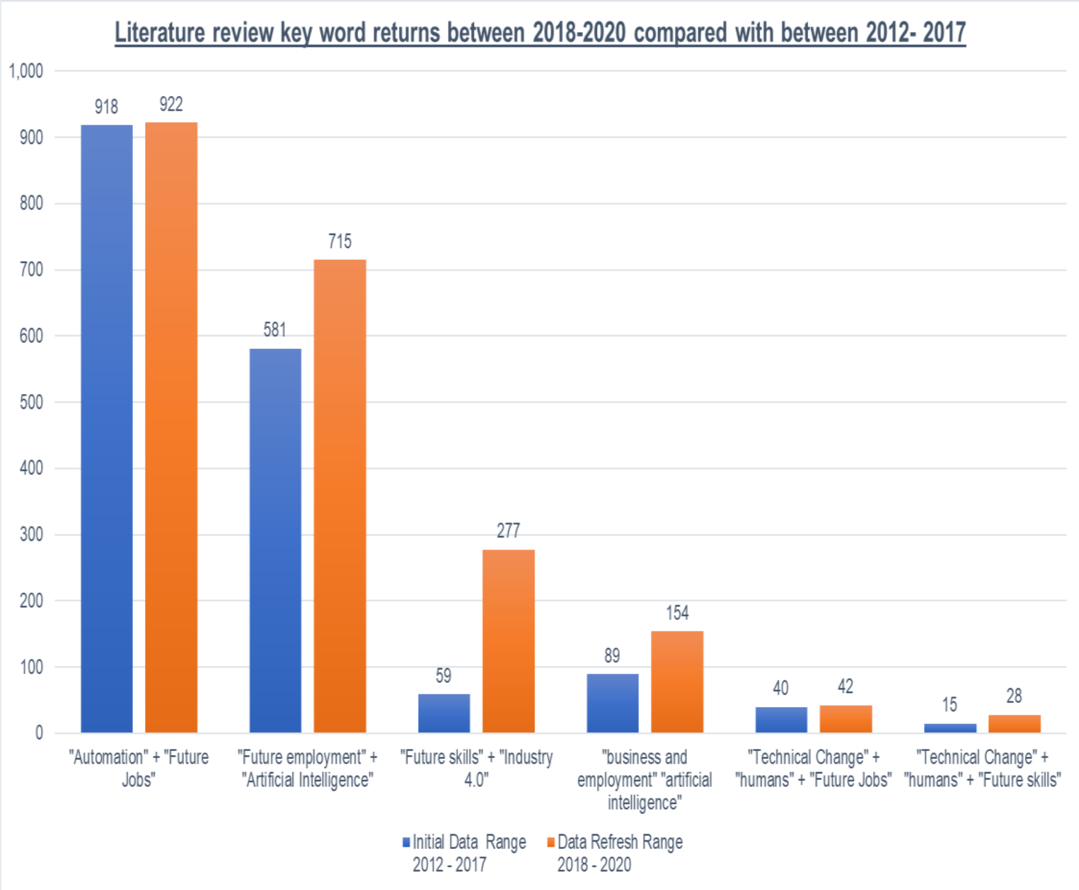

Figure 2-2 Literature review key word search increases after 2017

The literature review captured 2,460 items of literature (see Figure 2-3) The number of items were condensed by a high level first pass. Which was reviewed the abstract and conclusions to appraise relevance to this research area of technological change and future work; approximately 1,000 of these items were directly linked to AI, when the abstracts were reviewed, they had no reference to workforce impacts, either skills or occupations and they were filed in Endnote under technical AI.

Once articles had been identified through the key word searches and snowball approach, the journals where the articles were published were cross referenced with the ABS Ranking, by looking up the ISSN number or searching for the Journal name (CABS, 2018). The identified ranked journal articles were flagged by allocating stars against them in the EndNote tool. This was to help identify the rated literature on the research topic. See Appendix 8.1 for the full list of identified ABS rated journals containing articles that provided insight and debate on this research aim. Figure 2-3 provides a breakdown of the 2018 ABS Ratings and the number of articles associated with the reviewed literature. The pie-chart captures the literature count and the percentage next to each segment. Almost two thirds of the literature identified were not from ABS rated journals (65%). These sources included other peer reviewed journal articles; Conference proceedings documentation; Government reports (Green and White Papers); Standards, Industry reports; Post Graduate Theses; Industry Books and Online Media articles. The 35% from ABS rated academic journals, were broken down across the 5 categories; 1 or 2 rated journals contributed 24% (16% being one and 8% under a two rating). 6% came from articles with a rating of three, 2% with four and lastly the remaining 3% had the highest rating of four*.

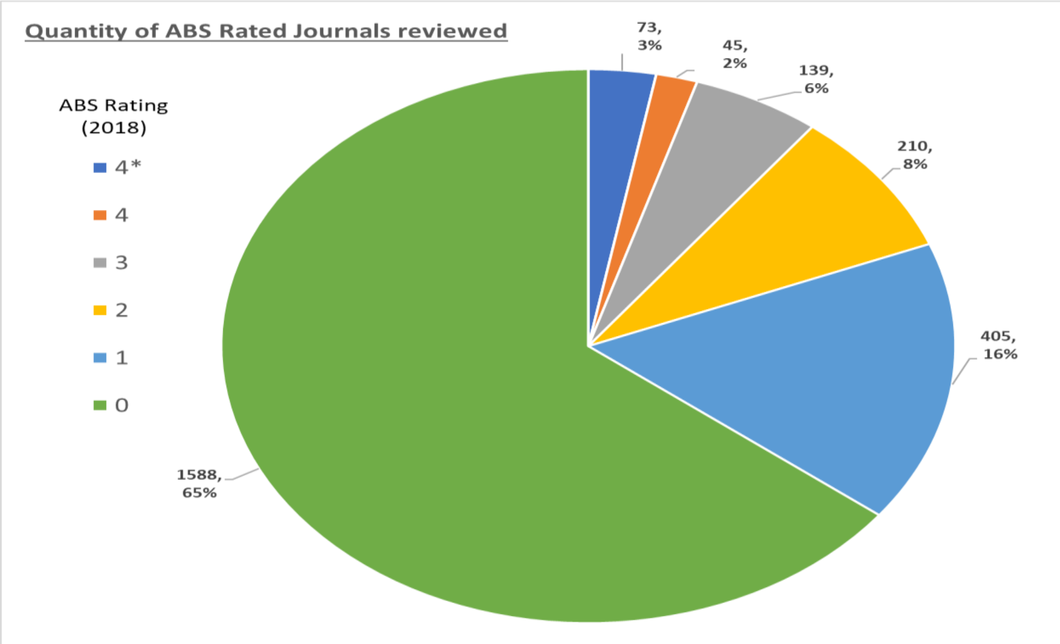

Figure 2-3 Breakdown of journals by 2018 ABS Rating

The key journals that published germane articles in relation to the research aim and objectives were (CABS, 2018): *Technological Forecasting and Social Change, Industrial Management and Data Systems, Strategy and Leadership, Foresight, Journal of Knowledge Management and Research Policy* journals. Other key sources, outside of the ABS Rated journals were from: *Industry reports from Mckinsey Global Institute, The World Economic Forum Reports, conference papers and Communications of the ACM*. Table 2-1 captures the article count by ABS journals, the table captures the journals where the count was equal to or more than five articles as captured in the Endnote tool. The high volume of articles (160) logged under the '*Kybernetes*' Journal related to the technical AI articles that were filed in endnote as not being linked to future work after a review of the abstracts.

Journal	1	2	3	4	4*
Kybernetes	160				
Technological Forecasting and Social Change			46		
Industrial Management & Data Systems		35			
Strategy & Leadership	27				
Foresight	24				
Journal of Knowledge Management		24			
Research Policy					21
Futures		18			
Journal of Service Management		17			
Business Process Management Journal		16			
Management Decision		15			
Communications of the ACM		15			
Benchmarking: An International Journal	14				
Worldwide Hospitality and Tourism Themes	14				
The Quarterly Journal of Economics					12
New Technology, Work & Employment			12		
Journal of Quality in Maintenance Engineering	11				
American economic review					10
Journal of Manufacturing Technology Management	9				
Journal of Business Strategy	9				
Journal of Science and Technology Policy Management	8				
Journal of Systems and Information Technology	8				
International Journal of Web Information Systems	8				
Engineering, Construction and Architectural Management	7				
Online Information Review	7				
Tourism Review	7				
Computers in Human Behavior			7		
International Journal of Operations & Production Management				7	
Organizational Research Methods				6	
International Journal of Contemporary Hospitality Management			6		
Academy of management journal					6
Work, Employment and Society				6	
International Journal of Productivity and Performance Managemer	5				
Academy of Management Review					5
Journal of Strategic Information Systems			5		

Table 2-1 Count of articles by ABS rated journal

Figure 2-4 captures the count of the articles reviewed by the ABS journal name that the articles were published in, where the count was equal to or greater than five articles. Figure 2-4 also excludes the Kybernetes journal article count from Table 2-1 due to them being outliers on the grounds that they were AI technical papers that did not refer to future work.

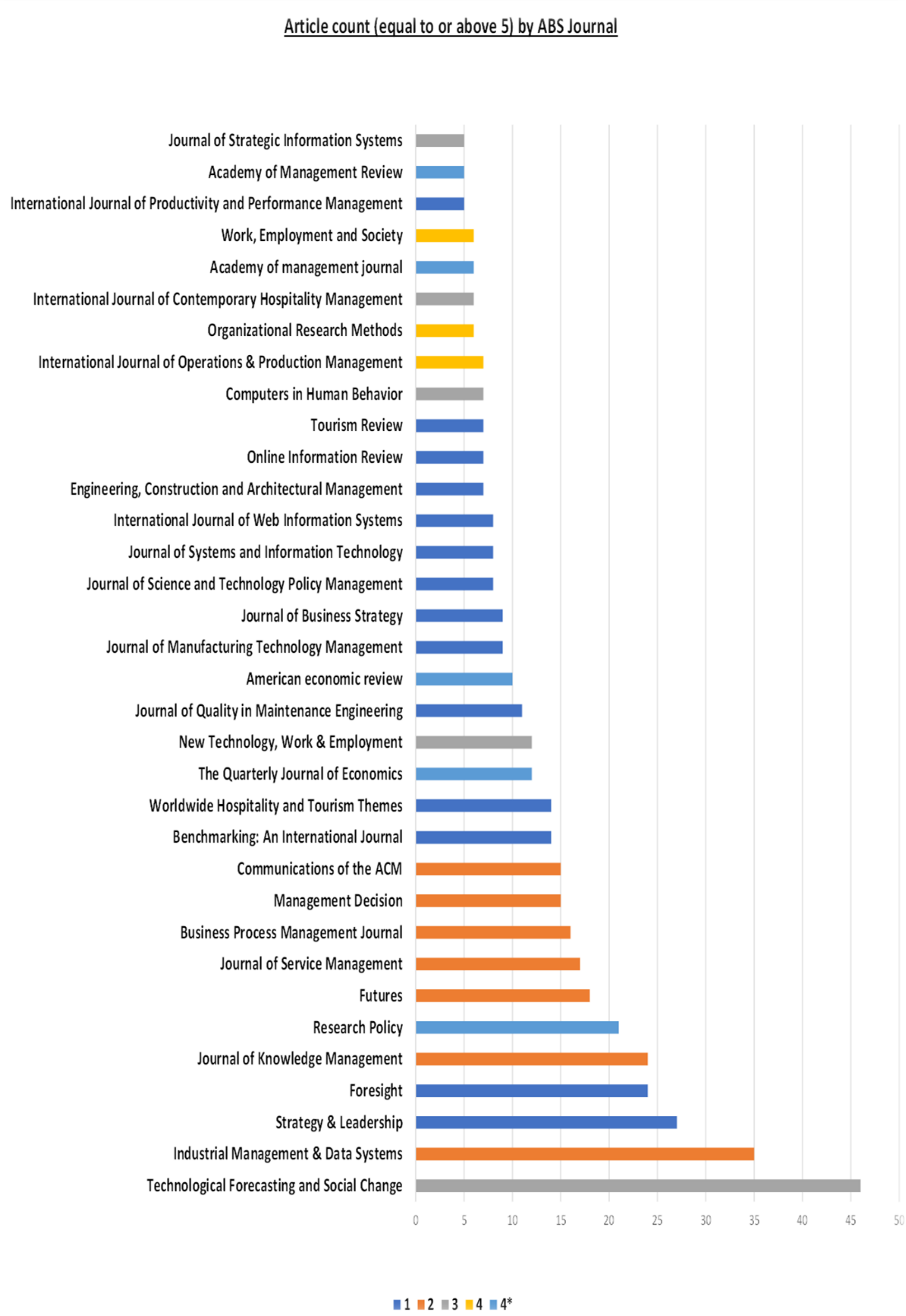

Figure 2-4 Article count (equal to or above 5) by ABS Journal

To keep up to date on emerging literature a series of alerts were set up in the search engines, FindIt and Google Scholar. Against the key word searches, new literature was evaluated against the research aim and objectives as a continual activity throughout the research.

The objective of the literature review was to evaluate the documented key themes and theories in relation to the technological change and the workforce. To assist with evaluation of the literature, Mind Mapping software was used to track the authors against literature areas and key theories and perspectives that emerged from the review. Figure 2-5 captures the mapping of the key theories and themes that emerged from the literature review and the key links between the authors and those identified themes. The map depicts Four key areas:

1. Technical Change, also referred to as Technological Change (captured in **blue**).
2. Technology Forecasting (captured in **orange**).
3. Workplace Impact (captured in **yellow**).
4. Worker Skills (captured in **purple**) and Societal Impact (captured in **red**).

The map has the research aim towards the centre in a **Grey** circle and the identified key authors are depicted in **bright green**. A key author categorisation was allocated where the author had multiple publications associated with this research area.

Other authors are denoted in **pale green** boxes. The author rectangular boxes capture the author, the year of publication and the ABS rating is articulated in square brackets, [ ] if applicable. In addition to this information a short descriptor is also documented to help the researcher identify the pertinent literature. The boxes are connected and do where appropriate have one to many relationships or links between the individual author boxes and the high-level area boxes. The technical change blue boxes are further broken down into sub-areas to capture the technological change themes that emerged from the literature being evaluated, these were: Industrie 4.0 or Fourth Industrial Revolution; Internet of Things; Digitalisation; Blockchain; Processing Power; Big Data; Cloud Computing; Machine Learning; Automation; and AI. Under the yellow boxes Workplace Impact, the identified sub-areas are: Job Polarisation; Technical Unemployment; Displacement; Comparative Advantage and Creative Destruction. The Purple Worker skills box had a corresponding sub-area of Skill Biased Technical Change (SBTC); Societal Impact had a linked box relating to Ethics. Lastly Technology Forecasting did not have any attached sub area boxes noted. An observation when building the mind map was that the literature items crossed over multiple theories and perspectives and there was a density of literature in relation to artificial intelligence (AI) displacement and job polarisation and far less literature that studied job creation.

This concludes the overview of how the literature review was conducted, the next section will provide an introduction to the literature review and explain the proceeding subsections to guide through the key theories and debates in relation to exploring the impact of technological change and future professional high skilled work.

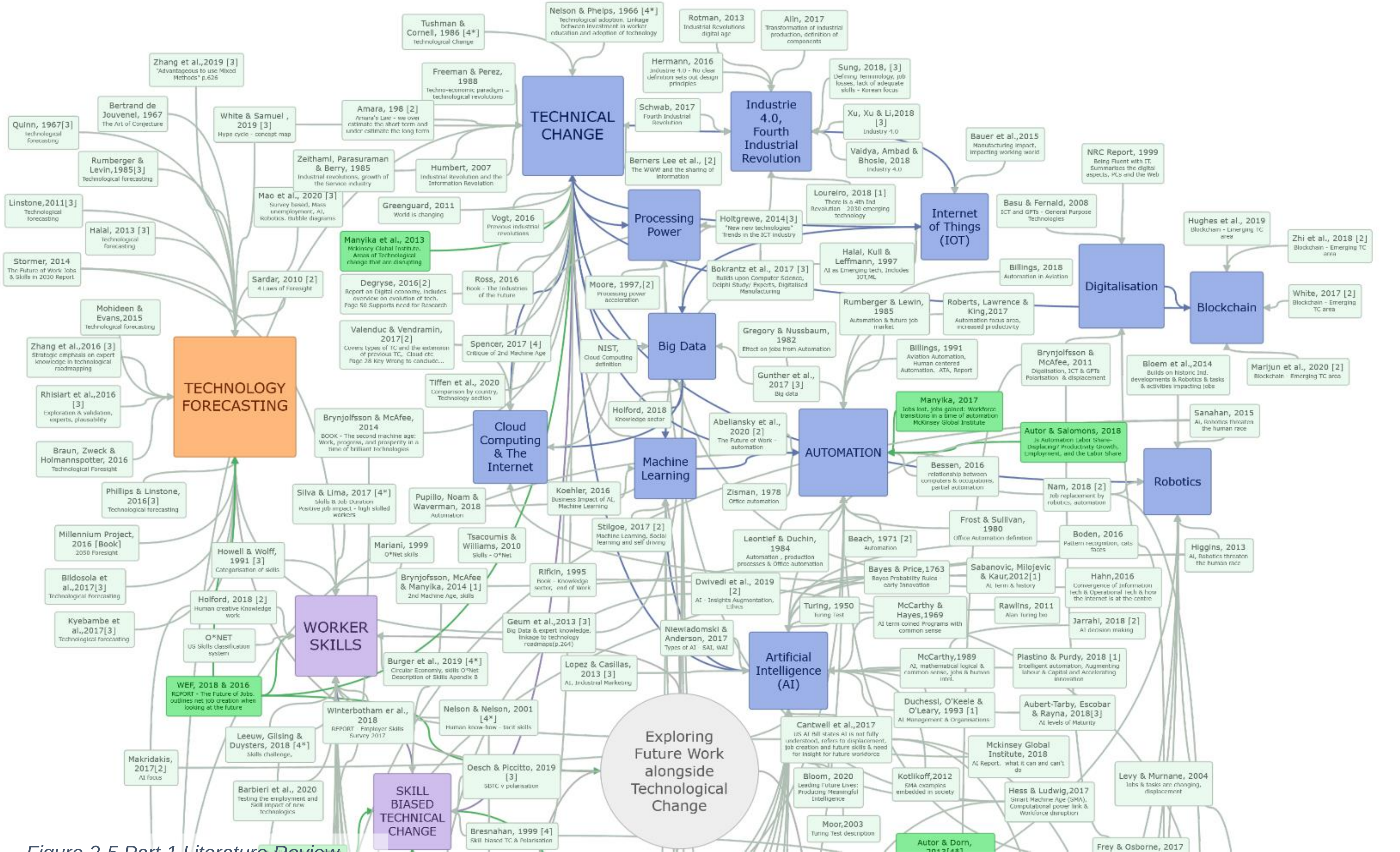

Figure 2-5 Part 1 Literature Review

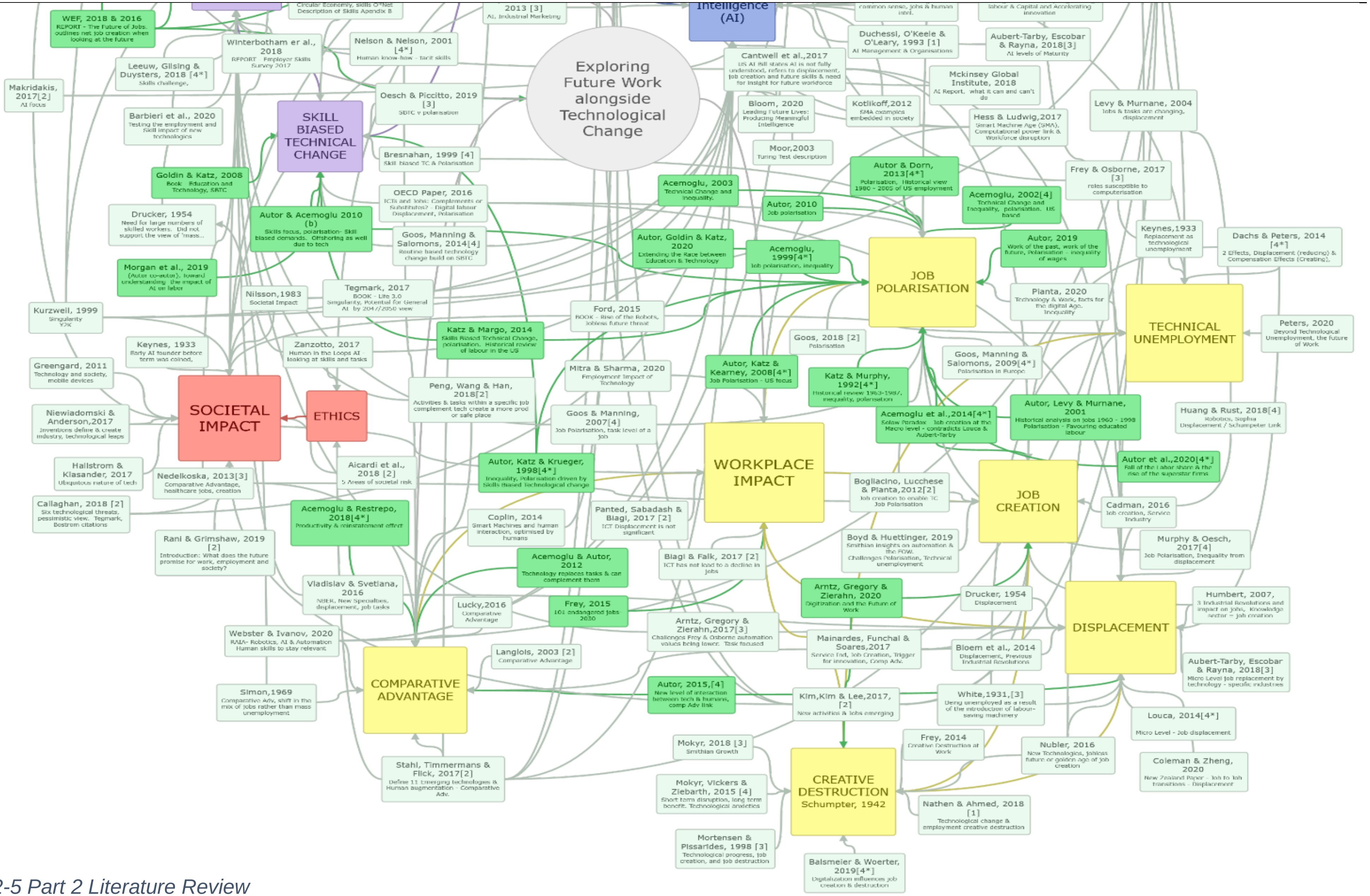

Figure 2-5 Part 2 Literature Review

2.3 Introduction to the Literature Review

The previous section, 2.2 presented a mind map of the literature revie w which captured the output by author and linked the author/s to the literature discussed and reviewed. At the beginning of the literature review five high level questions were considered, these are captured in Figure 2-6. This chapter is structured around these five questions. Starting with a review of the historical background relating to technological change, followed by what is technological change, how it is defined and what constitutes technological change. The third question evaluates the literature on future studies, this research aim is exploring future impact, this sub-section reviews the existing literature relating to technological forecasting to gather insight on how others have approached and conducted researching the future. The fourth question relates to how the workforce is defined and section 2.7 will cover the literature to address this question. The fifth question builds on the second and fourth questions and evaluates the existing literature that has studied the impact of technological change on the workforce to date. The Chapter then concludes with a summary of the literature and confirmation of the research aim and objectives.

Before we review the technological change areas, this section will provide an introduction to the Literature review followed by a look at the historical approaches and views on technological change.

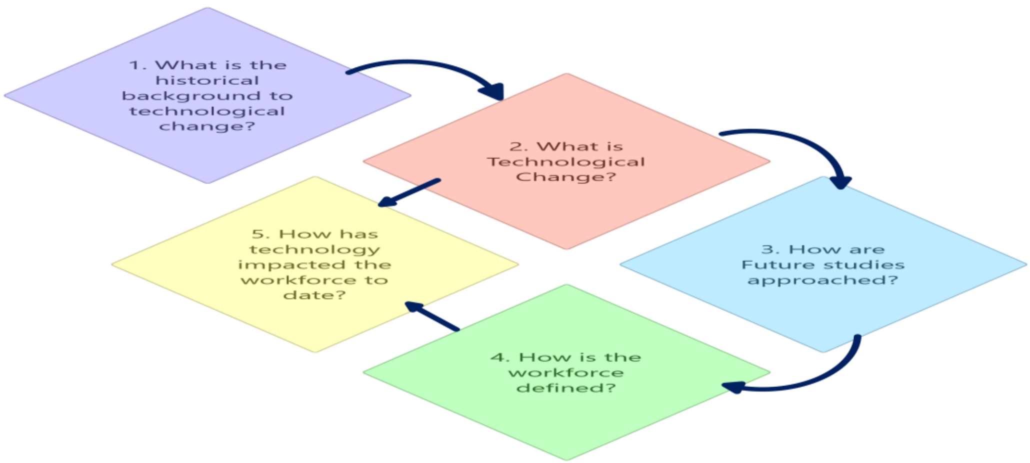

Figure 2-6 Literature high level summary – Introduction

2.4 Historical Context

Previous industrial revolutions saw the introduction of mechanical machines followed by electronic machines that provided computing power (Vogt, 2016). Then came the introduction of the internet. All of these inventions changed how routine, repetitive tasks were carried out. Automation became a focal area with increased productivity being one outcome. Changes in tasks and activities that make up a job role are not a new phenomenon, a brief review back of the previous industrial revolutions demonstrate a pattern of how people have had to adapt to accommodate growth in productivity through the introduction of machines. Schwab (2017) provides a brief chronology of the Industrial revolutions in figure 2.7:

- 1780s - through the introduction of mechanical equipment powered by steam and water, this was called the First Industrial Revolution.
- The 1870s - some ninety years later the Second Industrial Revolution driven by electricity and mass production through factory-based models.
- The 1960s - another ninety years on and then the Third revolution introduced IT and electronics and driving further efficiencies through automation.


Navigating the next industrial revolution

Revolution	Year	Information
1	1784	Steam, water, mechanical production equipment
2	1870	Division of labour, electricity, mass production
3	1969	Electronics, IT, automated production
4	?	Cyber-physical systems

Figure 2-7 Navigating the next industrial (Schwab, 2016, p.1)

During the last two hundred and thirty plus years industry has experienced three industrial revolutions (Spencer, 2017). Brynjolfsson and McAfee (2014), studied the impact on the workforce, when mechanical equipment disrupted the way in which people lived and worked, their findings will be discussed in more detail in section 2.8 that looks at the literature relating to Workforce Impact. The second industrial revolution saw further disruption with mass production factories affecting how people worked in the manufacturing industry. The third disruption was through automation and advancements in electronics and information technology which disrupted the workforce and displaced jobs (Arntz,Gregory and Zierahn, 2017). If advancements were to follow the same historical pattern, we would expect the next industrial revolution to occur around the 2050s. However technological advancements are disrupting how people work and live much earlier than previous timelines (Aubert-Tarby,Escobar and Rayna, 2018) with Artificial Intelligent (AI) solutions and robotics maturing and disrupting industries earlier than previous industrial revolutions patterns. These advancements have been referred to as the '*Fourth Industrial revolution'* or '*Industry 4.0'* (Bauer *et al.*, 2015; Schwab, 2016b; 2017; Fantini,Pinzone and Taisch, 2018; Schwab, 2018). The Industry 4.0 literature evaluation is discussed in the next section as part of the review of technological change areas, see 2.5.2.

An explanation for the more recent technological advancements is that the third industrial revolution introduced technology which has enabled people to be much more connected. Computers along with advancements in processing power, as predicted through Moore's Law (Moore, 1997), the introduction of Cloud computing (Aubert-Tarby,Escobar and Rayna, 2018) has created a connected digital world. Whilst AI is not a new term, the ability to collate massive amounts of data and search autonomously through a data corpus at rapid speed has meant that some job tasks and activities that used to be manual, repetitive and time consuming can now be automated with minimal or no human interaction. This ability to automate has driven a change to the workforce (Frey and Osborne, 2017). Tasks and activities that have historically been carried out by people have been displaced. The options and capabilities that are possible through these advancements could significantly change how we live (Bauer *et al.*, 2015), disrupting healthcare, defence, travel, education and all aspects of commercial business along with how we learn and work. The impact to the workforce and how jobs are affected is a key area of interest which underpins the future workforce and helps inform future training and education needs of people. Workforce impact literature is examined in section 2.8.

Alin (2017) described the fourth industrial revolution, as being the *'transformation of the entire industrial production by merging digital and internet technologies to conventional industry'* (p.74). Alin explained how the connection of sensors and wireless components, alongside enhancements in robotics and machine intelligence; added with real-time data analysis connected to the internet has created a huge potential for industry and society. Technologies underpinning the declared fourth industrial revolution are enabled through AI. The next section will review the literature on technological change and is presented in multiple sub-sections, starting with a review of the term and its history, followed by individual key areas of technological change.

2.5 Technological Change

This section is set out over thirteen sub-sections, comprising of an initial sub-section that reviews how '*technological change'* is defined, followed by individual subsections that evaluate the literature and terminology on each of the technological change areas which are depicted in Figure 2-8. This section, 2.5 then concludes with a summary.

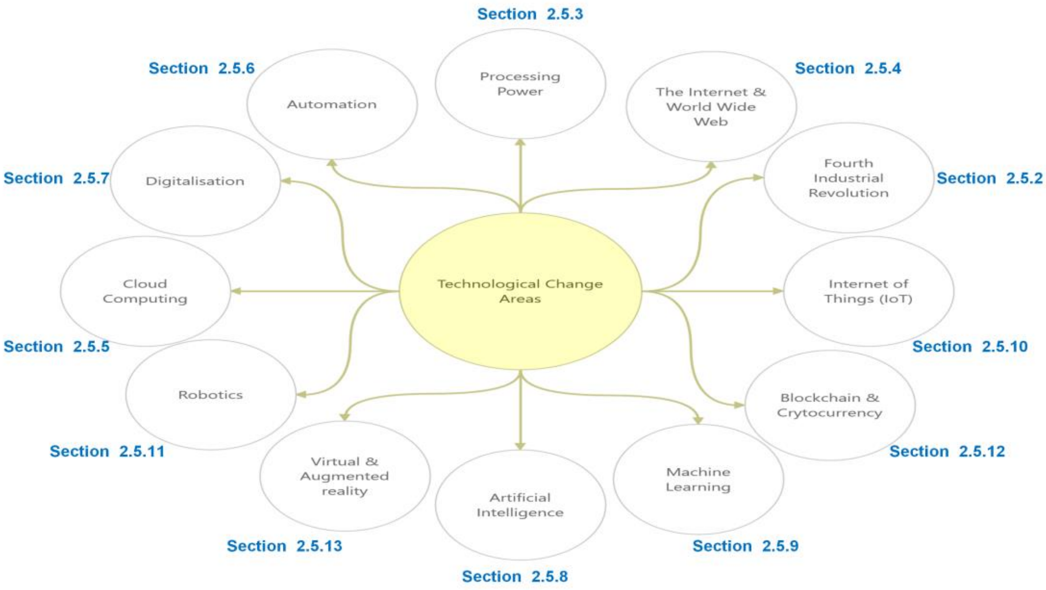

Figure 2-8 Literature high level summary – Technological Change

2.5.1 Defining Technological Change

The term '*Technical change*' has been applied for many years, early references of the term were noted by Schumpeter (1942) and then later by Solow (1957) who expressed the term in the context of a shift in production that impacted the workforce, stating,

> *"It will be seen that I am using the phrase "technical change" as a shorthand expression for any kind of shift in the production function. Thus slowdowns, speedups, improvements in the education of the labor force, and all sorts of things will appear as "technical change*" (Solow, 1957, p.312).

Since the first industrial revolution machines have disrupted and evolved, influencing how people work and live. The world of work and more specifically '*labour*' has underpinned economies for hundreds of years. Adam Smith (1776), referred to '*inventiveness*' and highlighted the role human capital played in the progress of innovation. Early economists (Babbage, 1832; Barnett, 1925; Schumpeter, 1934; 1942) highlighted the importance of machines and technology as a major disruptor to world economies. Comparisons have been drawn from early economic and political theories relating to machine and technological disruptions and how they impacted the labour force through the implementation of automation. Boyd and Huettinger (2019) talked about the uniqueness of automation, citing automation as '*technical change*' highlighting that it had been powered by '*robotics, computerisation, big data, machine learning and artificial intelligence (AI).*' Technical Change was established as an economic measure that captured the impact to labour and more specifically the productivity or output within an economy. Over time the term has morphed into '*technological change*' which in some instances relates more to the progression of innovation through technological phases. Innovation drives productivity, Nordhaus (1969) presented "*two conventional factors of production, capital and labor, which are combined to produce output by an aggregate production function."* Fifty years on, capital is presented in a different way through investment in, "*the adoption of new production processes or launching new products*" (Dachs and Peters, 2014b, p.1519). This is supported by the introduction of services such as 'Uber' and 'Airbnb' (Van Roy,Vértesy and Vivarelli, 2018). Where new processes have led to the introduction of service consumption and new *service*s are launched as products that can be consumed. The internet has also enabled this adoption of new ways of consumption resulting in technical change in the way we book holidays or taxi travel, both of these examples resulted from social demand for an easier way to interact in these specific areas, supporting the view of Smith that invention and change is driven by humans (Smith, 1776). Smith believed innovation was as a result of motivation to identify the most productive and labour-saving route to perform work. Weitzman (1998), defined this as '*recombinant innovation*,' which was further supported by others (Romer, 2008; Brynjolfsson and McAfee, 2014), claiming that we find new ways of doing historical things which then generate new concepts and ideas, therefore driving innovation through new inventions. This approach goes back to the 1930s, where economists identified that "*development* *consists primarily in employing existing resources in a different way, in doing new things with them"* (Schumpeter, 1934, p.68).

There is no clear distinct or unified documented definition of '*technical*' or '*technological change.*' However, the existing literature supports the interpretation that technological change is the emergence of adopting new ways whether that be through machinery like the early Industrial revolution, or through inventions such as the introduction of steam or electricity. More recently this adoption of new ways extends to the adoption of computerisation and digitalisation. This introduces another term that falls under innovation and invention that is driving technical change, '*digitalisation*' (Larson and DeChurch, 2020). Digitalisation refers to the move to more online services and the rise of social media platforms and collaboration tools (Zemtsov, 2020). The literature demonstrated that there are multiple definitions and areas that relate to technological change. Rotolo, Hicks & Martin (2015), referred to '*Emerging Technologies*,' setting out five characteristics which would qualify innovation as being an emerging technology. The five characteristics are:
"*(i)radical novelty, (ii)relatively fast growth, (iii)coherence, (iv)prominent impact and (v)uncertainty and ambiguity" (p.1827)*. Rotolo, Hicks & Martin also referred to the theory of technological change, supporting the economic view set out by earlier economists (Smith, 1776; Babbage, 1832; Barnett, 1925; Schumpeter, 1934; Solow, 1957), who referred to innovation or inventions and how they were key to driving productivity whether that be at organisation, industry or individual level.
Another term which has been captured in relation to '*Emerging Technology*' is '*Information Communication Technology' (*ICT) (Stahl,Timmermans and Flick, 2017).

> "*ICTs as those large-scale socio-technical systems that make use of computer, network, and other information technology to significantly affect*

the way humans interact with the world" (Stahl,Timmermans and Flick, 2017, p.370).

The connection between humans and capital (technology) supports the Smithian view (Smith, 1776) that inventions drive the economic position. Vivarelli (2012) referred to similar factors and provided the following definition: "*Technological change allows to produce the same amount of goods with a lower amount of production factors, namely capital and labor"* (p.3). Therefore, the question that arises is not what is '*technological*' or '*technical change*' more what constitutes '*technological change*' and this is also unclear. Different authors provide their individual descriptions of what the term encompasses. The consistent theme is the linkage to innovation or inventions as set out above. A fundamental component of technological change is the creativity associated with the introduction of new inventions. Romer (2008) captured the importance of human capital in that process, "*people take resources and rearrange them in ways that make them more valuable*" (p.1). The literature supports the position that technological change is adaptable, it is defined by inventions that are adopted and may vary over time. Adoption of innovation drives technological change, Boyd and Huettinger (2019) highlighted a significant observation, which is because something is technically feasible it does not mean that it will be adopted and they oppose the view of '*autonomous technical change,*' which is a position where it is believed that technology or innovation is independent of human intervention (Newell,Jaffe and Stavins, 1999). Boyd and Huettinger dispute autonomous technical change and are supported by others highlighting the need for caution when considering technology is "*out of control"* and "*no longer guided by human purposes*" (Winner, 1978, p.13). Schwab (2016b) clarified, "*technology is not an exogenous force over which humans have no control.*"

Acknowledging the variability in what constitutes technological change, the following sub-sections review the documented areas of technological change.

Table 2-2 provides quotations from a snapshot of authors that capture areas that have been cited under the umbrella of '*technical*' or '*technological change.*' The table presents the quotation and the corresponding authors, this is presented to demonstrate the wide array of areas that can be included under 'technological change.'. The areas of technological change captured in Table 2-2 align with the views cited on innovation and invention that they are areas that adopt new ways of doing things (Schumpeter, 1934).

Technological change area	Author & Year
"Robotics, and advancements in computing power and artificial intelligence" and "Machine learning, mobile robotics and processing power"	(Dachs and Peters, 2014a, p.1520)
"Mobile Internet, Automation of Knowledge Work, The Internet of Things, Cloud Technology, Advanced Robotics, Autonomous and near autonomous vehicles, Next generation genomics, Energy Storage, 3D Printing, Advanced materials, Advanced oil and gas exploration and recovery and Renewable energy"	(Manyika *et al.*, 2013, p.4)
"Automation technologies including artificial intelligence and robotics"	(Manyika *et al.*, 2017, p.1)
"Affective Computing, Ambient Intelligence, Artificial Intelligence, Bioelectronics, Cloud Computing, Future Internet, Human-machine symbiosis, Neuroelectronics, Quantum Computing, Robotics and Virtual / Augmented Reality"	(Stahl,Timmermans and Flick, 2017, p.371)
"Increased automation through Improved computing power, artificial intelligence, and robotics"	(Autor, 2015, p.4)
"Digital technology, computers and robots, automation, Developments in robotics and artificial intelligence (AI)"	(Spencer and Slater, 2020, p.2&3)
"Automation, digital technologies, robotics, and artificial intelligence"	(Acemoglu and Restrepo, 2018d, p.1)
"Algorithmic, intelligent machines deploying big data, machine learning and Artificial Intelligence"	(Maelle, 2017)
"Nonmachine-based digital technologies (such as ERP (Enterprise Resource Planning) social media, or ecommerce) and rather complex machine-based digital technologies (such as robots, 3D printing or the Internet of Things). Machine-based technologies are characterized by a powerful combination of data access, computation and communication technologies with acting hardware"	(Balsmeier and Woerter, 2019, p.2)
"Automation, machine learning, mobile computing and artificial intelligence"	(Keywell, 2017)
"Cyber-physical systems, the Internet of Things (IoT) and the Internet of Services, Artificial Intelligence, big data and connectivity"	(Roblek,Meško and Krapež, 2016, p.2)
"IOT: RFID Sensors, actuators, mobile phones, integrations of computation and physical processes"	(Hermann,Pentek and Otto, 2016, p.3929)
"The digitisation process. Increasing computer power coupled with the growing penetration of the internet, Big Data, the Internet of Things (IoT) and Artificial Intelligence (AI)"	(Pupillo,Noam and Waverman, 2018b, p.1)
"Machine learning, big data analytics, artificial intelligence, blockchain technology, robotics, additive manufacturing, augmented and virtual reality, cloud computing, Internet of Things"	(Bhattacharyya and Nair, 2019, p.175)
"Ubiquitous high-speed mobile internet; artificial intelligence; widespread adoption of big data analytics; and cloud technology"	(World Economic Forum, 2018, P.vii)

Table 2-2 Emerging Technologies Summary

This sub-section has reviewed the literature relating to the term technical and technological change. The term is grounded in economic drivers and represents areas of innovation, where machinery and technology are applied to drive efficiency and generate labour saving ways of carrying out processes and work. The literature has presented multiple areas of emerging technological change. One area of technological change that has been referred to is the Fourth Industrial Revolution (Loureiro, 2018; Schwab, 2018; Sung, 2018), this will be discussed in more detail in the next sub-section 2.5.2.

2.5.2 The Fourth Industrial Revolution

When reviewing the literature and definitions in relation to technological change, the fourth industrial revolution was presented as an area of emerging technological change and some debate surfaced in relation to the terminology and definition of what constitutes the fourth industrial revolution, this debate adds confusion to the terminology in this area. The term 'Industrie 4.0' (Roblek,Meško and Krapež, 2016) was claimed to have been instigated in Germany as part of an economic policy, describing, "*technologies that include cyber-physical systems, the Internet of Things (IoT) and the Internet of Services.*" Also referring to introduction of the internet progress which was pivotal to digitalisation, drawing attention to areas that are still maturing, "*Artificial Intelligence, Big Data and connectivity*" (2016, p.2). Hermann, Pentek and Otto (2016), supported the views of Roblek, Mesko and Krapez (2016), that it was established as an initiative by the German authorities. They provided further clarification that it is a, "*convergence of industrial production, information and communication technologies*" (p.3928). Hermann, Pentek and Otto (2016) further highlighted a difference in terminology, highlighting that there two terms that are used interchangeable for the fourth industrial revolution. They stated that '*Industrie 4.0'* referred to the,

> “*fundamental improvements to the industrial processes involved in manufacturing, engineering, material usage and supply chain and life cycle management”* (p.3929).

Hermann, Pentek and Otto articulated that the term *‘The fourth industrial revolution’* represented, “*a paradigm shift from centrally controlled to decentralized production*” (p.3929). The article provided further insight, through consolidation of terminology that had been associated with the fourth industrial revolution; ‘*Industrial Internet*, Advanced *Manufacturing, Integrated Industry along with Smart Industry and Smart Manufacturing.’*

Sung (2018) supported the views set out by Hermann, Pentek and Otto (2016), confirming that there is a difference between the two terms, ‘*Industry 4.0*’ and ‘*The fourth industrial revolution.*’ Sung reinforced the origins of the terminology supporting the claims of Roblek, Mesko and Krapez (2016) agreeing the linkage to a German Government initiative. Similar to Hermann, Pentek and Otto in 2016, Sung (2018) believed that ‘*Industry 4.0’* focused on manufacturing, whereas the fourth industrial revolution applied to the broader view capturing the,

> *“systemic transformation that includes an impact on civil society, governance structures, and human identity in addition to solely economic and manufacturing ramifications”* (2018, p.41)*.*

Schwab (2017) claimed that we are experiencing the start of the Fourth Industrial Revolution, which is building on the third revolution, the introduction of computers, electronics and automation. The fourth revolution (Alin, 2017) has been described as many things, Alin stated it is, ‘*transformation of the entire industrial production by merging digital and internet technologies to conventional industry’* (p.74).

Although there are variances in the descriptions and terminology of the fourth industrial revolution, there were common themes that emerged from the literature; that the disruption is driven by increased connectivity, the use of sensors and wireless components, enhancements in robotics and machine intelligence are enabling real-time data collection and analysis. The enhanced connectivity through the internet is creating huge potential and innovative options to industry and society. Alin also describes the '*connecting the physical world to the virtual world through cyber-physical systems (CPS)*' (Alin, 2017, p.74).

The next section will describe in more detail the key emerging technologies that have been captured in Table 2-2 from the previous sub-section, 2.5.1, which also incorporates the component parts that have emerged from this section on the fourth industrial revolution. The next sub-section, 2.5.3 will review the literature relating to the technological change area of processing power followed by, the internet, cloud computing, automation, digitalisation, Blockchain, AI, Machine Learning, the Internet of things (IOT) and lastly Robotics.

2.5.3 Processing Power

In 1965 Gordon Moore noticed that the growth of microchip innovation was doubling year on year (Eeckhout, 2017). He predicted the exponential growth of transistors (Moore, 1997), stipulating that integrated circuits would double the numbers of transistors consistently every two years and this doubling would drive an increase in computing power. His views were not taken seriously until a decade later which was when the term Moore's Law was coined. The realisation of the law in the growth of processing power was presented which has led to faster and more powerful machines. At the time (circa 1970) technological innovation had peaked with the latest chip containing fifty transistors; fast forward to 2008 and the transistor numbers within a chip were at two billion (Moore, 2008). The prediction of exponential growth was profiled by Moore and commonly known as '*Moore's Law*.' Figure 2-9 graphically shows the exponential growth of the transistor chip innovation. It shows the chronology along the bottom of the graph and the transistor volumes along the left hand-side.

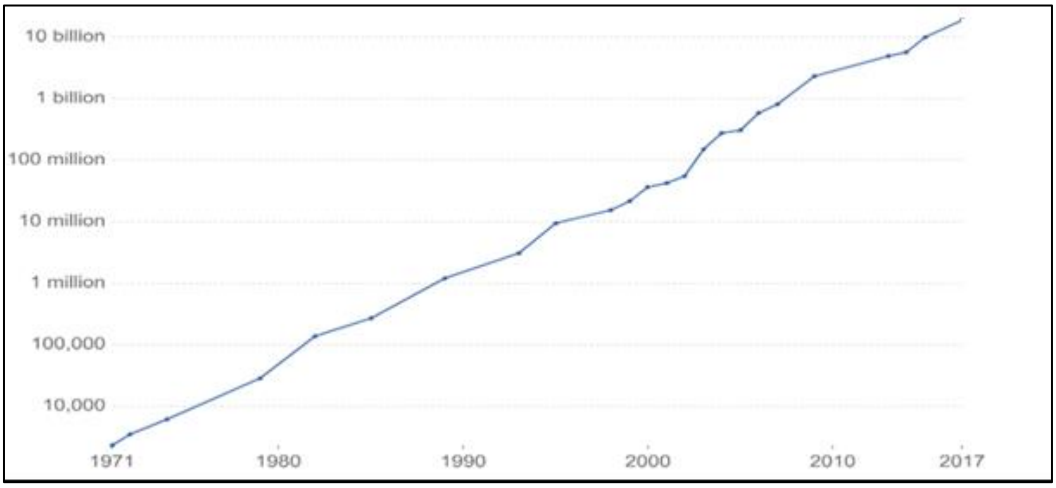

Figure 2-9 Moore's Law: Transistors per microprocessor (Rupp, 2018)

Kurzweil (1999) explained that the '*evolution of technology*' is "*in accordance with the Law of Accelerating Returns, the value – the power – of computation increases exponentially over time*" (p.27). In 2005 Kurzweil captured the changes in computing efficiency correlating the processor chip enhancements with efficiencies being realised in running or computing power. Figure 2-10 captures the profiling of the reduction over time, depicting the increase in efficiency and the amount of electricity required reducing significantly. Therefore making the computing power more efficient and cheaper to run, a "*shift in the production function*," as articulated by Solow (1957, p.312).

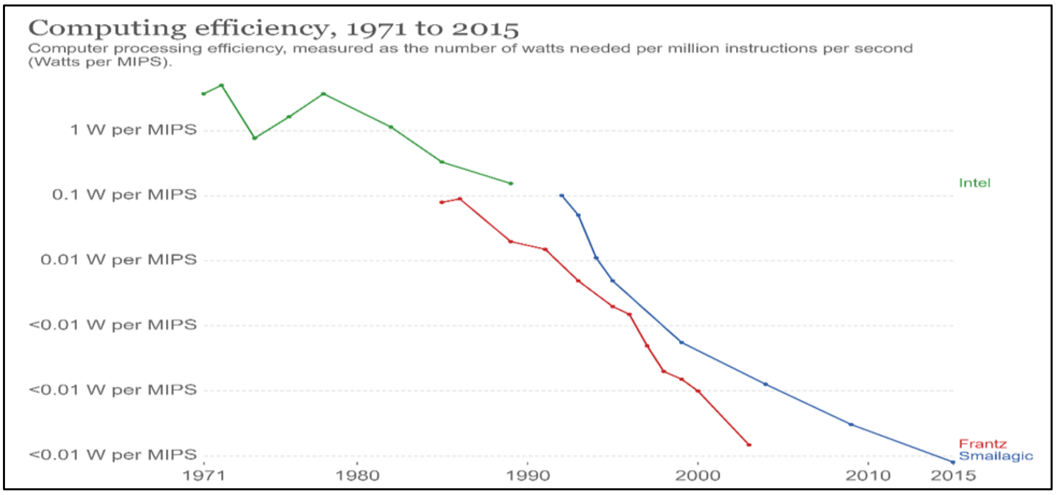

Figure 2-10 Computing Efficiency (Kurzweil, 2005, p.129)

The improved running efficiency along with a reduction in pricing is significant in relation to technological change, it enables faster, more efficient and also more economical options to entrepreneurs and inventors to enable innovation in other areas, such as developing applications and robotics, which will be covered in subsequent sub-sections.

The importance of processing or computing power is one of social and technological significance (Roser and Ritchie, 2013), one example is the computing power of a laptop. In 2013, Roser and Richie demonstrated that a personal laptop device had the same computing ability of the "*most powerful computer on Earth in the mid- 1990s.*"

The service and manufacturing industries with the emerging knowledge sector (Kurzweil, 2013) have been further enhanced, enabling greater productivity due to the growth in computing power, 'LOAR' (p.164) the '*Law of accelerating returns'* and how biology and technology evolves over time calls out the '*predictable exponential growth in the capacity and price/performance of information technologies*' (p.165). An example of LOAR is the introduction or creation of computers and the evolution of how knowledge or data is transferred or communicated. This acceleration was linked to predictions by Gordon Moore back in 1965 (Moore, 1997; Sabanovic,Milojevic and Kaur, 2012). This exponential growth has underpinned what is being called a 'Smart Machine Age' (SMA) (Hess and Ludwig, 2017). The Smart machine age has been made possible through a number of innovations, the advancements in computing power being one of them. A further contributory invention to the smart machine age was the launch of the Internet, which will be discussed in the next sub-section, 2.5.4.

2.5.4 The Internet

In the 1990's the technological world evolved with the launch of the World Wide Web (WWW) or 'W3' as it was originally named by Sir Tim Berners-Lee. He wanted to "*enable the sharing of knowledge by complex distributed teams*" (Berners-Lee *et al.*, 1994, p.82). Today the terms '*Internet*' and '*World Wide Web*' are used interchangeably to represent the connected web. However, there is a difference between the two terms. The first 'host to host connection' was made through the Internet in 1969 (Paloque-Bergès and Schafer, 2019). Work on the network dates back to 1958 and was part of a US Department of Defence (DoD) programme. There were a number of advancements from 1969 to 1990, the most significant relating to the Transmission Control Protocol/Internet Protocol or TCP/IP, which provided a set of rules that provided governance over the connections between computers (McKenzie, 2011).

To help clarify the terminology, the '*Internet*' provides the network infrastructure, whereas the '*World Wide Web*', or '*W3,*' provides the ability to share information and content through the Internet on web pages. The first website which can still be accessed today (http://info.cern.ch/hypertext/WWW/TheProject.html) provided the ability to share documentation and had '*hypertexts*' (Berners-Lee *et al.*, 1992; 2010). Hypertexts are

> "*links between pieces of text (or other media) mimic human association of ideas,"* these along with,
> "*text retrieval, which allows associations to be deduced from the content of text. The W3 ideal world allows both operations and provides access from any browsing platform"* (p.461).

One of the key goals of the Web was to provide practical human knowledge techniques and to "*bring a global information universe into existence using available technology*" (p.461).

A major benefit of the internet was captured by Feldman (2002), who stated,

> *"The Internet allows anyone with a small capital investment in a computer and access to a server to connect to other computers all over the world in an interconnected web of machines, data, and people" (Feldman, 2002, p.48).*

Over time the internet has expanded, the Mckinsey Global Institute (du Rausas *et al.*, 2011) described it as a "*vast mosaic of economic activity, ranging from millions of daily online transactions and communications to smartphone downloads of TV shows"* (p.1 Summary document). The internet has enabled innovation across all areas of business and social collaboration. The Global nature of the internet removes boundaries and has reduced communication costs. Feldman (2002) cited the Internet as a revolution in the ICT (Information Communication and Technology) space, uniting telecommunications and computers together.

The Internet and enhancements in microchip processing capability seeded another type of technological change, Cloud Computing which will be covered in the following section, 2.5.5.

2.5.5 Cloud Computing

Comparable, to the evolution of compute power, which we discussed in section 2.5.3, Cloud computing demonstrates the evolution of infrastructure provisioning. The introduction of the internet enabled globalised solutions to be created, such as cloud computing. The National Institute of Standards of Technology, or NIST (Mell and Grance, 2011) provided the following definition for Cloud computing it is,

> "*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (p.2)*

Cloud computing provides efficient, scalable compute resources. NIST set out five characteristics that constitute Cloud Computing, along with options on deployment models and service models these are captured in Appendix 8.2. Cloud Computing offers more than just compute power, consumers of cloud can benefit from online storage and data transfer for example. The ability to scale and also consolidate resources and assets supports and endorses innovation (Voorsluys,Broberg and Buyya, 2011).

Big data, artificial intelligence and machine learning have been enabled by cloud computing; these areas will be described in more detail in later sections. The next section, 2.5.6 will discuss the technological progress of *'automation'* an area that evolved over time, the advancements in processing power and cloud computing have enabled further automation to extend into new areas of labour-saving activities.

2.5.6 Automation

Automation goes back as far as the Luddites, at the beginning of the nineteenth century (Autor, 2015). Machines automated labour activities, agriculture saw the tractors invented to aid farmers, sewing machines were introduced to aid the seamstress. Bessen (2019) referred to "*productivity-improving technology"(p.1)* when discussing automation, this supported the earlier views presented where,

> *"Technological change allows to produce the same amount of goods with a lower amount of production factors, namely capital and labor"* (Vivarelli, 2012, p.3)

Figure 2-11 captures a timeline of key automation milestones to highlight the evolution of technological change. In 1589 William Lee tried to patent an automated knitted machine, the patent was refused by Queen Elizabeth, the reigning monarch. It was feared that it would have a detrimental impact on workers and the economy. Today, automation includes technological change areas such as the Internet of Things (IOT) which automates the collection of data through sensors. IOT will be covered in more detail in sub-section 2.5.10. These inventions were designed to simplify existing processes and to increase productivity. Automation can take many forms, mechanical, digital or process driven. An example of early day automation is described by Adam Smith in The Wealth of Nations (1776):

> *"In the first fire-engines, a boy was constantly employed to open and shut alternately the communication between the boiler and the cylinder, according as the piston either ascended or descended. One of those boys, who loved to play with his companions, observed that, by tying a string from the handle of the valve, which opened this communication, to another part of the machine, the valve would open and shut without his assistance, and leave him at liberty to divert himself with his play-fellows. One of the greatest improvements that has been made upon this machine, since it was first invented, was in this manner the discovery of a boy who wanted to save his own labour"* (Smith, 1776, p.21).

Figure 2-11 depicts the chronology of some of the key '*automation*' innovations over the centuries, it also highlights that automation is not a new phenomenon (World Bank, 2019). There is no clear definition for '*automation*,' similar to technological change, the literature illustrates that the term is defined by what it achieves, such as '*improves productivity*' (Bessen, 2019). This view also supported by others (Leontief and Duchin, 1984) who refer to "*Technological change: computer based automation*" (p,19) and then the '*labour saving*' that is generated from new technology. Leontief and Duchin reference two types of automation, the first being "*computerization of production processes*" and the second being "*office automation*"(p.106). Defining the former as being the increased use of ; "*two specific microprocessor based machines, robots and computer numerically controlled (CNC) machine tools"*(p.106). The latter was defined as incorporating "*appropriate technology to help people manage information"* (p.106).

In 1978, an article was published (Zisman) that described office automation as, "*revolutions of timesharing, database management, the minicomputer, the "total" MIS, distributed data processing, distributed databases, structured programming, microcomputers, and now upon us is the "revolution" of office automation"* (Zisman, 1978, p.1). [MIS stands for Management Information Systems]. Automation transformed office work for people. Section 2.8 reviews the literature on how technology has impacted workers. Office automation is just one area where technological change has been adopted.

Multiple industries have applied or adopted automated machinery or technology (Beach, 1971; Zisman, 1978; Leontief and Duchin, 1984; Vladislav and Svetlana, 2016; Arntz,Gregory and Zierahn, 2017; Roberts,Lawrence and King, 2017; Autor and Salomons, 2018; Billings, 2018; Acemoglu and Restrepo, 2019a; Bessen, 2019; Nam, 2019) manufacturing and agriculture were disrupted by mechanical automation prior to computerisation. Office workers across all industries and the aviation sector have all applied automation in a number of areas. Billings (2018) explained how in 1947 the introduction of transistor technology and the evolution of the '*miniaturisation*' of components along with computerisation transformed the aviation world through automation. He referred to automated areas such as, air traffic control, management activities and aircraft automation. Key to his literature was the emphasis to '*Human-centered automation.*' In a 1991 report written by Billings on behalf of NASA the term was clarified, "*'Human-centered automation' is a systems concept. Its focus is a suite of automated systems designed to assist a human operator/controller/manager to accomplish his or her responsibilities"* (Billings, 1991). Appendix 8.3 captures the six key principles associated with '*Human-centered automation'* within Aviation. The reference to assisting a human resonates with other areas of technological change and the '*labour saving*' nature of automation (Vivarelli, 2012).

Automation can take many forms, c*loud computing* which was described in the previous sub-section, 2.5.5 has driven the maturing of several technological interfaces, including APIs, '*Application Programming Interfaces*' (Goodwin, 2018). *"APIs are a set of techniques used by computer programs to request services from the operating system, software libraries or any service providers [are] running on* *the computer" (p.161).* APIs have revolutionised how developers share and interface across organisations leveraging the innovation of others, driving and enabling the automation of business processes, and this adds value through, "*automated Service discovery*" (Goodwin, 2018, p.162) and is an area that is still evolving and through automation of software integration is driving further innovative options for organisations. APIs are not new, they have evolved over the decades, starting in 1960 through to 2000 (Collins and Sisk, 2015). APIs are an example of where technological change has and is evolving over time, the advancements are built on technological innovations from previous industrial revolutions. For further information on the API evolution see Appendix 8.4.

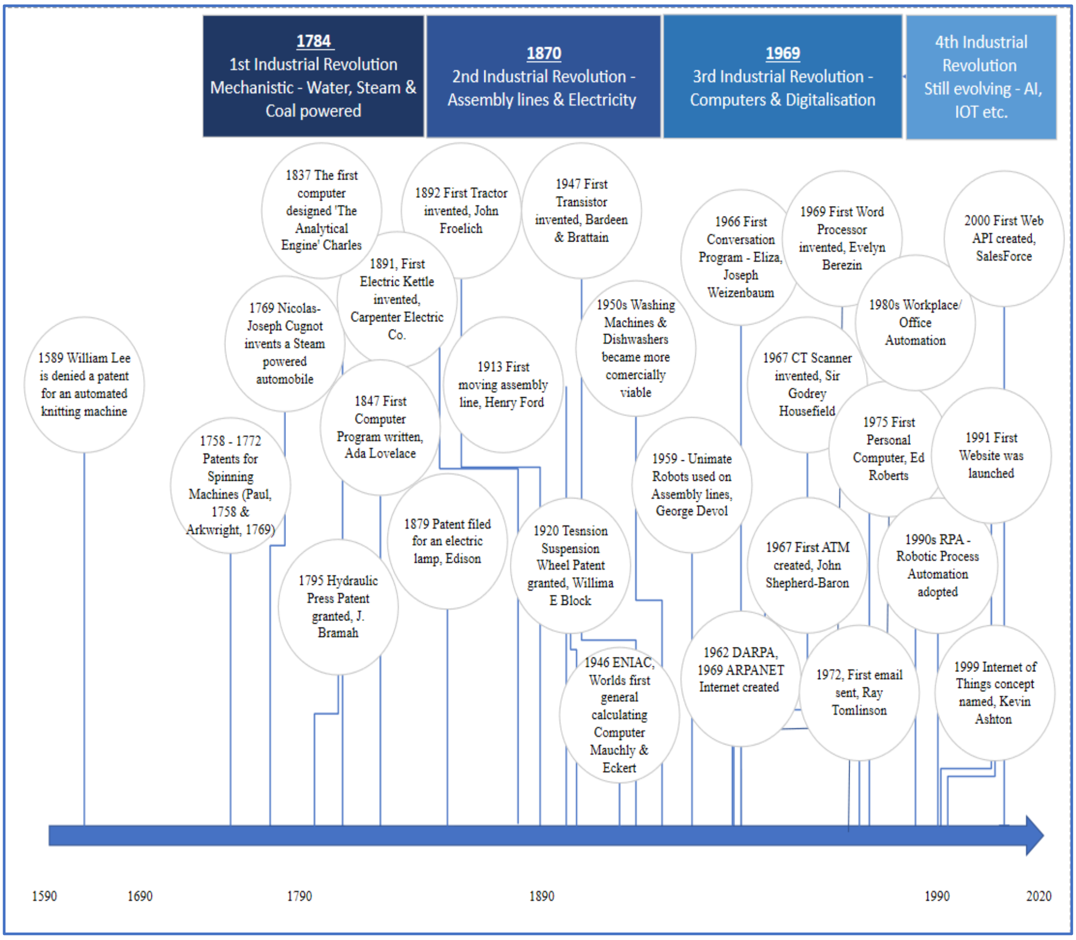

Figure 2-11 Automation timeline, [Source: created by author to show chronology]

More sophisticated examples of automation are robotics and software driven programs such as chatbots. Robotics will be covered in a separate sub-section, 2.5.12. Figure 2-11 captures '*Eliza*' back in 1966, which was the first conversation program, created by Joseph Weizenbaum (Mauldin, 1994; Dale, 2016). The term *'Chatbot'* was not coined until much later by Michael Mauldin (1994) who used the term '*Chatterbot*' which was created and tested through a game called *'TinyMuds,'* where players could converse with the Chatterbot. It was run using conversation rules such as "IF-THEN-ELSE." Chatbots will be discussed further in the next sub section, 2.5.7 Digitalisation.

Automation has evolved over the years. The introduction of computer automated office work and procedures has introduced the computerisation of information and information systems (Gregory and Nussbaum, 1982). This focus on information automation has evolved and driven a far more digital world, where data and communications are digitalised. This has been referred to as a '*deepening of automation*' (Acemoglu and Restrepo, 2018a). Digitalisation will be discussed in the next sub-section.

2.5.7 Digitalisation

Computers have been classed as *'General Purpose Technologies'* or GPTs (Basu *et al.*, 2008; Brynjolfsson and McAfee, 2011). These GPTs evolve over time and create the foundations of future innovation. Brynjolfsson and McAfee (2011), in their seminal book '*Rage against the Machine*,' refer to Moore's Law and how it matured over time, as a GTP. In addition to highlighting the importance of computers as a '*GPT*' they proffer an explanation to what digitisation is, referring to the marriage of computers and networks which forms ICT (*Information Communication Technology).* Setting out that,

> *"Digitization, in other words, is not a single project providing one-time benefits. Instead, it's an ongoing process of creative destruction; innovators use both new and established technologies to make deep changes at the task, job, the process, even the organization itself*" (Brynjolfsson and McAfee, 2011, p.21).

The reference to '*Creative Destruction*,' supports earlier views (Schumpeter, 1942) where technological change was seen to have a labour saving effect, which is sometimes referred to as the '*Displacement Effect*' (Leontief,Leontief and Duchin, 1986; Metcalfe,Leontief and Duchin, 1988; Dachs and Peters, 2014b), which is followed by a creative or '*Compensation Effect.*' The impact of the labour force and workers will be covered in a later sub-section (2.8). Digitalisation has also been captured as an area of '*digital divide'* (Levy and Murnane, 2005), which referred to the potential inequality of children not having access to computer skills in readiness for future work, the focus for the '*digital*' element referred to the computer and to have '*digital skills*' meant being able to use and operate a computer, referring to email and "*a number of applications, including word processing and spreadsheet programs" (Levy and Murnane, 2005, p.107).*

When the Internet and World Wide Web were released for general consumption at the beginning of the 1990s, a wave of digitalisation was triggered which changed how people lived and worked (National Research Council, 1999). Social and work-related activities have been digitalised, the first email was sent in 1972 (Tomlinson, 2009) and the launch of the world wide web in 1991 connected people. Digitisation evolved through multiple areas, personal email engines such as Hotmail in 1994 digitised communication, Amazon launched its online bookstore in 1994 (Goodwin, 2018), a milestone in the e-commerce and digital marketplace. Social platforms followed with LinkedIn, MySpace and Skype in 2003 and Facebook followed a year later in 2004 (Fry, 2018). This formed the evolution of digitalised work processes, through process automation (Pupillo,Noam and Waverman, 2018a). There is a gap in the literature that consolidates the chronology of the technological evolutions, to help build a picture of the various components the researcher compiled an overview, through literature searches on the internet, triangulating findings with different sources to validate as much as possible, see Figure 1-1 and Appendix 8.25.

Balsmeier and Woerter (2019), provided the following high level description that helps define areas of digitalisation,

> "*specific digital technologies that ranges from well-known technologies such as ERP, customer relationship management (CRM) supply chain management (SCM) systems, e-commerce and robots to fairly recently adopted technologies such as social media, cloud computing, 3D printing, autonomous vehicles, and the Internet of Things" (p.2).* [ERP stands for Enterprise Resource Planning].

There are multiple examples of where technology has digitalised some aspects of work, specific activities were highlighted in a report published by the Mckinsey Global Institute *(Bughin,LaBerge and Mellbye, 2017).* The report captured findings from a survey which indicated that on average 40% of industries were fully digitalised. They highlighted five areas that organisations should have digital strategies for, they were: "*Marketing and distribution; Products and services; Processes; Eco-systems; and Supply chains" (p.6).*

Digitalisation has also led to application maturity. Through the adoption of mobile phones and more specifically smart phone technology (Arntz,Gregory and Zierahn, 2020). E-commerce, email, social platforms are all easily accessible through mobile applications (Fry, 2018). In 1999 (National Research Council, 1999) digitisation through computers and ICT was referred to as the '*Information Age.*' The information age is referred to in several studies (O'Leary, 2013; Brynjolfsson and McAfee, 2014; Fosso Wamba and Fosso Wamba, 2017; McAfee and Brynjolfsson, 2017; Mariani *et al.*, 2018; Bonesso,Bruni and Gerli, 2020; Sabaitytė,Davidavičienė and Karpovičiūtė, 2020). Highlighting the emerging areas of technological change, such as advancements in artificial intelligence, IOT and online storage. These areas are transforming the information age into '*Big Data,*' which are fundamental to advances in artificial intelligence and machine learning. These areas of technological change will be reviewed in sections 2.5.9 artificial intelligence, 2.5.10 machine learning and 2.5.11 internet of things. A further area of emerging technological change as a result of digitalisation is Blockchain, the literature relating to this area of technological change will be reviewed next is section 2.5.8.

2.5.8 Blockchain

In section 2.5.1 technological change was described as a shift in production that impacted the workforce (Solow, 1957). Blockchain is an example of an emerging technological change area that presents potential for operational business savings, both from a cost and efficiency perspective (Hughes *et al.*, 2019). In 2008 digital currency emerged and was known as 'Bitcoin,' later in 2013 focus was given to the 'Distributed Ledger Technology' (DLT) technique that became known as Blockchain. The DLT technique presented significant promise to businesses by providing a mechanism for creating immutable transactions that cannot be changed and are transparent and logged. White (2017) highlighted a lack of literature on the subject of Blockchain and conducted a study to elicit expert opinion on the subject and how it could change future business. The findings provided a list of potential uses of the 'Disruptive Innovation' (DI) and importantly flagged the lack of knowledge that existed in relation to the emerging technology. The study called for focus to be given to improving the awareness of the field and highlighted the potential ethical implications of future adoption. Hughes et al. (2019) also highlighted the requirement for further research on mitigating future potential negative implications of Blockchain adoption whilst also capturing the potential for citizens, farmers along with supply chain use cases. As an emerging technological change, it is unclear from the literature what the future training requirements could be to adopt and leverage the business value referred to by both White (2017) and Hughes et al. (2019). Janssen et al. (2020) described a number of areas that hindered the adoption of Blockchain, institutional factors are captured along with specific challenges, including opposition for change and also a lack of understanding and knowledge, which supports the earlier views of White. It was noted that whilst workers skills and training were not explicitly captured a lack of knowledge and resistance to change suggests there is a requirement for workforce enablement and training to assist in the adoption of the emerging technological change.

Blockchain is a relatively new area of technological change which is still maturing through organisational experimentation, to date studies have concentrated on the financial services sector (McWaters,Galaski and Chatterjee, 2016; Janssen *et al.*, 2020) with additional use cases emerging in other sectors such as logistics and supply chain areas. There is agreement that Blockchain is a technological change area that is still maturing and further research is required on the subject matter. A further area of technological change that is evolving, although is not a new topic is AI which will be discussed further in the next section.

2.5.9 Artificial Intelligence

Artificial intelligence, 'AI' is not a new term or phenomenon. It dates back to the second world war, before the term AI was officially named by John McCarthy (Sabanovic,Milojevic and Kaur, 2012). AI was built on innovative thinking from the 18th Century in the form of Thomas Bayes probability rules (Bayes and Price, 1763) by Alan Turing, an English, mathematician, cryptanalyst, philosopher, and theoretical biologist at Bletchley Park to unravel the Enigma code (Rawlins, 2011). John McCarthy in 1959 (McCarthy and Hayes, 1969) wrote about '*Programs with common sense'* (p.99) and later in 1989 about AI, mathematic logic and common sense, he claimed that mathematical logic was the route to '*human-level AI*' (p.99). The extent to which AI can replicate human intelligence is key to exploring the effect of AI on job roles (McCarthy, 1989). Alan Turing devised a test (Turing, 1950) to measure the maturity of AI and Human Comparison Modelling. The '*Turing Test*' (Moor, 2003) tested whether AI can convince a panel of experts that it is human and can demonstrate human intelligence. The Turing test was a way of measuring progress in AI. Understanding the development of AI is key to evaluating the workforce requirements for people in the future. McCarthy (2007) defined AI as a science rather than a specific solution, "*It is the science and engineering of making intelligent machines, especially intelligent computer programs*" (p.2).

AI has been evolving since the 1950s, Figure 2-12 which is from a report published by the World Economic Forum (WEF) (McWaters, 2018). It depicts the technological advancements and how they correspond with the evolution of AI. This supports the earlier views captured on the General Purpose Technologies, GPTs (Basu *et al.*, 2008), that GPTs evolve over time and create the foundations of future innovation.

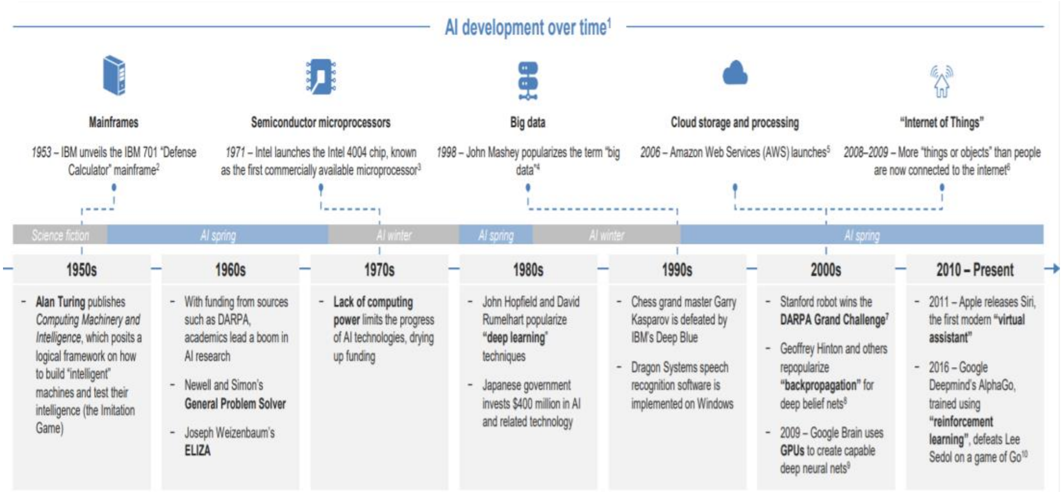

Figure 2-12 Advancements of AI, WEF Report (McWaters, 2018, p.8)

An observation of Figure 2-12 would be that '*Big Data*,' the '*Internet of Things*' along with '*deep learning*' all sit under the AI umbrella. Halal, Kull and Leffman (1997) described AI as being part of the emerging technologies. Including '*Machine learning*' (ML) and the '*Internet of Things*' (IoT). The term AI is broad and there are varying levels of maturity (Aubert-Tarby,Escobar and Rayna, 2018). Other definitions of AI include the '*Smart Machine Age*' (SMA) (Hess and Ludwig, 2017).

Which captured the acceleration of AI related technologies due to the growth in computational power as discussed previously in section 2.5.3 (Moore, 1998).

The onset of the Smart Machine Age (SMA) which included AI is and will continue to disrupt the human workforce (Hess and Ludwig, 2017). Smart machines are affecting how people work and live. People interface with smart machines daily, Kotlikoff (p.2) listed examples of where smart machines are in use, stating that they:

> *"collect our highway tolls, check us out at stores, take our blood pressure, massage our backs, give us directions, answer our phones, print our documents, transmit our messages, rock our babies, read our books, turn on our lights, shine our shoes, guard our homes, fly our planes, write our wills, teach our children, kill our enemies'* (2012, p.2).

These activities involved smart machines however, the activities to set up and enable the functionality of the smart machines was not possible without the interaction and input of humans. Very few of the above activities could be achieved in isolation by a smart machine. This view is supported by the views of Coplin (2014) who argued whilst technology, smart machines or AI driven solutions drive efficiency and productivity they can only be optimised by a balance of human involvement. This is key when exploring the impact of technological change and future work as the 'balance' between the human and technology needs to be understood.

There is an increasing interest in the theoretical and practical implications associated with AI (Niewiadomski and Anderson, 2017). Inventions define and create industry and impact the work market and these drive 'technological leaps' (p.29). These 'leaps' create disruption across society including the work people are employed to do and how they carry out that work. Literature (Koehler, 2016) highlighted the need for caution to businesses and industries, in that there is a need for them to understand the operational risk associated with technological change such as applied AI and specifically the business processes and required decision points that exist. Highlighting that there are limitations which need to be understood within the field of AI.

On the people side there is research and claims around how the application of AI solutions has impacted society in general (Nilsson, 1983). Analysis is available on people development as a subject matter area (Pfeffer, 1994). The effect on the job roles alongside technological change such as AI is not clearly defined or captured in relation to skills, training and development. This is due to the developments and adoption of the emerging technology being piecemeal, and not yet being fully understood or studied.

The rate of progress within the field of AI has triggered the creation of advisory and review groups worldwide (Stone *et al.*, 2016), along with new legislation across the world, in an attempt to understand and protect against any negative societal impact. In 2017, a US Bill was established for AI. Supporting the view that the pending change would have significant impact to society and the workforce. The Act acknowledged the gap in knowledge on this progressing area and stipulated the requirement for an advisory group to be established. This group advised on the potential impact of AI and the workforce which was an area flagged in need of review (Maria Cantwell *et al.*, 2017). The Bill captured that AI is a key area of technical change that is not fully understood and an area of considerable concern. The Bill acknowledged the future workforce and stipulated the need for further study and assessment on,

> *"how networked, automated, artificial intelligence applications and robotic devices will displace or create jobs and how any job-related gains relating to artificial intelligence can be maximized"* (p.7).

The 2017 Bill supported the view that technological change driven by advancements in AI will impact the future workforce, and through a committee set out to minimise the impact through understanding the potential for maximising the "*job related gains"* (p.7). The Bill acknowledged displacement and job creation as valid outcomes of technological change in relation to the emerging technologies. The Bill did not put forward a view on what those required skills could be and supported the requirement for further research to address the gap. The captured gap supports the need for this research aim, which is to explore the impact of technological change on future high skilled professional work. Job displacement and creation will be reviewed in more detail in section 2.8.

One of the key review groups established was the 'AI100' or '*One Hundred Year Study on Artificial Intelligence*,' through Stanfield University. The group issued a report based on a series of workshops which informed and discussed all aspects of AI. The report covered technological advancements and also societal implications and concerns. The 2016 report (Stone *et al.*, 2016) focused on eight areas that were captured as having or envisioned to have the most impact, they were: "*Transportation, healthcare, education, low-resource communities, public safety and security, employment and workplace, home/service robots, and entertainment" (p.6).* The AI100 consortium, highlighted the challenge and the lack of a clear agreed definition. The consortium cited the work of Nilsson (2010) and his definition, which they claimed was valid; *"Artificial intelligence is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment*" (p.xiii). Stone et al. acknowledged that 'AI' has evolved and they offered a further definition that AI is, "*a branch of computer science that studies the properties of intelligence by synthesizing intelligence*" (p.13). As part of the 2016 Report eleven areas were cited as being AI research topics that were trending, these were: '*Large-scale machine learning,* Deep learning, Reinforcement learning, Robotics, Computer vision, Natural Language Processing, Collaboration systems, Crowdsourcing and human computation, Algorithmic game theory and computational social, Internet of Things and Neuromorphic computing' (Stone *et al.*, 2016, p.9). See Appendix 8.5 for a further description of the eleven areas.

The definitions provided by Stone et al. in their 2016 report referred to AI as a science or intelligent activity rather than a specific or single technology. This reaffirms the original views presented by the founder of the term, *'Artificial Intelligence*' John McCarthy who described AI as, "*the science and engineering of making intelligent machines, especially intelligent computer programs"* *(McCarthy, 2007).* This presents AI as a concept and an evolving area, which concurs with the advancements depicted in the WEF report, Figure 2-12 (McWaters, 2018). The report captured the development of AI over the years, highlighting the emergence and maturing of, '*Deep Learning, recognition software, Internet of Things and reinforcement learning.'* All examples of '*machine intelligent activity*,' and included in Stone et al.'s (2016) declared '*trends'* which are underpinning the key areas of AI research.

A Mckinsey discussion paper (Chui, 2017) explained that, "*AI generally refers to the ability of machines to exhibit human-like intelligence"* (p.7), emphasising that there is no discrete agreed list of technologies and that it varies depending on the solution being developed. In some instances, it may be an amalgamation of multiple technologies or applications, advising that functionality is sometimes grouped '*image recognition*', '*speech*' and or '*text*' were cited as examples. Chui's explanation supported the view that there is not a single component to AI and further supports the definition set out by Stone et al. (2016) that AI is a science that synthesises the various elements of machine intelligence under a single term. AI is a far-reaching topic and the maturity level has been captured through further terminology or definition, these have been pulled out into a final AI sub-section, which is below.

2.5.9.1 AI Terminology

This small sub-section captures terminology that is frequently presented through literature relating to AI and captures the maturity stages of AI.

2.5.9.2 Good old-fashioned AI (GOFAI)

Nilsson (2010) captured '*Good old fashioned AI (GOFAI)* ' as AI that utilises "*heuristic search and discrete collections of symbolically represented facts and rules*" (p.312).

2.5.9.3 Weak or Narrow AI (NAI)

Niewiadomski and Anderson (2017) referred to '*Narrow AI, (NAI).*' This includes solutions including autonomous cars and discrete activities, where "*the concept asserts that machines could act as if they were intelligent. It is a sort of limited intelligence"* (p.30). The level of AI maturity we are currently experiencing falls under weak or narrow AI.

2.5.9.4 Strong AI or Artificial General Intelligence (GAI)

The last type of AI is '*Artificial General Intelligence, AGI,'* or '*strong AI,'* Niewiadomski and Anderson (2017), referred to this as being when machines think and their capability grows exponentially. We enter the territory of '*singularity*.' There is consensus (Niewiadomski and Anderson, 2017; Brynjolfsson,Mitchell and Rock, 2018) that technological change is not at the stage of AGI. "We *are far from artificial general intelligence (AGI) which would match humans in all cognitive areas"* (Brynjolfsson,Mitchell and Rock, 2018, p.43).

The three definitions of AI above refer to the maturity of AI. Huang & Rust also offered stages of intelligence (see Appendix 8.6) *"Mechanical, Analytical, Intuitive and Empathetic*" (2018, p.4), advising that analytical intelligence would fall under '*Weak AI*,' whereas '*Intuitive'* and '*Empathetic*' would be considered '*Strong AI.'*

AI has also been referred to as '*Machine Learning*' which describes one of the activities or processes of how AI can be applied. The next sub section 2.5.10 will review the literature relating to the definitions and applications of machine learning, to help inform the impact of technological change and future work.

2.5.10 Machine Learning

As described in the previous sub-section, Artificial Intelligence 2.5.9, Machine learning or 'ML' is as an area that sits within the science of Artificial intelligence (Halal,Kull and Leffmann, 1997; McWaters, 2018). This section explains the captured terminology in relation to machine learning which is an area of technological change. Machine learning algorithms train machines to be '*intelligent.*' Stilgoe (2018) explained that there are two approaches to machine learning, rule-based and algorithmic. Stilgoe also highlighted the importance of '*big data'* and how the machine learns by identifying patterns in massive amounts of data and moves away from a rule-based model. Deep neural networks are part of this learning model and such solutions are possible through advancements in compute power and the ability to store vast amounts of data. Other explanations of machine learning have included the role of '*classifiers*' and '*learners*' (Burrell, 2016). Stilgoe (2018) further confirmed the importance of '*big data*.' The '*learners*' use test data to learn and train which then feeds the '*classifiers*' which produces the output.

Additional terms that are used to describe the classification and learning approach include '*supervised learning*' (Louridas and Ebert, 2016). This incorporates several techniques, one of these is called '*classification,*' where the machine learns from an initial set of classification algorithms against a given dataset. The machine learns the classification, then applies the learnt classification to new data. There are also regression algorithms that can be used as part of '*supervised learning*,' which involve the prediction of a value rather than classification. Louridas and Ebert also captured '*unsupervised learning*.' Where the machine trains itself from a dataset but no outcome is predetermined like in '*supervised learning*.' Louridas and Ebert (2016) highlighted two types of '*unsupervised learning.*' '*Clustered'* and *'dimension reduction.'* The multiple approaches that fall under these four types are captured in Figure 2-13.

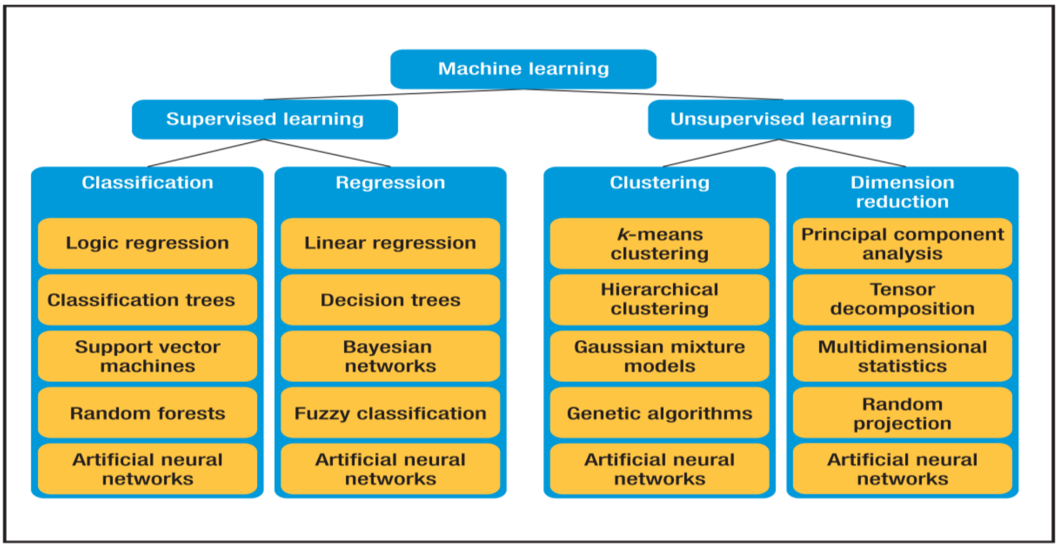

Figure 2-13 Machine Learning approaches (Louridas and Ebert, 2016, p.113)

Louridas and Ebert (2016) provided context and purpose for the use of algorithms, highlighting that they sit behind search engines, interrogating huge databases or the internet, they map and predict preferences. The significance is that unless there is data the algorithms are meaningless. The ability to collect and interrogate data is key to this type of technological change. Another important factor is the role humans play in machine learning. The techniques that were described earlier in this section, require human interaction. What is unclear from the literature is the role humans play in training and maintaining the machine learning models. This is an area that requires further exploration.

The increase in connected devices that collect data has fuelled machine learning and algorithmic elements that help provide insight and meaning to data, informing all industries. These connected intelligent devices form part of what is known as the Internet of Things (IoT) which will be discussed in the next subsection 2.5.11.

2.5.11 Internet of Things (IoT)

The World Economic Forum (WEF) report (McWaters, 2018), recorded that in 2008-2009, there were more devices or things connected to the Internet than people. These devices collect data and are a key component of IoT (Internet of

Things). The Fourth Industrial Revolution (Bloem *et al.*, 2014; Erol *et al.*, 2016; Alin, 2017; Keywell, 2017; Schwab, 2017; MüLler and Voigt, 2018; Wilkesmann and Wilkesmann, 2018) is underpinned by Cyber Physical Systems (CPS) and the Internet of Things. Sung (2018) defined this as "*Cyber physical systems that communicate and cooperate with each other and humans in real time via the internet*" (p.40). Other descriptions (Hermann,Pentek and Otto, 2016) of IoT include, enabling items, such as sensors and devices to connect and communicate. This connectivity can achieve mutual outcomes or objectives. Hermann, Pentek and Otto added that the connections or '*integrations*' are possible due to CPS, which are "*computation and physical processes*" (p.3929). This area of technological innovation of connecting devices creates an intelligent network, that has been tailored for specific industries or environments, '*Smart Factory, Smart Home, Smart Office*' where devices are connected to help control or manage the environment. This links back to the literature on technological change driving '*recombinant innovation*' (Weitzman, 1998), finding new ways to do historical things.

This subsection has described the technological change area known as the internet of things, IoT. There is one further area of technological change to be discussed, robotics. The next sub-section 2.5.12 will review robotics as an area of technological change, followed by the last sub section which will provide a summary for section 2.5.

2.5.12 Robotics

The last area of technological change that is reviewed is '*Robotics.*' Similar to the previously discussed area of technological change it is an area that is evolving and disrupting how we work and live. The term Robot came from '*Robota*' back in 1920 by Karel Capek (World Bank, 2019). The word '*Robota*' is the Slavic work for slavery (Reese, 2020). Capek introduced it through a play which saw robots carry out the work humans did not want to do. The play went on to close with the robots encroaching on all work and then killing the humans, similar to the modern day pessimistic views of singularity and the technological existential threat (Bostrom, 1998; Kurzweil, 2005; 2017). Robotics (Bloem *et al.*, 2014) is an example of where mechanical advancements from the 1st and 2nd Industrial Revolutions have led to the innovation and automation in factories experienced in the third round of industrial innovation. Although the term '*Robot*' was coined in 1920 by Capek, stories of automated beings date back further under '*automata*' (Susskind, 2020). The advancements in the Fourth industrial revolution indicate mechanical machines are being transformed into intelligent machines and these are evolving into personal assistants and connected devices that can react and respond based on sensors. Robotics like computers are not a new invention, the tasks and activities that they can carry out are evolving and it is these advancements that are impacting the workforce. DeCanio (2016), defined '*robots*' as AI. Advising that AI "*will designate the broad suite of technologies that can match or surpass human capabilities, particularly those involving cognition. Systems with these qualities will be referred to as "robots" for short"* (p.280). The article does not offer any further insight into what constitutes cognition and the study is focused on how AI decreases wages because of robotic substitution rather than defining robotics. Frey and Osborne (2013; 2017) claimed that '*mobile robotics*' are made possible by the advancements in machine learning, enabling more manual work tasks to be '*computerised*.' The advancements in sensor technology has enabled greater data collection which feeds further advancements into robotic technological change. Frey and Osborne claimed that technological advancements have enabled more '*non-routine,*' activities and tasks to be fulfilled by technology, providing examples of autonomous driving and robotics that can climb and carry out maintenance, along with advanced technology that can be fitted to cars which create the potential for them to be a *"fly-by-wire robot"* *(p.22)* describing this as being controlled remotely by a computer.

The area of robotics highlighted the coordination of multiple technological change areas coming together to provide further innovation. Data is driven through IOT devices, which are made possible through the internet and enhanced computing power, storage flexibility through cloud computing and encompassed through the science of artificial intelligence and machine learning approaches. A further example includes the advancements in visual recognition which have enabled robots to react to operational situations (Chui, 2017). Applying deep learning techniques, robots have become more autonomous and flexible identifying objects and circumstances in which to respond, such as an empty shelf. Chui, captured the collaboration between robotics and humans with human roles such as a "*robot instructor*" and "*collaborative robots*" (2017, p.26). Together human productivity can be increased up to twenty percent, this links back to the technological change definition, where technology drives '*recombinant innovation*' (Weitzman, 1998). A significant observation from Chui, is that the robots augment the human in the workplace, rather than replace them. The literature stated a twenty percent increase in productivity, further research is required to evaluate the future predictions in this area and whether further productivity gains would mean to more or less human work alongside robots.

This concludes the review of literature on robotics as a technological change area, the next section will summarise section 2.5.

2.5.13 Technological change summary

An observation of the review of technological change is that whilst robotics, AI, machine learning and other technological areas have been studied, there is a lack of consistent terminology and definition provided, presenting a gap in existing literature. There is an assumption in the literature (DeCanio, 2016; Makridakis, 2017; Bhattacharyya and Nair, 2019; Leahy,Holland and Ward, 2019; Marnewick and Marnewick, 2019) that the terms are understood and the focus of such literature is on the impact of the technology rather than contributing to clarity on the terminology. The exception is Stone et al. (2016) who contributed by providing clarity, defining AI as a science supporting the earlier view articulated by John McCarthy who described AI as, "*the science and engineering of making intelligent machines, especially intelligent computer programs"* (McCarthy, 2007).

To summarise this sub-section (2.5) technological change can be one or a myriad of technological evolutions, economists (Smith, 1776; Babbage, 1832; Schumpeter, 1934; 1942; Solow, 1957) referred to technical change as '*a shift in production.*' Industrial revolutions have driven change: mechanical, process and digital change through innovation. Using old things in new ways, Reese (2020) described, *"technology advances; by making incremental improvements on work done by others, a process Isaac Newton described as seeing further by standing on the shoulders of others*" (p.27). Smith (1776) believed that invention and change is driven by humans and there is a motivation to identify the most productive and labour saving route to perform work. Weitzman (1998), defined this as '*recombinant innovation*' which was further supported by others (Romer, 2008; Brynjolfsson and McAfee, 2014) where through innovation new ways are found of doing historical things. Generating new concepts and ideas, therefore driving technological change. The areas of technological change that are evolving, some claim are part of the Fourth Industrial Revolutions (Schwab, 2017; 2018; Sung, 2018; Kadir,Broberg and da Conceição, 2019; Kadir and Broberg, 2020). The 'I*nformation age*' of the 1990s, is now '*Big Data'* underpinned by AI, cloud computing and the internet. The term AI is all encompassing, and viewed as the science of making intelligent machines *(McCarthy, 2007, p.2; Nilsson, 2010; Stone* *et al., 2016)* which includes robotics, IoT devices and machine learning algorithms and approaches.

A further key observation when reviewing the multitude of technological change areas is the significance of the worker in the role that technology plays. Billings (1991; 2018) captured the importance of designing technology that is human-centric and ensures the human retains overall responsibility. This is further supported by Coplin (2014) who stressed that for efficiency and productivity of technology to be optimised human involvement is key. The augmentation between areas of technological change and the human worker is underrepresented in the literature and warrants further research to explore the impact of technological change and future work.

This section has visited the emerging areas of technological change and highlighted a gap in relation to how workers augment and interface with the technology in the future. When looking forward there is a need to forecast or predict future considerations. This will be reviewed in the next section 2.6, Technological Forecasting.

2.6 Technological Forecasting

This thesis explores the impact of technological change on future work. The review of literature that has studied or published opinion on future insight or foresight is an area of interest for the literature review. Evaluating existing literature on future studies, helped to inform the methodological choices, which are described in more detail in the next chapter (3 Methodology) and to understand existing theories and views on the exploration of future work studies. The ability of planning for the future requires a level of technological forecasting (Quinn, 1967). Technological forecasting was carried out when machine automation (Malm et al.,1969) challenged the workforce and impacted people's job roles. AI is already disrupting roles and the effect on future job roles is unclear and heavily debated (Keynes, 1933; Autor, 1998; Acemoglu, 2003; Autor, 2010; Acemoglu and Autor, 2011; Frey and Osborne, 2013; Goos,Manning and Salomons, 2014; Valenduc and Vendramin, 2016; 2017). Futurist (Kelly, 2010) highlighted that technology can bring opportunity and predicted that jobs will be impacted, through displacement, retirement and creation. Retraining and redeployment (Susskind, 2017) within the workforce may be required as the world enters a new era and professions such as Accountancy may require fundamental rethinking to exist in a Smart Machine Age (SMA) (Hess and Ludwig, 2017). The debate on workforce impact will be discussed in more detail in section 2.8.

Futurology (Sardar, 2010) is a field ranging from '*the destiny of man, the future of his society to the entire range of his future cultural activities*' (p.178). Sardar provided guidance on the claims of the field of future foresight, highlighting that it merely makes suggestions, "*Predictions, forecasts, scenarios etc do not provide us with knowledge of the future but only suggest certain, limited possibilities"* (p.178)*.* Sardar highlighted a key focus of future studies included looking backwards and he proposed four laws of future studies. The first was that '*future studies are 'wicked' (p.183),* this captured the complexity and uncertainty associated with the exploration of future insights. The complexity of '*Wicked problems*' referred back to the sixties, Professor Rittel (Churchman, 1967) who used it "*where information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing"* (p.141). The second law set out by Sardar, related to cultural considerations acknowledging humanity, Sardar called this '*MAD,*' "*Mutually Assured Diversity*" (p.183) and stressed the importance of these considerations in future studies. The third law was being '*Sceptical*' bringing together the first two advising that the future is not certain and therefore future studies should involve a level of scepticism to reflect this uncertainty. The fourth and final law presented was '*Futureless*,' highlighting the importance of future studies being captured in the here and now and that, *"the impact of all futures explorations can only be meaningfully assessed in the present"* (p.183). Sardar captured the importance of future studies on influencing decisions and perceptions in the present. The four laws supported the need for future studies to help inform and shape current policies and strategies.

The approach of forecasting goes back many decades. Simon (1969) made a number of predictions based on developments at the time and the author's experience and proximity to computers, these included: "*Business organization in 1985 will be a highly automated man-machine system and the nature of management will surely be conditioned by the character of the system being managed" (p.206).* Simon also made predictions about roles that would be affected by the automation created by machines and referred to the *'Occupational profile'* (p.211) and whether prediction was possible; he believed it was and claimed that that a more fundamental approach was required, considering the tasks that either the human or machine would fulfil, highlighting the need to understand the "comparative advantage." Simon's literature did not expand on the tasks or a potential split of work between machine and human, he set out his expert view at the time and invited others to conduct further research.

Simon's expert opinion as a futurist supported De Jouvenel's (1967) argument of conjecture and its validity when forecasting. De Jouvenel, believed it would be, *"logically absurd to expect the scientific perspective to inform us of unforeseen discoveries*" (p.282). The ability to plan ahead for eventualities and workforce requirements is key to any business or establishment that has to compete for skilled resources, all organisations require a resource plan to meet business objectives and to stay competitive in their market. Understanding the drivers and disrupting factors is essential. A Foresight Policy group (Rhisiart,Störmer and Daheim, 2016) explored the disruptors of the future and highlighted key trends as part of a 2030 Future Work study. This research focused on utilising a foresight approach and how impactful that was. The literature supported the view that technological forecasting is a key area of interest where there are disrupting factors, such as technical change. Similarly, the Millennium Project (Glenn and Gordon, 1997; 1999; 2001), was established in 1996 to explore the area of technological forecasting. The project was made up of a group of global experts, who were called the '*Global Look-out Panel.*' The aim of the panel was to carry out a multi-round study to, "*identify issues, opportunities, and prospective actions"* (p.203) in relation to the state of the future. The internet was described by the project as being: "*technological global convergence creating the planetary 'nervous system' necessary for improving the prospects for humanity'* (p.203). The relevance of this group was that they looked forward, anticipating potential global impact and they identified technological advancement as a one of the factors that would impact the future workforce. The project did not explain further how the impact may materialise, which highlighted the need for further research.

Two years later in 1999, experts from around the world were brought together (Glenn and Gordon) as part of the Global look-out panel to review a list of global issues. Fifteen issues were captured to help research future outcomes to improve humanity. Two of the fifteen items are of significance for this literature review as they related to technological change and the future workforce. Global issues 10 and 15 were,

> *"10. Information technology holds both promise and peril.*
> *15. The meaning of work, unemployment, leisure and underemployment is changing"* (p.98).

In the 1999 group, there were 250 participants which led to 180 developments being suggested by the lookout panel. The developments were classified as; *"could evolve over the foreseeable future to significantly improve the human condition"* (p.99). Within the 180 was the recommendation to expand the potential for technological breakthroughs and applications, citing great improvements within engineering and medicine specifically and the importance of brain like intelligence which utilised neural networks and other simulation technologies. The group mentioned that the technology, *"promises to lower unit cost, and spread the benefits of technology while lowering the environmental impact of a growing world economy and population"* (p.104).

The Millennium Project (Glenn and Florescu), in 2017 started additional research, conducting surveys to review the future of work. The research is still underway and its associated approach stands out from that of others, with the focus being on "*Global Scenarios and Strategies*" (p.153) in relation to the workforce extending out to 2050. The project is collating input from hundreds of futurists, experts in the field of AI and other relevant subject matter experts from 45 countries. The Millennium Project claim that their research is different in relation to technological change and the future workforce, citing that previous studies have focused on the volume or metrics associated with job losses, or technological unemployment (White, 1931); whereas the objective of their research is to identify what can be done in advance to prepare for the anticipated changing world of work. This in-progress study which in 2017 had run workshops in 17 of the intended 45 countries, will be of great interest due to it taking a proactive approach utilising technological forecasting from experts in the field. The approach being applied is utilising three '*2050 Scenarios'* (p.155) *that* have been compiled from information and views previously collated from 450 Futurists and associated field experts specifically in relation to *"future work-technology dynamics"* (p.153). The drawback of this approach is that at the point of writing this thesis the Millennium Project study is still ongoing and the results unavailable to feed into this literature review, however their approach is acknowledged and the area of research supports the need for further research in the area of understanding the impact of technological change on future work.

Technological forecasting is conducted by Futurists or visionary thinkers, such as Kelly (2010) who made specific predictions that technology would bring opportunity and that it would displace and replace jobs, whilst also creating new jobs and opportunities. Kelly also stated that we should encourage technology as it is *'an active agent in increasing the options, choices and possibilities of others*' (p.3937). Three potential scenarios were captured; Scenario 1 was that technology complexity would remain '*simple, basic and primeval because its works;'* Scenario 2 was that the complexity was growing and Scenario 3 was that there '*is no limit to how complex all things can get'* (p.280).

It was predicted that technological complexity would follow scenario 1, including a specific prediction that: '*Cities and houses remain similar, populated with a veneer of fast-evolving gadgets and screens on every surface'.* Kelly contributed to the forecasting of technological ability. However, the predictions did not go as far as forecasting what this may mean to the workforce. The predictions provided insight into what the technological platform could look like, this information needs to be evaluated alongside what the comparative advantage (Simon, 1969) considerations could be to establish a view of a future workforce. Later in 2016, further predictions were captured (Kelly, 2016) forecasting what 2046 or 2050 may look like. Twelve continuous actions are described, along with a prediction that '*products will become services and processes*' (p.6). Examples are given such as: *'the web in 2050 won't be a better web'* (p.24). Kelly identified how search will grow, and everything will be searchable, and the web will be able to reach everything, '*most objects in your room will be connected enabling you to google your room'* (p.24). Similar to the forecasting in 2010, it is limited to the view at that time and raises more questions as to the associated impact with the predictions set out, creating a platform for further research. Kelly acknowledged that some of the technological capability already partially exists, such as the connected home, the ability to control things remotely, such as your heating or music system from your phone. The prediction was that there will be greater overlap of devices and that the web will *'expand to the dimensions of the physical planet'* (p.24). These predictions support the view of Coplin (2013; 2014) and Mainardes, Funchal and Soares (2017) that the future technical change will be underpinned by AI and big data. Kelly made predictions of potential technical change, similar to Simon (1969). The predictions are not reviewed alongside any occupational impact, whether that be job replacement, displacement or creation, further analysis and research is required to understand the implications of such predictions coming to fruition, partially or completely.

A challenge associated with technological forecasting or 'technology road-mapping' (Zhang *et al.*, 2016) is being able to capture the, "*known, knowns and the known unknowns*" (p.175). Zhang et al., highlighted the importance of gaining knowledge and insight from experts. They do not define what would constitute an expert but do stipulate that using different approaches is important when carrying out technical road-mapping given the complexity of emerging technologies. Zhang et al. (2016) focused on proving a technology road-mapping model, highlighting the need for qualitative approaches utilising experts, also capturing the evolving nature of the technical change and how the forecasting also needs to evolve. The set-out recommendations for further research to be conducted utilising experts to help predict the various levels of advancement. This approach to forecasting supports the previous literature on conjecture (De Jouvenel, 1967), highlighting that quantitative scientific data is not best placed to forecast events that have not yet occurred.

Technological forecasting is highly relevant to this thesis due to the rate of change in which AI is progressing across multiple industries, supporting the view of Zhang et al. (2016) that forecasting needs to evolve with change. Scenarios and examples are included of where AI is being applied and planned, the adoption and consumption is still being evaluated. The House of Lords Select Committee Report

(2018) cited the observations of experts that responded as part of their Inquiry into AI. They stated that AI will have "*significant implications*" (p.6) on society. They identified that jobs will be affected, some for the better and some may no longer exist, they also put forward that new jobs will be generated, but that these were not known. Technological forecasting is key to enabling businesses and academic organisations to plan and devise strategies to remain current and meet future demand. The report also noted the views that were submitted to the inquiry, and that one theory is that the impact to the workforce would not be extensive and may even generate a positive impact, flagging that components of a job may change rather than the role itself be retired. The approach is one of '*augmentation*' and not '*technological unemployment*.' Referring to the CIFAR (Canadian Institute for Advanced Research, 2018) evidence submitted to the AI inquiry, there are two views, the first being:

> "*Enabling technologies complement and increase the productivity (and wages) of certain types of skills (e.g., laptops for managers and workers specializing in problem-solving, scanners for cashiers)*" (p.4) and the second being, *"replacing technologies conduct tasks previously performed by labour (e.g., assembly tasks, switchboard operation, mail sorting). This can further lead to displacing labour, reducing wages and polarizing employment"* (p.4).

The inquiry captured key technological driving forces, a limitation of the literature was that no specific roles were mentioned or included in the evidence submitted, similar to the predictions of Kelly (2010 & 2016) and Zhang et al. (2016) further research is required to build on the technological forecasts to link these to the future workforce and explore further the impact of technological change.

Callaghan (2018) also highlighted the importance of technological forecasting due to emerging technologies, acknowledging the field of AI. Callaghan claimed that there were two views of future technological impact, '*pessimism*' and '*optimism.*' However, Callaghan's study focused on six threats posed by technology, highlighting the uncertainty associated with the emerging technologies, whilst he claimed to apply a balanced view the literature is heavily focused on seeing technology as a threat, it highlighted negative scenarios such as 'Singularity' (Bostrom, 1998; Kurzweil, 2005) and the end of humanity. A noteworthy aspect of his work is that he invites further, "*research into technological futures"* (p.16) stressing the need for more focused research in this area. The limitation of the literature is that it supported a pessimistic view, further research is required on the pragmatist counter-claims such as those set out by Makridakis (2017). The view of the optimist set out by Makridakis explained that AI will provide a 'utopian' where technology, robots and AI carry out all the essential work and people are free to do more creative activities and have a choice as a result of the social freedom technology will provide. There is limited literature available to support this '*utopian*' position.

Makridakis (2017) maintained that technological change will drive an impact, referring to a world where data is exploited on a major scale and used to inform decisions, which is made possible by the connectivity enabled through the internet. Challenges were also predicted around the ability to consume the benefits that technological change such as AI could bring. Makridakis (2017) explained the alternative views which directly contradict the pessimistic threats claimed by Callaghan (2018). Makridakis argued that there is, *'significant comparative advantage*' (p.46) which will grow and that there is the potential for new service lines along with enhanced productivity whilst also negating the need for unemployment and wage inequalities. Makridakis (2017) like Callaghan (2018) confirmed that there is a high level of uncertainty associated with the future impact of AI, both utilised scenarios for forecasting and captured the views of optimists and pessimists. Makridakis adopted two other scenarios in addition to the optimist and the pessimist. One of the '*pragmatists'* and the other the '*doubters*' (p52) articulating the varied views and concluding that the majority of research in relation to the workforce has focused on existing job roles rather than exploring the compensation effect of job creation, as set out by Dachs and Peters (2014b). A key scenario under the limited available views of the 'pragmatists' predicted two approaches that intelligent technology could adopt. The first being duplication of '*human intelligence'* (p.51) and the second of '*augmentation*.' Where people manipulate the technology to maximise the human capability. The literature highlighted further research is essential and needed to converge on *'intelligence augmentation'* (p.52) to proactively address the negative predictions put forward by the pessimists. Such as Bostrom (1998 & 2017) Kurzweil (2005) Frey (2015) and Frey and Osborne (2017). Evaluating the comparative advantage highlighted by Makridakis, who did not expand on what the advantage could look like. The literature is limited to forecasting technological scenarios which are predicated against the four mindsets; "*optimists, pessimists, pragmatists and doubters"* (p.50) stressing the major gap in the literature related to the pragmatists view, where technology augments human decision making.

Further to the view of the pragmatist, in 2016 the World Economic Forum (WEF) produced a report on the '*Future of Jobs*' (2016). The report focused on the Fourth Industrial Revolution and what this may mean to the workforce. The report summarised the views of respondents and contained an element of '*conjecture*' (De Jouvenel, 1967). It attempted to forecast what this could mean to specific job role families. The study considered both negative and positive growth across multiply sectors, predicting job impact in the following areas,

Growth in *"Architecture and engineering and computer and mathematical job families,"* a slight reduction in, *"manufacturing and production roles,"* major reductions in, "*Office and administrative roles,*" with potential neutral impact to, "*Business and Finance operations, Sales and related, and construction and extraction*" (p.11).

The relevance of the WEF (2016) report is that it not only predicted technological change alongside other disrupting factors through a global survey, it predicted impact between a set time frame (2015-2020) it also cross referenced this by industry and specifically job family (see Appendix 8.7). Further research is required to evaluate the insight collated from 371 individual companies. The study focus was not confined to technological change, the survey asked respondents to consider other disrupting factors, with a view to profiling employment changes, therefore it is unclear how much of the projected disruption was linked to technological change. Another significant limitation is that the survey did not extend to public sector, which challenges the negative position put forward by the survey. The survey presented that 5.1 million jobs would be lost as a result of *"disruptive labour market changes"* (p.13) however the study was limited to non-public sector roles due to a lack of response in that sector. Nedelkoska (2013) claimed a key area of human comparative advantage involved skills such as compassion, empathy and that there was significant employment growth recorded in the Health industry which would have offset the employment reductions set out by the WEF predictions. The human skills highlighted by Nedelkoska (2013) are supported by the views of Hess and Ludwig (2017) and Huang and Rust (2018). Excluding public sector from the study provided an incomplete view of the potential workforce alongside technological disruptions.

In 2018, the WEF issued an updated report on the '*Future of Jobs Report*' (World Economic Forum, 2018). The aim of the updated report was to provide, "*a better understanding of the potential of new technologies, including automation and algorithms, to create new high-quality jobs and vastly improve the job quality and productivity of the existing work of human employees"* (p.v). The report highlighted four key areas of technological change and innovation between 2018 and 2022, which were:

1. "*Ubiquitous high-speed mobile Internet*

2. *Artificial Intelligence*
3. *Adoption of Big Data and*
4. *Cloud Technology*," (p.vii)

The World Economic Forum (WEF) 2018 Report referred to ten trends that they predicted as a result of a survey will affect business growth up to the year 2022. Capturing both positive and negative projected impacts. Many of the entries relate to technology, the advances and increased adoption and availability of those technological areas. The technological change items have been highlighted in figure 2-14.

Trends set to positively impact business growth up to 2022	Trends set to negatively impact business growth up to 2022
Increasing adoption of new technology	Increasing protectionism
Increasing availability of big data	Increase of cyber threats
Advances in mobile internet	Shifts in government policy
Advances in artificial intelligence	Effects of climate change
Advances in cloud technology	Increasingly ageing societies
Shifts in national economic growth	Shifts in legislation on talent migration
Expansion of affluence in developing economies	Shifts in national economic growth
Expansion of education	Shifts of mindset among the new generation
Advances in new energy supplies and technologies	Shifts in global macroeconomic growth
Expansion of the middle classes	Advances in artificial intelligence

Figure 2-14 World Economic Forum, Future of Jobs Survey 2018 Business Growth impact trends

The 2018 version of the report focused on the country profiles and the emerging skills and job roles; the report was focused on a fixed timeframe 2018 to 2022. The report concentrated on trends across industries and geographic areas looking at roles that were created and declined between 2013 and 2017, providing a historical snapshot of changes based on hiring trends through LinkedIn data. An area of significance from the 2018 report was the evaluation on future job roles. Respondents were asked to capture whether they believed specific job roles were '*stable*,' and therefore remain in place, roles that would be *'created*' and roles that would no longer be required and therefore '*redundant.*' Figure 2-15 captured the results. When you compare the three lists against the Standard Occupational Classification, the observation is that the roles cut across all Major Group

Categories and are varied, they do not focus on a specific occupation group or industry. The report is caveated to flag that roles may appear in multiple columns due to variance in responses representing sector demand differences. This approach is significant as it provides a fresh perspective and first attempt to evaluate future work and specifically occupations. A limitation to the 2018 World Economic Forum study is that akin to the previous 2016 report, where the survey struggled to obtain public sector responses. The Public Sector is a major contributor to the work force and the lack of representation from this area in the reports significantly underrepresents the future workforce view. In addition to this the report was not limited to technological change impact, it was all encompassing and the scope included environmental, political and other factors that could impact future work. Further research is required to evaluate the impact of technological change on future work.

Stable Roles	New Roles	Redundant Roles
Managing Directors and Chief Executives	Data Analysts and Scientists*	Data Entry Clerks
General and Operations Managers*	AI and Machine Learning Specialists	Accounting, Bookkeeping and Payroll Clerks
Software and Applications Developers and Analysts*	General and Operations Managers*	Administrative and Executive Secretaries
Data Analysts and Scientists*	Big Data Specialists	Assembly and Factory Workers
Sales and Marketing Professionals*	Digital Transformation Specialists	Client Information and Customer Service Workers*
Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	Sales and Marketing Professionals*	Business Services and Administration Managers
Human Resources Specialists	New Technology Specialists	Accountants and Auditors
Financial and Investment Advisers	Organizational Development Specialists*	Material-Recording and Stock-Keeping Clerks
Database and Network Professionals	Software and Applications Developers and Analysts*	General and Operations Managers*
Supply Chain and Logistics Specialists	Information Technology Services	Postal Service Clerks
Risk Management Specialists	Process Automation Specialists	Financial Analysts
Information Security Analysts*	Innovation Professionals	Cashiers and Ticket Clerks
Management and Organization Analysts	Information Security Analysts*	Mechanics and Machinery Repairers
Electrotechnology Engineers	Ecommerce and Social Media Specialists	Telemarketers
Organizational Development Specialists*	User Experience and Human-Machine Interaction Designers	Electronics and Telecommunications Installers and Repairers
Chemical Processing Plant Operators	Training and Development Specialists	Bank Tellers and Related Clerks
University and Higher Education Teachers	Robotics Specialists and Engineers	Car, Van and Motorcycle Drivers
Compliance Officers	People and Culture Specialists	Sales and Purchasing Agents and Brokers
Energy and Petroleum Engineers	Client Information and Customer Service Workers*	Door-To-Door Sales Workers, News and Street Vendors, and Related Workers
Robotics Specialists and Engineers	Service and Solutions Designers	Statistical, Finance and Insurance Clerks
Petroleum and Natural Gas Refining Plant Operators	Digital Marketing and Strategy Specialists	Lawyers

Figure 2-15 Examples of stable, new and redundant roles, all industries (World Economic Forum, 2018)

Figure 2-15 above captured specific job roles that were forecasted to be impacted against three high-level classifications. This closes the subsection on technological forecasting and steers us into how human work or jobs are defined and captured. The next section, 2.7 Human Workforce explores the literature that describes how the human workforce is defined.

2.7 Human Workforce

This Sub-section reviews how work is defined. The classifications and standards that have been published and relate to the workforce. This research explored future work, this section helps understand how '*work*' is defined and how worker skills are articulated in existing literature. Figure 2-16 captures the key topics discussed in this section, 2.7. In addition to these areas section 2.7.4 provides a closing summary for this section on the human workforce.

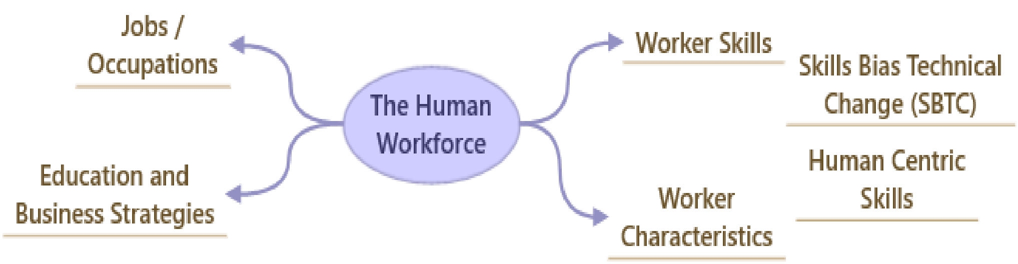

Figure 2-16 Human Workforce sections

Skidelsky and Craig (2020) when describing a conference that focused on '*Work in the Future'* that was held in 2018, claimed that meaning of '*work*' in the twentieth century has lessened, they referred to work as being defined as "*paid employment*" (p.3). This sub-section is split into two parts, the first reviews the classification of occupations and the second the characteristics of a job and how skills are portrayed.

A countries labour is key to the *"necessities and conveniences of life which annually it consumes"* (Smith, 1776, p.7). Smith highlights the importance of the regulation of the annual supply of labour. Capturing two key areas. First being the *"skill, dexterity and judgement with which labour is generally applied."* Secondly, "*the proportion between the number of those who are employed in useful labour and that of those who are not so employed."* Smith's reference to labour is still valid today, the skills in which labour is applied will be reviewed more closely in the second subsection, 2.7.2 along with types of useful labour such as the types of jobs and occupations that exist today and how they are classified which we will review next in 2.7.1.

2.7.1 Occupation Classification

The UK Standard Occupation Classification (SOC) is the UK framework that provides descriptions of what people do by job groupings (Mannetje and Kromhout, 2003; Elias and Birch, 2010). The classification is updated every decade and was refreshed in February 2020. There are nine Major occupational Groups, Table 2-3 captures the major groups, 1-9. Along with the corresponding descriptions. The structure and descriptions of the groups are volume one of the SOC. There are two additional volumes that make up the SOC. The second is the complete index (Office for National Statistics, 2020a). Which details 29,664 entries numerically coded into groups. The third volume is the Socio-economic classification, of which there are eight analytical classes. A copy of the eight classes can be found in Appendix 8.9.

SOC 2020 Major Group	SOC 2020 Group Title	Groups Classified Within Sub-Groups	Group Description
1	Managers, directors and senior officials	Occupations in this major group are classified into the following sub-major groups: 11 Corporate managers and directors 12 Other managers and proprietors	This major group covers occupations whose tasks consist of planning, directing and coordinating resources to achieve the efficient functioning of organisations and businesses. Working proprietors in small businesses are included, although allocated to separate minor groups within the major group. Most occupations in this major group will require a significant amount of knowledge and experience of the production processes, administrative procedures or service requirements associated with the efficient functioning of organisations and businesses.
2	Professional occupations	Occupations in this major group are	This major group covers occupations whose main tasks require a high level of knowledge

SOC 2020 Major Group	SOC 2020 Group Title	Groups Classified Within Sub-Groups	Group Description
		classified into the following sub-major groups: 21 Science, research, engineering and technology professionals 22 Health professionals 23 Teaching and other educational professionals 24 Business, media and public service professionals	and experience in the natural sciences, engineering, life sciences, social sciences, humanities and related fields. The main tasks consist of the practical application of an extensive body of theoretical knowledge, increasing the stock of knowledge by means of research and communicating such knowledge by teaching methods and other means. Most occupations in this major group will require a degree or equivalent qualification, with some occupations requiring postgraduate qualifications and/or a formal period of experience-related training.
3	Associate professional occupations	Occupations in this major group are classified into the following sub-major groups: 31 Science, engineering and technology associate professionals 32 Health and social care associate professionals 33 Protective service occupations 34 Culture, media and sports occupations 35 Business and public service associate professionals	This major group covers occupations whose main tasks require experience and knowledge of principles and practices necessary to assume operational responsibility and to give technical support to Professionals and to Managers, Directors and Senior Officials. The main tasks involve the operation and maintenance of complex equipment; legal, business, financial and design services; the provision of information technology services; providing skilled support to health and social care professionals; and serving in protective service occupations. Culture, media and sports occupations are also included in this major group. Most occupations in this major group will have an associated high-level vocational qualification, often involving a substantial period of full-time training or further study. Some additional task-related training is usually provided through a formal period of induction.
4	Administrative and secretarial occupations	Occupations in this major group are classified into the following sub-major groups: 41 Administrative occupations 42 Secretarial and related occupations	Occupations within this major group undertake general administrative, clerical and secretarial work, and perform a variety of specialist client-orientated administrative duties. The main tasks involve retrieving, updating, classifying and distributing documents, correspondence and other records held electronically and in storage files; typing, word-processing and otherwise preparing documents; operating other office and business machinery; receiving and directing telephone calls to an organisation; and routing information through organisations. Most job holders in this major group will require a good standard of general education. Certain occupations will require further additional vocational training or professional occupations to a well-defined standard.
5	Skilled trades occupations	Occupations in this major group are classified into the following sub-major groups: 51 Skilled agricultural and related trades	This major group covers occupations whose tasks involve the performance of complex physical duties that normally require a degree of initiative, manual dexterity and other practical skills. The main tasks of these occupations require experience with, and understanding of, the work situation, the materials worked with and the requirements of the structures,

SOC 2020 Major Group	SOC 2020 Group Title	Groups Classified Within Sub-Groups	Group Description
		52 Skilled metal, electrical and electronic trades 53 Skilled construction and building trades 54 Textiles, printing and other skilled trades	machinery and other items produced. Most occupations in this major group have a level of skill commensurate with a substantial period of training, often provided by means of a work-based training programme.
6	Caring, leisure and other service occupations	Occupations in this major group are classified into the following sub-major groups: 61 Caring personal service occupations 62 Leisure, travel and related personal service occupations 63 Community and civil enforcement occupations	This major group covers occupations whose tasks involve the provision of a service to customers, whether in a public protective or personal care capacity. The main tasks associated with these occupations involve the care of the sick, the elderly and infirm; the care and supervision of children; the care of animals; and the provision of travel, personal care and hygiene services. Most occupations in this major group require a good standard of general education and vocational training. To ensure high levels of integrity, some occupations require professional qualifications or registration with professional bodies or relevant background checks.
7	Sales and customer service occupations	Occupations in this major group are classified into the following sub-major groups: 71 Sales occupations 72 Customer service occupations	This major group covers occupations whose tasks require the knowledge and experience necessary to sell goods and services, accept payment in respect of sales, replenish stocks of goods in stores, provide information to potential clients and additional services to customers after the point of sale. The main tasks involve knowledge of sales techniques, a degree of knowledge regarding the product or service being sold, familiarity with cash and credit handling procedures and a certain amount of record keeping associated with those tasks. Most occupations in this major group require a general education and skills in interpersonal communication. Some occupations will require a degree of specific knowledge regarding the product or service being sold but are included in this major group because the primary task involves selling.
8	Process, plant and machine operatives	Occupations in this major group are classified into the following sub-major groups: 81 Process, plant and machine operatives 82 Transport and mobile machine drivers and operatives	This major group covers occupations whose main tasks require the knowledge and experience necessary to operate and monitor industrial plant and equipment; to assemble products from component parts according to strict rules and procedures and to subject assembled parts to routine tests; and to drive and assist in the operation of various transport vehicles and other mobile machinery. Most occupations in this major group do not specify that a particular standard of education should have been achieved but will usually have a period of formal experience-related training. Some occupations require licences issued by statutory or professional bodies.
9	Elementary occupations	Occupations in this major group are classified into the following sub-major groups:	This major group covers occupations which require the knowledge and experience necessary to perform mostly routine tasks, often involving the use of simple hand-held tools and, in some cases, requiring a degree of physical

SOC 2020 Major Group	SOC 2020 Group Title	Groups Classified Within Sub-Groups	Group Description
		91 Elementary trades and related occupations 92 Elementary administration and service occupations	effort. Most occupations in this major group do not require formal educational qualifications but will usually have an associated short period of formal experience-related training.

Table 2-3 Standard Occupation Classification (SOC) Major Groups (Office for National Statistics (ONS) 2020d)

Table 2-3 captures the high-level framework of the UK SOC, the United States also has a Standard Occupation Classification (Watson, 2013). The current version was released in 2018. The US SOC contains 867 '*detailed*' occupations, with 459 '*broad*' occupations, 98 '*minor*' groups and 23 '*major*' groups. Compared to the UK SOC which has 9 '*major*' groups, 26 '*sub-major*' groups, 91 '*minor*' groups and 412 '*unit*' groups.

Goos, Manning and Salomons (2014) utilised the ISCO-08 (International Labour Organization, 2012) which enables classification of worldwide jobs and has a similar structure to the UK SOC. It entails 436, '*unit groups,*' 130 '*minor groups,*' 43 '*sub-major groups*' and 10 '*major groups,*' a comparison of the three classifications is outlined in Table 2-4. The ISCO-08 was compiled in 2008 and replaced the previous version of 1988, to date a revised version has not been issued. The US SOC was updated in 2018 and the UK more recently in 2020. Both the UK and US SOC updates have noted changes to Health and technical roles. Table 2-4 presents the three standards all together capturing the group volumes for each for comparison.

Group Headings UK & ISCO	UK SOC 2020	ISCO-88		US SOC 2018	Group Headings US
Major Groups	9	10		23	Major Groups
Sub-Major Groups	26	43		98	Minor Groups
Minor Groups	91	130		459	Broad Groups
Units	412	436		867	Detailed Groups

Indexed jobs	29,664*	Not published	Not published

** recorded on the 14th of Feb 2020*

Table 2-4 Summary of the three-occupation classification standard framework models

Several roles in the UK SOC 2020 were moved from the major group 3, '*Associate Professional Occupations*,' to major group 2, '*Professional occupations*.' The amendments also captured changes to administrator roles, recording an update from '*typist*' to '*data entry administrators.*' Other technical professional role changes that were acknowledged in the ten-year refresh were the growth in '*cyber security*' roles and '*web and multi-media design.'* Figures 2-17 and 2-18 represent the changes based on the SOC updates from the 2010 version to the 2020 update. The data represents employment data taken from the UK Labour Force Survey between January 2014 and September 2017. A key change is the increase in Major Group 2 which reflects the re-classification of roles from Major Group 3 into that group and this applies to both males and females.

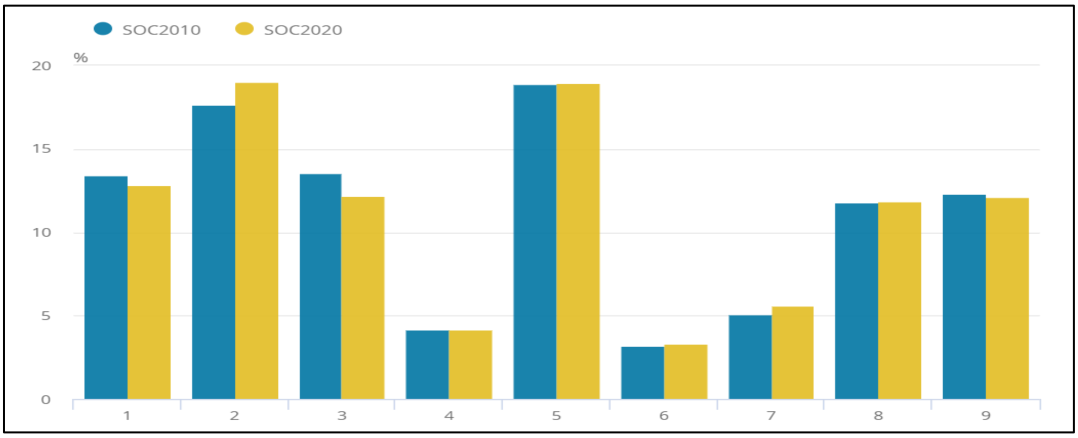

Figure 2-17 Percentage distribution of male employment by SOC major groups (Office for National Statistics, 2020a)

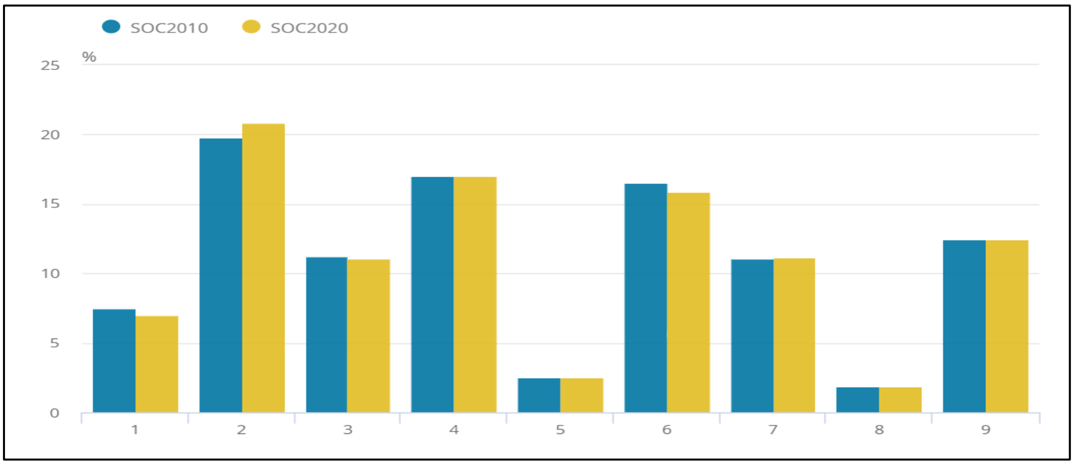

Figure 2-18 Percentage distribution of female employment by SOC major groups (Office for Statistics, 2020a)

An observation from the SOC changes between 2010 and 2020 would be that the changes were minimal. This suggests that whilst there is agreement technological change has and is disrupting the workplace (Autor,Katz and Krueger, 1998; Acemoglu and Autor, 2011; Frey, 2012; Autor and Dorn, 2013; Frey and Osborne, 2013; Acemoglu *et al.*, 2014; Autor, 2014; Frey, 2014; 2015; Frey, 2015; Bessen, 2016a; 2017; 2017; Kim,Kim and Lee, 2017; Autor and Salomons, 2018; 2018; Boyd and Huettinger, 2019; Bessen *et al.*, 2020a; 2020b) the types of jobs being removed or created in their entirety are minimal. An alternative explanation is that the SOC can only cater for occupations that exist today creating a snapshot of existing roles in 2019, on the basis that the review window was conducted in 2019 and published in 2020.

The SOC captures the types of occupations by grouping. Research has been conducted (Autor and Acemoglu, 2010; Frey and Osborne, 2013; Autor, 2015; 2017; Kim,Kim and Lee, 2017) that examined the job or occupation tasks and activities, the job role characteristics and skills will be discussed next in subsection 2.7.2. How technology has impacted workers occupations along with the role activities and tasks will be reviewed in the following section 2.8.

2.7.2 Job role characteristics & skills

Workers are allocated job roles which were described in 2.7.1 as being classified into occupation groups. The components that make up the work carried out by people are described as tasks and activities. Another factor of a job role are the skills and characteristics required by workers to carry out a specific job or occupation. This subsection reviews the literature to understand the attributes and approaches taken in relation to human work.

The US SOC provided an explanation as to the difference between a *'job'* and an '*occupation,*'

> *A job is a set of work activities performed by an individual. The exact set of activities varies depending on the size and organization of the establishment and is often, but not always, unique to that individual worker. An occupation is a grouping of a number of individual jobs* (Bureau of Labor, 2019, p.2).

This definition highlighted the importance of understanding the activities performed by an individual as part of a job role. In a study (Autor et al., 2003) that looked at how computerisation effected job skill demands, a job was described as '*a series of tasks: moving an object, executing a calculation, communicating a piece of information, resolving a discrepancy*' (p.3). This supports the definition provided in the US SOC. The same study also utilised job task metrics from the Dictionary of Occupational Titles (DOT) which was a standardised list of occupations in the United States (US) (United States Employment, 1949). The DOT has since been replaced by the US SOC (Standard Occupation Classification) (Mariani, 1999) and the O*NET, which stands for Occupational Information Network. The O*NET is a, "*comprehensive database of occupational competency profiles"* (Bureau of Labor Statistics, 2018, p.2). The O*NET is established through a series of surveys that collates labour information from workers in a number of occupations, providing details on worker characteristics and requirements which are mapped against the US SOC. See Appendix 8.10 for a copy of the O*NET content model.

The SOC, DOT and O*Net have been used in a number of studies (Goos and Manning, 2007; Ananiadou and Claro, 2009; Acemoglu and Autor, 2011; Goos,Manning and Salomons, 2014; Chung and Elliott, 2015; De La Rica and Gortazar, 2016; Arntz,Gregory and Zierahn, 2017; Frey and Osborne, 2017; Burger *et al.*, 2019) these will be evaluated in the next section, 2.8 where the literature relating to the impact of technological change on the workforce is reviewed.

In 2017, the Department of Education issued the UK Employer Survey (ESS) (Winterbotham *et al.*, 2018). The results included 87,430 responses from employers who had responded to a two-part survey on worker skills and specifically on the skill challenges employers had both when recruiting and also with their existing workforce. The report summarised that there were '*technical*' and '*practical*' skills gaps along with '*people'* and '*personal skill*' shortages, highlighting "*complex analytical skills,*" along with '*digital skills'* (p.13) as a specific area. The report acknowledged there was variability depending on the role area, for example, "*skills disproportionately lacking for Professionals included advanced IT skills and complex analytical skills*' (p.13). The report highlighted that there are several areas where there is an insufficient supply of skills to meet workforce demand, capturing a shortage in the professional occupation group. The report stressed the linkage between productivity drivers and the need to improve UK worker skills to unlock future potential. New technology was rated as one of the transformation factors for contributing to a skills gap. However, transient factors featured higher in the report, such as new starters and performance challenges. It was unclear from the report the role that technological change has played in the responses from employers. The report highlighted the importance of professional workers in relation to productivity drivers, professional work has been linked to a skills bias driven by technological change, this will be discussed in the next sub-section.

2.7.2.1 Skills Bias

Evaluating the literature on worker skills, a key theory emerged one of, *'Skills Bias Technical Change (SBTC)*' (Autor,Katz and Kearney, 2006; Deming, 2017; Holzer, 2019). The term was founded in economic studies and represents the '*skills bias*' that technology has driven in the workplace as opposed to '*skills neutral*' (Holzer, 2019). The bias is based on the substitution and complementary impact technology has had on workers, that disruption has favoured more skilled or educated workers creating '*SBTC.'* Ford (2015) explained that '*SBTC*' was as a result of the automation of work that was historically carried out by less educated workers. Therefore, automation has '*deskilled*' their work, whilst driving an increase in the more complex work carried out by graduates and professionals. Deming (2017) spoke of:

> *"increasing returns to skill as a product of the complementarity between technology and high-skilled labor, or skill-biased technological change*" *(p.1594)*.

This complementary force has been linked to social skills, capturing a *'comparative advantage'* (Simon, 1969) for humans in relation to machines. '*Skills bias,'* has been cited in studies (Acemoglu, 1999; Goos,Manning and Salomons, 2009; Bogliacino,Lucchese and Pianta, 2012; Murphy and Oesch, 2017) which have focused on the inequalities that technological change has driven, along with the polarisation of skills and therefore wages. Section 2.8 will review these claims in more detail. Another area that has been flagged in the literature when reviewing human workplace skills is an area of human centricity, the literature on this topic will be reviewed in the next section.

2.7.2.2 Human Centric Skills

A further area of interest when reviewing the literature on human workplace skills is the focus on human centric skills. Webster and Ivanov (2020) when discussing '*Robotics, Artificial Intelligence and Automation'* (RAIA) captured that the "*role of the human will be different*" (p.138). They described a number of pertinent human centric skills flagging that workers need to develop; "*Problem solving, emotional intelligence, interpersonal communications" (p.137).* Webster and Ivanov noted that the skills are "*uniquely and emotional in nature*" *(2020, p.135).* This supported the earlier view presented in the World Economic Forum Report (2018), that captured the top ten skills (see Figure 2-19) predicted to increase and decline in demand by 2022, along with the current skills recorded in 2018.

Today, 2018	Trending, 2022	Declining, 2022
Analytical thinking and innovation	Analytical thinking and innovation	Manual dexterity, endurance and precision
Complex problem-solving	Active learning and learning strategies	Memory, verbal, auditory and spatial abilities
Critical thinking and analysis	Creativity, originality and initiative	Management of financial, material resources
Active learning and learning strategies	Technology design and programming	Technology installation and maintenance
Creativity, originality and initiative	Critical thinking and analysis	Reading, writing, math and active listening
Attention to detail, trustworthiness	Complex problem-solving	Management of personnel
Emotional intelligence	Leadership and social influence	Quality control and safety awareness
Reasoning, problem-solving and ideation	Emotional intelligence	Coordination and time management
Leadership and social influence	Reasoning, problem-solving and ideation	Visual, auditory and speech abilities
Coordination and time management	Systems analysis and evaluation	Technology use, monitoring and control

Figure 2-19 Job skill demand comparison 2018 - 2022 (World Economic Forum, 2018, p.12)

Understanding the human centric skills is an important consideration when exploring technological change and future work to understand the relationship between technology and the human worker. In section 2.5.6 we reviewed automation, where Billings (1991; 2018) highlighted the importance of a human-centric approach to technology which supports the worker. Understanding the human centric skills alongside the technological change is an important consideration when exploring future work.

Limited research has been conducted on exploring future skills for professional workers, the World Economic Forum Report (WEF) (2018) demonstrated in Figure 2-19 the importance of exploring future skills to help determine future workforce demand, prior to the WEF report minimal insight had been provided on the types of skills that organisations should consider in readiness and training policies. Further research is required and reinforced by the views of Van Laar et al. (2019) who also concluded further research is required to define policies for the development of digital skills for the twenty first century. The literature highlighted that the focus has been on the basic technical skills rather than 'content-related skills' (Van Laar *et al.*, 2019, p.11). The next sub section is the penultimate one that reviews the literature relating to the human workforce, it considers the key strategies and policies relating to the future workforce.

2.7.3 Key Strategies and Policies

This sub-section, 2.7 has reviewed the occupation and skills classifications along with discussing the skills shortage and theory of skills bias towards higher skilled workers. A further area of literature which is pertinent to future work are the strategies and policies that set direction and focus for education and corporate organisations. This sub-section will explain the identified key strategies and programmes relating to the workforce.

In 2017 the UK Government issued an Industrial Strategy White Paper (UK Department for Business) setting out that the goal was to *"create an economy that boosts productivity and earning power throughout the UK" (UK Department for Business, 2017, p.10).* The strategy document highlighted five foundations of productivity, see Figure 2-20. People were captured as a key consideration to the strategy with a focus on driving equality in relation to decent jobs and better earning capability. The strategy also captured four '*Grand Challenges'* of meeting a further strategic aim of the UK which was to become a leader in future industries.

Technological change is fundamental in addressing all four of the challenges. However, two of the challenges specifically related to technology; "*AI & Data Economy and Future of Mobility*" (UK Department for Business, 2017, p.10). The strategy highlighted the importance of the workforce and technology in meeting strategic goals that underpin productivity and ultimately future economic growth.

Figure 2-20 UK Industrial Strategy five foundations (UK Government, 2017, p.10)

The strategy articulated a number of key policies relating to people and work. These included establishing a best in class '*technical education system*,' which included investment into STEM (Science, Technology, Engineering and Maths) skills acknowledging a shortage of skills in this specific area, along with implementing a scheme to retrain, re-skill and support people. The strategy document set out the areas of focus and intention, further policy documentation is required to implement programmes and initiatives against the strategy goals.

The ministerial documentation owned by the Department for Education in the UK points to National Curriculum documentation which sets the subjects and study areas for students across the multiple key stage areas. The National Curriculum sets the policy for school learners. Higher education is administered through the UK Vocational Education and Training Structure, see Appendix 8.8 for a copy of the Structure, which also includes consideration for Adult learning. Another area of policy setting is the consideration for the retraining of workers, which is covered through the National retraining scheme, which acknowledged the requirement to retrain workers through the scheme and online Blog pages (Caplan, 2018). The National retraining scheme is focused on helping adults through retraining to move into better jobs. The Department of Education explain through their online Blog (Watts, 2020) that they are utilising a 'theory of change' to help policy and service makers in relation to retraining workers. In addition to the government strategies and policies, education and corporate organisations also have their own strategies and policies for setting training and learning for students and employees.

The relationship between 'the State' or government bodies and society is an important link when considering the future workforce. Cook (2016) captured environmental levels, with the '*macro level'* being the interactions between society and governmental organisations or departments. In relation to education and future work this would be the ministerial departments referred to above. In addition to the macro level, Cook referenced a '*meso-level*,' which focused on the individual societal practices and behaviours. These behaviours in the workforce would resonate as skills and competencies and understanding this 'meso-level' of behaviours is key for macro-level policy setting. The research aim and objectives of this thesis focus on the 'meso-level' of future work to help inform the 'macro-level' set through departmental policies and plans.

The next section will summarise section 2.7 before moving onto reviewing the literature in relation to how technological change has impacted the workforce to date.

2.7.4 Section summary

This chapter reviewed the literature relating to occupation and skill classifications along with the claim of human centric skills and key strategies, policies and approaches that support workers learning. The next section will bring together the areas of technological change, as discussed earlier in section 2.5 and the human workforce considerations reviewed in this section 2.7. Reviewing the claims and theories that have been published to date to help inform the high-level research aim which is to explore the impact of technological change and future work.

2.8 Technological Change and the impact on the workforce

2.8.1 Section overview

In the preceding sections we have reviewed the literature in several key areas to help inform the research aim of exploring the impact of technological change on future work. We have reviewed:

1. What constitutes technological change and the economic importance of '*inventiveness*' (Smith, 1776).
2. Technological areas, the key General Purpose Technologies (GPTs) (Basu *et al.*, 2008) compute power, the internet and how through automation and digitalisation the '*Science of Artificial Intelligence*' (Stone *et al.*, 2016) has grown.
3. The importance of foresight studies to help organisations prepare now for the future (Sardar, 2010) and
4. What is meant or defined when referring to '*work*' and '*jobs'* and the claim of skills bias that has emerged through technological change (Deming, 2017; Holzer, 2019).

This section brings together the above four previous literature review sections to examine the literature that evaluates one or more of these areas together to help build a picture of what literature currently exists in relation to future work and technological change.

The literature was evaluated following the approach described in section 2.2. Literature that discussed workforce impact and cited technological change (as described in section 2.5) was reviewed and the authors were mapped chronologically, using mind mapping software (see Figure 2-22) capturing the key themes at that point in time. When reviewing the literature, several claims and theories were presented. They were:

1. *Technological unemployment or redundancy, where jobs were claimed to be replaced or substituted by technology.*
2. *Job Displacement, where jobs or the work that people carried out changed or moved, this could be at the sector level or the individual job level.*
3. *Inequality, captured through job polarisation or skills bias, that technology displaced middle tier jobs creating a skills bias for higher skilled workers and an inequality in wages for workers.*
4. *A human comparative advantage, where specific skills, tasks or work activities are better placed to be carried out by people over technology.*
5. *Job Creation, capturing where technological change has created jobs, either more of existing roles to meet demand or new roles have been created as new areas and even industries have been created.*
6. *Creative Destruction, based on Schumpeter's (1942) theory which captured the two phases of impact, job destruction followed by job creation.*

The six theories were mapped into a mind map using the following key (Figure 2-21).

Figure 2-21 Theory mapping key

When reviewing the literature, a practical challenge was how to structure this chapter sub-section (2.8) due to the theories overlapping and also being contradictory in part. Sections 2.8.2 and 2.8.3 navigate through the chronology as captured later in the sections in Figure 2-22 and 2-23. It highlights where literature supports or contradicts previous studies, whilst also drawing attention to where theories build on existing research or theory. '*Creative destruction*' for example refers to both '*unemployment*' and '*creation*' of work. Whilst '*displacement*' challenges '*unemployment*' claiming that work is displaced or changed rather than being fully replaced. '*Job polarisation*' and '*inequality*' are driven by '*displacement*' of work where activities or tasks are displaced by technology, which establishes areas of '*comparative advantage.'* Furthermore, a '*polarisation*' effect captures a claim of technology hollowing out middle skilled work, creating a demand for jobs both at the low and high spectrum of skills which drives '*inequality*' across the workforce.

Section 2.8.2 discusses the theoretical positions presented between the 1930s and 1980s in relation to exploring the impact of technological change on work. Starting with the claims of Keynes, an economist.

2.8.2 Chronology of workforce impact theories, 1930s to the 1980s

The claim that technology will effect job roles is not a new claim, in the 1930s (Keynes, 1933) technology was described as a '*disease*.' Keynes focused on the economic fears, that the pace of the technology was far greater than the rate in which replaced labour could secure alternative work. He concluded there would be 'technological unemployment.' White (1931) offered an alternative view to that of Keynes, whilst he agreed that '*Technological Unemployment'* (p.572) was a result of machinery that caused unemployment through reducing labour. White declared that he believed the unemployment would be followed by workers moving to other areas of work, supporting a theory of displacement. The theory of displacement will be reviewed in the next sub section 2.8.3.2.

White (1931) claimed overall technical unemployment was impossible that the impact of technical change triggered improvements which had a timing affect. White believed that whilst some jobs may disappear or be removed by the technological advancements or "*labour saving tools*" (p.572) these would be absorbed into other areas and people would not be made unemployed. White referred to this as a *"transfer of labour"* (p.576). White (1931) provided a limited view on what that transfer may be, referring to macro levels of work, only capturing the industry level rather than the micro level of work which would detail the jobs and associated activity and tasks. White highlighted historical examples to support his claim that technology drives a temporary reduction or state of unemployment. That technical change drove unemployment first however, huge expansion followed, citing the example of the textile industry which created many more jobs. White did not expand on the types of jobs. The literature highlighted how the introduction of technological change, machinery in this case created a series of changes which over time resulted in more jobs in different areas. White's work dates to the 1930's and limited research has been conducted on the timing of job disruption in relation to recent technical change, such as AI, Machine Learning, and automated solutions. His claims of a dual effect later became known as '*creative destruction,*'(Schumpeter, 1942).

Schumpeter (1942) defined creative destruction as, "*incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one" p.82*. In the 1940's '*industrial change*' was referred to as '*productive apparatus*' (p.82) and created a process of '*industrial mutation*' and these were economic drivers to society and across industry.

In 1954, Drucker a management theorist stated that technological change would drive a need for large numbers of skilled and trained workers. Highlighting a shortage of skills to maintain and run the new technology. Drucker predicted that computers would have an effect. However, similar to White he did not believe that this would result in '*mass unemployment'* (p.8). Drucker's thoughts were later supported by Simon (1969), who claimed that the jobs would change rather than be destroyed. These predictions are still relevant today due to new advancements and capabilities, such as AI driving technological change.

Although White, Schumpeter and Drucker all published more optimistic views on the potential and outcomes that technology poised it was still an area of great concern and threat. Supporting earlier views of Keynes, in 1964 (Levy and Murnane, 2004) a memo was presented to the president of the United States of America warning that computers would lead to mass unemployment. In 1966 the President established a Commission. '*The National Commission on Technology, Automation and Economic Progress.'* This group debated the various issues and claims. The findings were that the fear of high unemployment as a result of technology was unsubstantiated. At the time of the debate unemployment rates had fallen, to under 5% (Rumberger and Levin, 1985), which challenged the fear and threat of technological unemployment. Today similar fears and concerns exist, with claims of singularity and existential threat from robots and artificial intelligence (Kurzweil, 2005; Higgins, 2013; Shanahan, 2015; Bostrom, 2017).

White's and Drucker's claims were reinforced by Simon (1969), who predicted that there would need to be a '*shift in mix of jobs rather than mass unemployment'* (p.8). These predictions are still relevant today due to technological change driving a similar disruption. The way in which people work and live is changing due to new advancements and capabilities (Hess and Ludwig, 2017). However, like White neither Drucker or Simon expanded on their claims, they did not quantify or qualify what the change may look like or what types of skills would be required alongside the technology being introduced, highlighting a limitation to the literature.

Simon (1969), a futurist wrote an article that predicted work in 1985. He spoke of automation and computers and the importance of "*applying the doctrine of comparative advantage*" (p.209). Identifying areas that devices have an advantage over people and conversely where the device or technological advantage over humans had the least advantage. The significance of this approach is fundamental in realising productivity and efficiency gains in completion of workplace tasks and activities. This is equally applicable today as it was in 1969. Simon observed that computers exceled and were significantly faster at arithmetic providing gains in the work of bookkeeping and similarly at executing investment decisions. However, when evaluating grievances in the workplace or taking dictation, humans had the comparative advantage and were better placed to carry out these activities. Simon captured fresh insight into areas of human comparative advantage over automation, '*flexibility*' and '*applicability*' and he raised important questions that are still valid today when exploring future work. How can these advantages be '*matched*' with the automation or the devices that provide the automation and can the human flexibility be reduced to help enable matching? To make the human work more routine or easier to automate. The questions poised in 1969 by Simon are relevant today when considering the comparative advantage over technology and the advancements in automation. A key takeaway from Simon's predictions for future work are that machines would have the technical capability to automate some aspects of work, but this would not lead to technological unemployment. Occupations would still exist. There would be collaboration, referred to as '*fraternization*' in the automated world with robots and understanding the comparative advantage over the automation is key.

Continuing with the theme of robotics. In 1983, the Institute of Economic Analysis (IEA) conducted a modelling exercise (Leontief and Duchin, 1984). Highlighting at the time, limited literature was available in relation to technological specialism. Specifically referring to limited research which explored robotics and that future research should be encouraged. The modelling was to profile future labour demand taking into consideration technological change, specifically '*computer-based automation*.' Building out projections for employment rates against a set of technological assumptions. This was achieved through four scenarios, each modelling different rates of technological advancement. The analysis looked at fifty-three occupation areas in the United States and utilised historical data to help inform predictions, modelling impact between 1963 to the year 2000. The technological assumptions were built on the actual rate of automation that was experienced in 1980. The key scenarios were: S1, which profiled that the automation capability remained the same through to the year 2000 as it was in 1980. The S2 & S3 profiled faster rates of automation, with three being faster than scenario two. The conclusions were that if the S3 scenario materialised there was a difference of twenty million jobs. Leontief and Duchin reported that technology could by the year 2000 remove the need for an additional twenty million jobs across all sectors and industries in the US. The report captured several important factors. Firstly, the research was based on assumptions in relation to the rate of technological advancements being adopted which would require at the time future organisational investment. Secondly, it raised the question whether there would be sufficient numbers of workers to meet the demand profiled. Although they capture a reduction of twenty million jobs between the results of scenario one and scenario three, this would have required 156.6 million workers to fulfil the demand. If technology did not advance as quickly as predicted the profiling claimed that 176.8 million workers would be required in the US. If you cross reference this with actuals that are now available from the 2000 US Census data (Clark and Weismantle, 2003). There were 166.3m people in the US aged between 20 and 64 years old. This would suggest that technological advancement is essential to be able to meet the labour demand profile and raises questions over the twenty million jobs claimed to be removed by technology.

Leontief and Duchin (1984) offered some important insight when exploring technological change and future work, which is valid today due to the emerging and evolving nature of technology. They highlighted the importance for continual education and training for professionals to stay current. They also described the importance of training updates for teachers and professionals within the education sector. The research assumptions when modelling technological advancements included a rate of readiness and training. Whilst a key finding from their research was that technological advancement in areas of automation could reduce the projected number of jobs required in the future. The supply of labour did not exist to meet such demand, which would present a different economic challenge for organisations. The original aim of their research was to address the gap in existing literature, the lack of analysis to support the generalisation of future technological unemployment. What is of great significance following their analysis, they concluded that they were unable to confirm technological unemployment by the year 2000.

A year later the IEA report, (Leontief and Duchin, 1984) was a key data feed along with a labour prediction report from the US Bureau of Labor Statistics (BLS) in research conducted by Rumberger and Levin (1985). The research set out to forecast impact of new technologies on future jobs. The work summarised how technology had disrupted all types of work. Listing factory, office and farming along with occupational changes to managerial and construction workers. Highlighting that technical specialist fields were growing, identifying computer science and engineering specialisms. These areas were referred to as '*high tech,*' whilst traditional skilled areas were declining. Rumberger and Levin identified that job skills were changing with historic skills becoming "*obsolete*" (p.399). The study supported Keynes (1933) view of technical unemployment, stating that whilst the technological change offered economic advantages it would significantly impact and change the workforce and lead to years of high unemployment. The literature went on to capture job creation in specific areas and referred to '*displacement.*' The research contested that technology would not drive a demand for higher skillset, claiming the opposite effect. Technology would reduce the '*mental demand*' on workers, citing areas of microelectronics and that future work demand will be in areas of lower skillset. The report is contradictory throughout, highlighting reduction and then articulating growth. In the concluding comments the literature summarised claims of both creation and destruction of jobs as implications of technological change, supporting the earlier view of Schumpeter (1942) and his theory of creative destruction. The report summarised a pessimistic view of technological change and the impact on workers in its final remarks. Citing substitution of workers by robots and the 20 million jobs being removed by the IEA modelling, along with the degradation of human skills and action being required to mitigate the negative impact that had been forecasted.

This section has reviewed the literature and claims relating to technology and workforce impact between the 1930s and the 1980s and included the earlier views of Smith from 1776 as depicted in Figure 2-22.

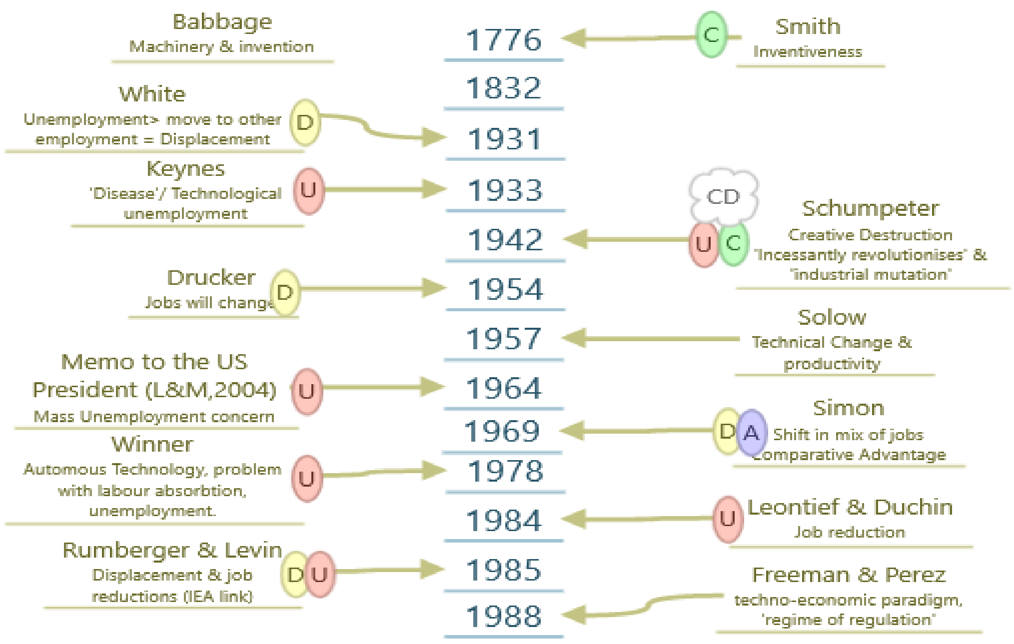

Figure 2-22 Workforce impacts chronology 1930s to 1980s

The bleak forecasts documented by Rumberger and Levin (1985) are not consistent with later research which provided a contrasting picture of '*skills bias'* driven out of technological change (Katz and Murphy, 1992; Autor, 1998; Goldin and Katz, 1998; Acemoglu, 1999), where technology creates a demand for higher skilled workers linked to a comparative advantage (Simon, 1969).

The next sub section builds on the theories set out by Keynes, White, Drucker, Schumpeter and Simon and how these key theories re-emerge in the literature from the 1990s through to the current day, starting with Simon's comparative advantage. Figure 2-23 provides the chronological mapping of the literature being covered. Appendix 8.27 captures the full chronology from 1776 through to 2020.

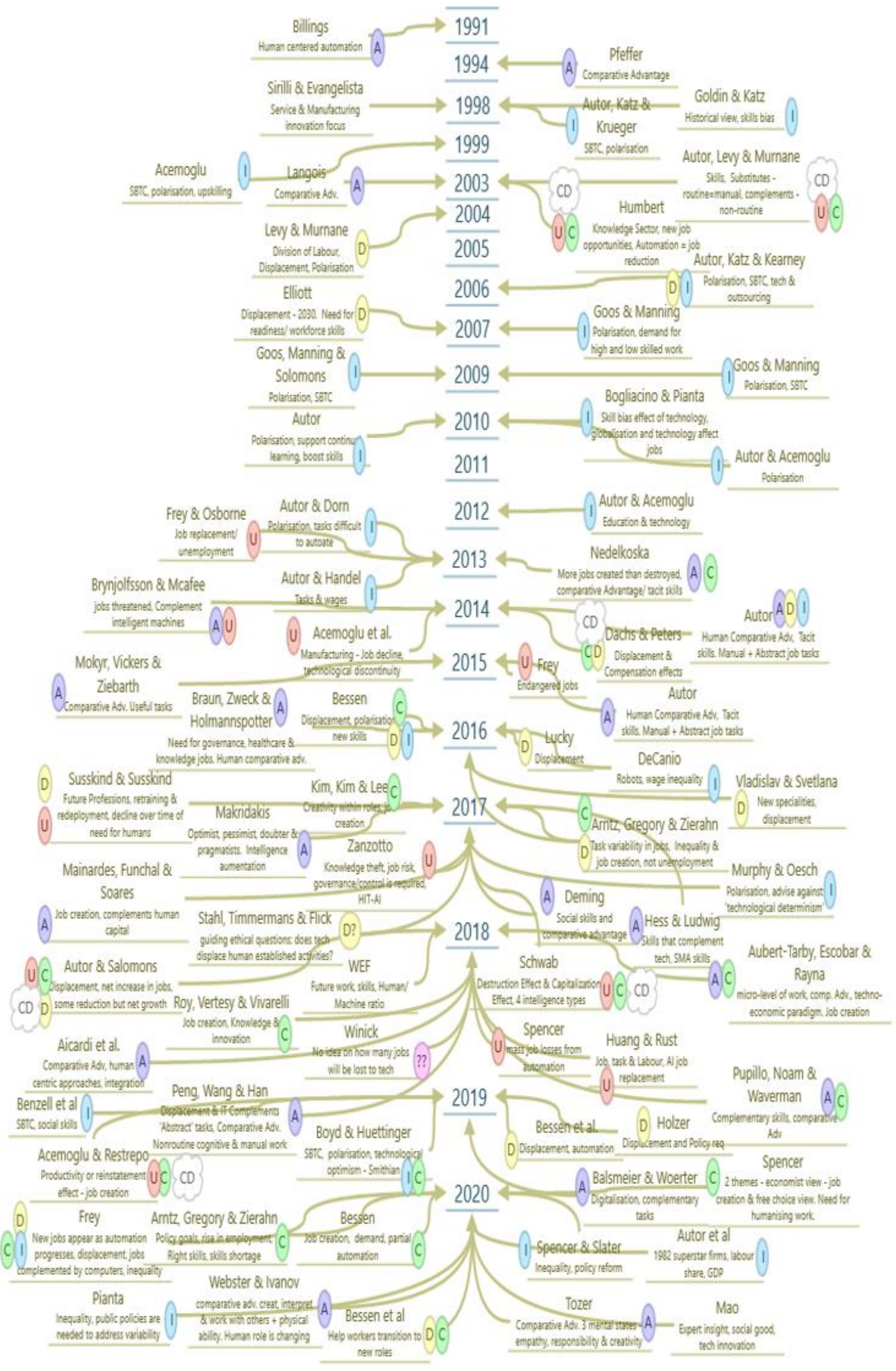

Figure 2-23 Workforce impacts chronology 1990s onwards

2.8.3 Chronology of workforce impact theories, 1990s to 2020

2.8.3.1 Comparative Advantage

In the 1990s, there were a number of studies (Billings, 1991; Pfeffer, 1994; MacDuffie, 1995) that supported the theory of comparative advantage (Simon, 1969) which evaluated technology alongside workers. In section 2.5.6 we discussed the work of Billings (1991), who wrote a report on behalf of Nasa which detailed principles for human centric aviation. Billings referred to automation as an '*effective tool or resource*' (p.3) for the pilot and stipulated that the human has responsibility over the automation and the complete system. The significance of Billings report not only provides practical contribution to the use of automated systems alongside the human worker he also emphasised the importance of management and responsibility being retained by the human. He highlighted that technology, automation in this example provided tooling or resources for just part of the work being fulfilled and ultimately under the responsibility of the human worker. Billings report enhanced Simon's theory of comparative advantage and the matching of technology with human flexibility and applicability. Billings referred to the need to augment the limited capabilities of the human pilot using technological instruments and sensors; automating some of the checks that must be conducted on a regular basis in a routine and prescriptive way. This augmentation was driven to achieve higher safety levels and to assist the pilot. Another important factor raised by Billings is that whilst the technology can fully automate the activities and tasks required to fly a plane, it is the unexpected events that require human intervention. This further supports Simon's claims on human comparative advantage in applying *'flexibility'* and '*adaptability,*' which are grounded in experience and difficult to imitate. Changes in the weather or an engine failure, are examples of scenarios that require judgement and evaluation of multiple variables which a fully automated solution would struggle to accommodate. Such eventualities would impact the ability to consistently meet the high standards in relation to aircraft safety, driving a need for technology to have '*purposiveness*.'

Pfeffer (1994), further supports the capabilities that the human worker presents over technology, the work which is titled, *'Competitive advantage through people: Unleashing the power of the work force*' highlighted the importance of the ingrained knowledge employees have, which provided the organisational capability and advised that imitating this knowledge is difficult. An important observation that Pfeffer made is that he believed organisations will invest heavily in skills and incentives for its employees in the future to protect their organisation capability. It has been demonstrated previously (Polanyi, 1966) that human knowledge and the ability to carry out certain skills is an area that is not easily replicated through technology, reinforcing the theory of a human comparative advantage over technology.

Understanding the '*Human Comparative advantage,'* over the technological advantage is key to exploring the future workforce. To understand the '*matching'* of skills to establish augmentation as explained by Billings (1991) at the start of this section, will result in technology being a tool or resource to workers that help maintain the organisational capability Pfeffer refers to. It also supports the '*Techno-economic paradigm*' presented by Freeman and Perez (1988) who identified the importance of technological revolutions and the matching of emerging technology with the social system of the economy including the workplace.

When reviewing the task makeup of work and the tasks that are carried out by humans in comparison with those fulfilled by machines, the Future of Job report (World Economic Forum, 2018) predicted an encroachment by machines with the ratio changing as technology matures. Figure 2-24 captures the profiling.

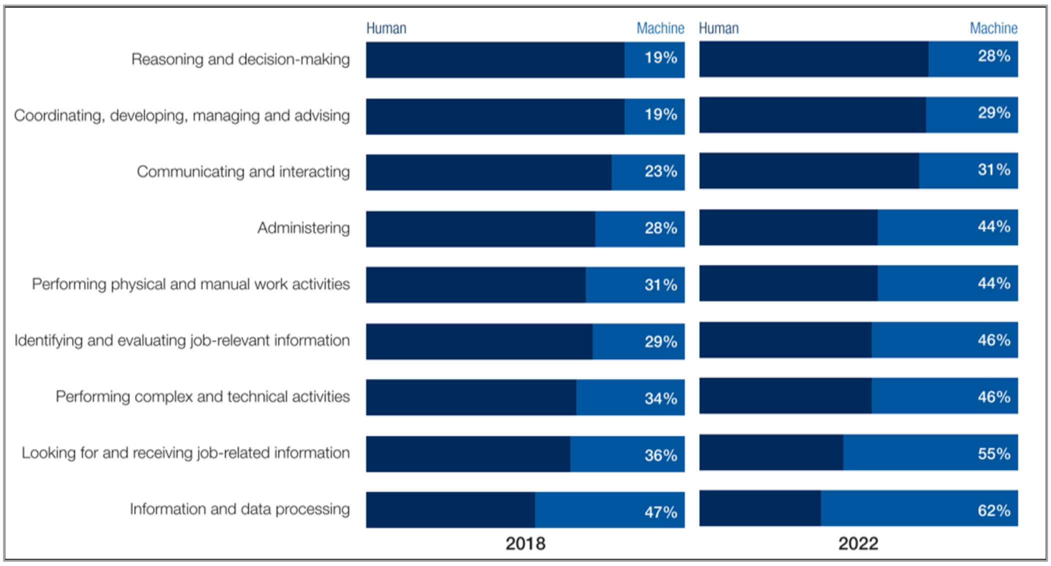

Figure 2-24 "Ratio of human-machine working hours, 2018 vs. 2022 (projected)" (World Economic Forum, 2018, p.11)

The report highlighted that specific tasks to date had been monopolised by humans, noting these as: "*Communicating and interacting; Coordinating, developing, managing and advising; as well as Reasoning and decision-making"* (World Economic Forum, 2018, p.11). The report predicted that machines, including algorithms will grow in capability and complete more working hours than previously. The significance of the WEF report is that it demonstrated the importance of understanding the 'comparative advantage' for both the human and the machine in tasks. Further research is required to understand how the workforce adapts with the evolving maturity of technology.

It has been established that humans have a significant comparative advantage over technology, one of context and being able to understand the '*whole*' sum of the parts (Polanyi, 1966). Whilst individual components have a "*functional appearance" (Polanyi, 1966, p.3)* there is an element of '*tacit knowing*' which is knowledge that a person has but cannot explicitly explain. Polanyi in setting out his claim described an '*act of integration*,' between '*visual*' experience and a '*tacit knowing.*' Examples included the ability to swim or ride a bike. However, explaining how to balance on a bike or float in the water are difficult activities to explain. The focus is on the whole task, to ride or swim rather than the component parts, to float or to balance. Polanyi argued that to understand explicit knowledge you must have tacit knowledge, using an example of driving. You can review the explicit knowledge relating to a car, the individual component parts and how they work, the pedals, wheel, gears. However, without the tacit skills to bring the parts together you could not drive the car. When evaluating Polanyi's theory of know-how and tacit skills in more current scenarios alongside technology (Autor, 2014; 2015) we find that tacit skills are still a significant comparative advantage for workers alongside the emerging technology.

Autor (2014; 2015) wrote seminal papers which built on Polanyi's theory of tacit skills, making reference to '*Polanyi's Paradox' (2014).* Autor evaluated, '*Why are there still so many jobs*' (2015) given the dystopian views presented by alternative claims of unemployment (Keynes, 1933) and the threat of singularity (Bostrom, 1998; 2017). Autor emphasised the importance of the human skills that have a comparative advantage over technology. He generalised job tasks into two high level areas, "*Manual*" or "*Abstract*" (p.10). His paper supported the findings from earlier research that he conducted with two other co-authors (Autor,Levy and Murnane, 2003) where they explored tasks that were non-routine and difficult to automate. In comparison to tasks that are routine and '*codifiable*' and more suitable for automating. They concluded that '*abstract tasks*' mapped to managerial, technical and professional roles and that these types of roles warranted a higher level of skillset. A key contribution from Autor's literature is he identified skill areas of higher skilled workers that were difficult to automate. They were, *'analytical capability, inductive reasoning, communication ability and expert mastery'* (Autor, 2015, p.12), suggesting areas of human comparative advantage over technology. The second area captured *'manual tasks'* which related to lower skilled non-routine work, tasks that required physical interaction and attendance, primarily in service or labourer roles. This separation and differentiation between skillsets presented a further theoretical claim, '*polarisation*' and '*inequality*.' Which will be discussed in subsection, 2.8.3.3.

Returning to Autor's (2015) focus on the human comparative advantage of tacit knowing, he highlighted additional skills that were challenging to be automated through technology. They were '*flexibility*' confirming Simon's earlier claims (1969), '*judgement and common sense.'* Autor flagged that with the evolution of technological change some activities and tasks are becoming more '*codifiable.'* Therefore more susceptible to being automated due to advancements in computing power (Moore, 2008) and the introduction of machine learning techniques. However, machine learning is cited as an area of potential technological maturity, he concluded that machine learning tools were inconsistent. Autor observed that sometimes machine learning results returned high accuracy rates, other times they were incomprehensible, confirming the significance flagged by Billings (1991) of the need for tooling to have *'purposiveness'* and also reliability to be consistently adopted. This is also confirmed by Boyd and Huettinger (2019) who captured that because something is technically feasible, that doesn't mean that it will be adopted, stressing the importance of understanding the value and applicability of the technological change.

In addition to Autor, Hess and Ludwig (2017) described artificial intelligent solutions as part of the current Smart Machine Age (SMA). Identifying the importance of understanding the areas where there is a human advantage. They acknowledged the need to understand how the human advantage could be applied for future workforce considerations alongside SMA technologies. Autor, Hess and Ludwig stressed that "*human jobs will need to complement technology or the jobs that computers don't do well*" (p.319). The SMA human comparative advantage skills that were flagged included, *"Critical thinking, Innovative thinking, Creativity, High emotional engagement of others and Collaboration"* (p.319). This further supported the views captured by Polanyi (1966) and Autor (2015) in relation to '*tacit knowing*' and the significance for investing in the identified human comparative advantage skills for workers.

Autor has contributed significantly to the literature on technological workforce related impact over the last twenty plus years. His primary focus has been job polarisation and the related inequality. The next sub-section will review these theories in more detail, starting with the influential work of Levy and Murnane (2004) who captured the workforce impact of displacement.

2.8.3.2 Displacement

Historically concern has been raised that technological advancements would lead to large scale unemployment, which would have significant economic and social implications. We discussed the views of Keynes (1933) and his future claim of unemployment in section 2.8.2. Along with the concerns raised in the 1960s to the US President. Levy and Murnane (2004) conducted research examining a thirty year window, 1969 to 1999 to evaluate the claim of mass unemployment that was set out in the 1964 presidential memo. The study reviewed the types of occupations in the US that had been affected by technological change. Figure 2-25 captures the findings of their research which utilised data from the Adult Occupational Distribution.

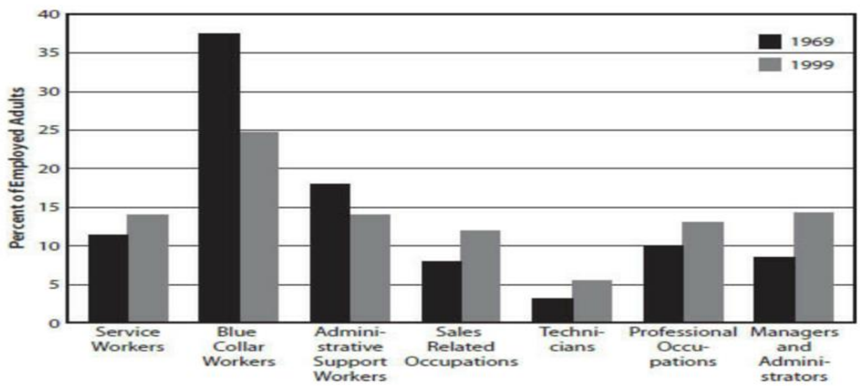

Figure 2-25 Technological Displacement (Levy and Murnane, 2005) (p.42)

The study was significant as it considered employment data alongside technological advancements of the third industrial revolution. The findings illustrated a pattern of movement across seven occupation groups, the movement was referred to as '*displacement*.' The captured change represented a reduction of blue-collar work and administrative support work. Across these two groups there was a 17% reduction. The two groups covered over half (56%) of the adult workers in 1969 and then later in 1999 this reduced to 39%. Levy and Murnane claimed that this was due to the roles being affected by computerisation and automation in the workplace. Whilst these occupation groups captured a decline other occupation groups saw an increase during the same timeline. The following occupations all increased during 1969-1999:

- Service Workers – up 2.3%
- Sales Related Occupations – up 4%
- Technicians - up 1.2%
- Professional roles – up 3%
- Managers and Administrators – up 6%

Levy and Murnane established that the changes demonstrated a '*Division in Labour.*' In that from a wage perspective there was also a change being observed. Their research is significant as it linked technological change and the third industrial revolution to changes in the workforce and specifically jobs. Levy and Murnane focused on the labour market from a wage perspective. The socio-economic elements of occupational impact which were believed to be attributed to technological advancements. The focus was on the worker pay inequality, concluding that technical change through the third industrial revolution had created a 'division' of work. The importance and originality of this study is that it captured job '*displacement,*' reviewing data across job roles to identify trends. A limitation of Levy and Murnane's work is the historical nature, the research did not consider future impact on occupations and was limited to job roles that already existed and were categorised. The research focused on a thirty-year data window, which is now over twenty years old. Further research is required to evaluate more recent and emerging technological change and the potential future displacement across jobs and how this could impact the workforce.

The study of how jobs have been impacted historically by technological change has attracted significant attention, with studies (Katz and Murphy, 1992; Autor, 1998; Goldin and Katz, 1998) looking to quantify the impact by extrapolating employment or census data against technological milestones such as the industrial revolutions. Limited consideration has been given to future profiling with the exception of Rumberger and Levin (1985) who attempted to build on Economic Analysis (Leontief and Duchin, 1984) to profile a future impact (both of these studies were introduced in the previous section, 2.8.2). Their research captured similar to Levy and Murnane a '*displacement effect*' across occupations and industries. Utilising actual employment and census data for 1900 to 1980 and modelling a prediction for 1995. Rumberger and Levin studied the impact of automated technology. In addition to the claim of job reduction that was discussed in section 2.8.2, the research confirmed displacement; Figure 2-26 captures the US labour distributions. The occupations that were identified as being impacted included '*Professional and technical,'* along with *'clerical*' and '*service*' occupation, these experienced a percentage increase. Whereas '*farm'* related roles reduced significantly. An area that profiled an increase and then a reduction was 'operative' roles, the literature did not put forward a rationale for the fluctuation in the occupation group.

Employment by Major Occupation Group: 1900 to 1995 (percentage distribution)[a]					
Occupation Group	1900	1930	1960	1980	1995[b]
Professional and technical	4	7	11	16	17
Managerial	6	7	11	11	10
Clerical	3	9	15	19	19
Sales	5	6	6	6	7
Craft	11	13	13	13	12
Operative	13	16	18	14	12
Laborer	12	11	6	5	5
Service	9	10	12	13	16
Farm	37	21	8	3	2

[a]Distributions for 1900 and 1930 based on experienced civilian labor force. Distributions for other years based on total employed persons.
[b]Data for 1995 based on moderate-trend projections.
Sources: U.S. Bureau of the Census, *Historical Statistics of the United States*, Part 1 (Washington, D.C.: U.S. Government Printing Office, 1975), Table D182-232; U.S. Department of Labor, *Employment and Training Report of the President* (Washington, D.C.: U.S. Government Printing Office, 1979 and 1982), Tables A-16 and A-18; George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, Occupational Employment Projections Through 1995, *Monthly Labor Review* 106 (Nov. 1983), Table 1.

Figure 2-26 Employment changes across occupation group (Rumberger and Levin, 1985)

The theory of displacement has presented itself through historical analysis of employment trends across occupation and industry groups. Displacement research has fuelled further study into the allocation of work and how technology has impacted the skills profile of work and driven a '*skills bias*' (Howell and Wolff, 1991; Acemoglu, 1998; Goldin and Katz, 1998). The skills bias claims higher skilled workers are in greater demand, meeting the needs of complexity and specialism driven by technological change. The skills prejudice in favour of higher skilled workers is challenged by Autor, Levy and Murnane (2003), their hypothesis is discussed in the next sub section, 2.8.3.3 Job polarisation, inequality and skills bias technological change.

2.8.3.3 Job Polarisation, Inequality and Skills Bias Technological Change

In section 2.8.3.1 we discussed some of the findings of Autor, Levy and Murnane (2003), whose approach has become known as the ALM hypothesis (Goos and Manning, 2007). Autor, Levy and Murnane challenged the view of skill bias technical change (SBTC) (Autor, 1998; Goldin and Katz, 1998; Autor and Acemoglu, 2010; Katz and Margo, 2014; Caines,Hoffmann and Kambourov, 2017;

Acemoglu and Restrepo, 2018c) that technology had driven a bias for higher skilled workers, which created a wage inequality for other workers. The ALM hypothesis proposed an alternative position when exploring technological impact of work, one of '*polarisation.*' Suggesting that technology through routinisation of '*codifiable tasks*' had carved out a middle layer of work for humans. Polarising work that was difficult to automate. The hypothesis generalised work into two task areas, '*abstract*' or '*manual*,' distributing work into low or high skilled jobs. Concluding that this polarisation effect established demand for both low and high skilled work, not just high skilled work as set out in the SBTC theory.

Goos and Manning (2007) supported the ALM hypothesis which confirmed the theory of comparative advantage when exploring workforce impact alongside technological change. A limitation of their research is that it evaluated historical impact of technological change, between 1975 and 1999 and focused on wage inequality. It did not proffer insight on the types of comparative human skills; the focus was driven by wage inequality. The significance in relation to this thesis aim is that it further confirms the claim that technological change drives a demand for human work. Furthermore the agreement with Autor, Levy and Murnane (2003) that there is a human comparative advantage over technology when reviewing non-codifiable or non-routine work. The limitation of both studies is they did not define what the future workforce may look like and they were restricted by evaluating a historical snapshot based on technological change that had already been adopted, against roles that were already established and categorised through standard occupational databases or reports.

A contrasting study (Frey and Osborne, 2013) which demonstrated originality in its approach and attempted to explore the potential future impact of work from technological advancements, was conducted through Oxford University. Its originality was born out of evaluating how susceptible work was to computerisation in the future. This seminal study will be discussed in the next subsection, 2.8.3.4 Job automatability.

Autor (2019) captured the polarisation effect and changes across the workforce referencing technological change as a contributor. His 2019 paper focused on the inequality for the lower skilled and '*non-college*' worker. Two key graphs emerge from Autor's study, Figure 2-27 and Figure 2-28. Figure 2-27 highlights the change and growth in the professional roles, specifically Technicians, Professionals and Managerial roles. Autor's focus was on the impact of the reduction of the orange roles in the middle of the diagram and the wage inequality this had driven for non-college workers. A gap in the literature and an area that has been neglected is the exploration and examination of the roles in blue that are captured as being in high demand across the labour force.

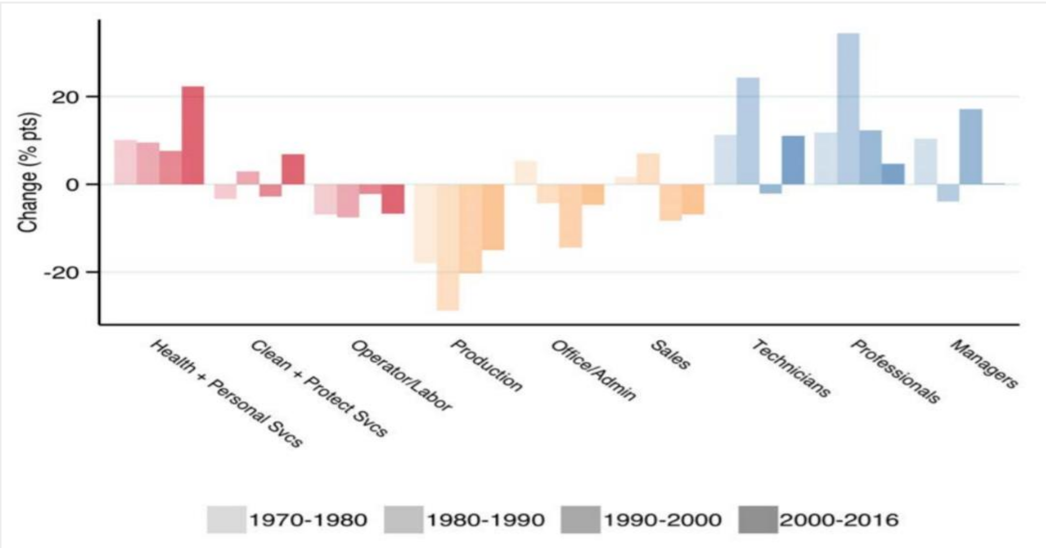

Figure 2-27 Percent Changes in Occupational Employment Shares among Working Age Adults, 1970 - 2016 (Autor, 2019, p.7)

Autor also captured this view by examining the skill profile of workers and how these related to the occupations. Figure 2-28 captures a similar view to that of Figure 2-28 where there is in increase in the employment share for higher skilled work against a significant reduction in the middle and lower skilled work. A limitation of Autor's paper is that the high skilled growth was not examined in any detail the focus of the literature was on the low skilled area and the inequality associated with it. This highlighted the need for further study and consideration to explore the high skilled aspects of the work force which Autor captured as professional, technical and managerial.

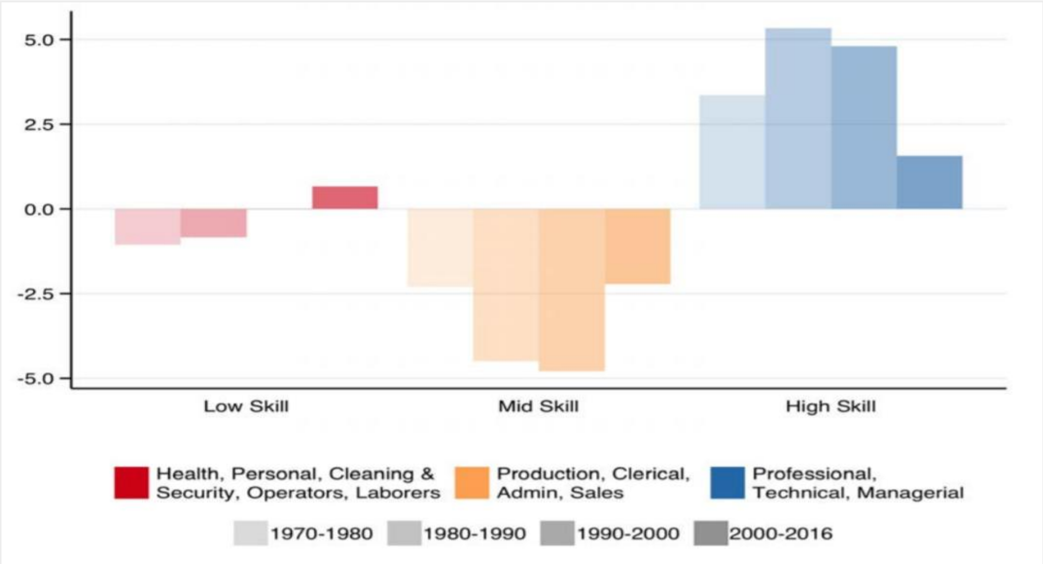

Figure 2-28 Changes in Occupational Employment Shares among Working Age Adults, 1970 – 2016 (Autor, 2019, p.8)

The next section will review the literature relating to how technological change has impacted the workforce through automation.

2.8.3.4 Job automatability

Workplace job inequality has been attributed to technological change (Katz and Murphy, 1992; Acemoglu, 1998; Goldin and Katz, 1998; 1999; 2002; 2003; Autor and Acemoglu, 2010; 2011; 2012; Bessen, 2016b; DeCanio, 2016; Murphy and Oesch, 2017; Acemoglu and Restrepo, 2018b; 2018c; Boyd and Huettinger, 2019; Pianta, 2020; Spencer and Slater, 2020) with significant focus being placed on evaluating the historical impact that technology has had on jobs with limited research exploring the potential future implications. Acknowledging the significant gap in literature, Frey and Osborne (2013; 2017) documented that *"no study has yet quantified what recent technological progress is likely to mean for the future of employment"* (p.6). Frey and Osborne conducted research to understand the susceptibility of jobs to '*computerisation.*' They clarified, "*computerisation as job automation by means of computer-controlled equipment"* (2013, p.3). The study was novel in approach and profiled a view on the potential future impact of technology, quantifying how the automation of activities and tasks could disrupt future jobs. A heavily criticised limitation of their approach and findings (Nedelkoska, 2013; Arntz,Gregory and Zierahn, 2016; Kim,Kim and Lee, 2017; Nedelkoska and Quintini, 2018) was that the research profiled full job automation and that they focused on existing roles, ignoring the potential job creation that may also be generated. The findings were highly disruptive, recording that almost half US jobs were at risk from being automated (47%). Frey and Osborne evaluated 702 occupations that already existed in the US. The relevance of their study to this thesis is that they explore future work impact, highlighting the gap in literature and acknowledging that research is warranted on understanding the potential future workforce as a result of technological change. Arntz, Gregory and Zierahn (2016) disputed the high rate of computer substitution presented by Frey and Osborne and published a conflicting view of technological job impact.

The study conducted by Arntz, Gregory and Zierahn (2016) acknowledged an additional significant factor when considering technological job impact. The variability of peoples jobs, '*heterogeneity of workers tasks*' (p.5). They established that not all jobs are the same, which makes it difficult to consistently automate. The results, across 21 countries, captured '*9% of jobs were automatable*' (p.5) contradicting the 47% put forward previously (Frey and Osborne, 2013). A key conclusion from the study conducted by Arntz, Gregory and Zierahn was that '*automation and digitalisation are unlikely to destroy large numbers of jobs*' (p.5).

The lower level of impact was further supported by Kim, Kim and Lee (2017), who also challenged the high negative effect predicted by Frey and Osborne. They claimed that occupations require a level of creativity to perform roles which is not possible by machines. Kim, Kim and Lee added that there would also be a level of intervention, through implementation of government policies and legislation. The intervention would establish control around the extent in which computerisation was implemented and would be required to safeguard jobs for socio-economic reasons. Kim, Kim and Lee (2017) examined the potential socio-economic impact of technological change on employment, through a linear applied system, specifically Leontief linear economic model and Markov Chains, quantifying susceptibility and non-susceptibility of occupations due to computerisation. They built on the research conducted by Frey and Osborne (2013; 2017), identifying technological advances such as Machine learning, Robotics, AI and automation had accelerated. This acceleration with the reduction in computing costs had instigated an increase in computerisation. Kim, Kim and Lee (2017) demonstrated that computerisation would lead to new technical roles, which would create opportunities for humans. This is a key consideration when exploring the impact of technological change and future work. The study challenged the findings of Frey and Osborne, building on their approach quantifying job role impact. However, a key differentiator was the identification that job creation was also an outcome. The literature did not elaborate on what those new roles may look like, further research is required to explore this gap.

When evaluating the literature in relation to automation and future work, Bessen et al. (2020a) provided a fresh perspective and recommendation. They highlighted, similar to Boyd and Huettinger (2019) that "*just because something can be automated, doesn't mean it will be" (2020a, p.3).* A key takeaway from Bessen et al.'s paper is the acknowledgement that automation does impact the workforce however, they stress the importance to policy makers to focus on the support required to help workers transition and develop new skills to move into new roles or roles that are changing, rather than focusing on the unsubstantiated claims of potential mass unemployment. The recommendation to address approaches to help people transition across the labour market was also confirmed by Holzer (2019) who captured that the future impact of automation on the workforce is unknown.

This subsection has demonstrated that there is a clear relationship between technology and workforce impact. The findings have been highly variable between studies, indicating the complexity in establishing agreement on the level of disruption that technology poises to the human workforce. The primary focus has been on whether computerisation (Frey and Osborne, 2013; 2017) or other technological change (Arntz,Gregory and Zierahn, 2016; Kim,Kim and Lee, 2017) replaces jobs, with some job creation being flagged by Kim, Kim and Lee. The next sub-section, 2.8.3.5 Job Creation will evaluate this in more detail.

2.8.3.5 Job Creation

In the last sub section we reviewed the research that tried to quantify workforce impact from automation and we closed the section with the need to consider job creation as an outcome (Kim,Kim and Lee, 2017). Nedelkoska (2013), studied the employment market between 1979 and 2006, utilising employment surveys that captured *"job tasks, Skills, Knowledge and Technologies"* (p.1588). The study examined 354 possible occupations between 1979 and 2006. Highlighting that during this time employment in 2004 was 5.6% higher than in 1979. The study analysed job roles and determined more jobs were created than destroyed. Recording that the types of roles that were created were highly qualified and paid more money. Noting one exception, health care which experienced job creation at all levels. A reason or theory put forward for this creation of jobs in the health care industry was one of '*comparative advantage*' (which we discussed in an earlier section 2.8.3.1). Nedelkoska articulated that humans are more suited to roles that require empathy and interaction with others. The scope of the study was limited to a single geography, Germany and captured a snapshot in time, 1979 to 2006. The research is of interest as it explored the impact of technological change and future work, drawing attention to an area of comparative advantage, describing the specific skill areas that humans are more suited to fulfil over technology. The study is of significance as it cited tacit and explicit skills as a differentiator when evaluating the impact of technical change on jobs. Nedelkoska (2013) stipulated the need for further research to evaluate the complex way in which technology and people interact, specifically calling out the advancing AI and the Service sector as areas that would benefit from further investigation.

Dachs and Peters (2014b) supported the view that studies have failed to consider the possible significance of job creation when evaluating technological change. They also highlighted that it is an area that is in need of further research. To date, studies (Levy and Murnane, 2004; Frey and Osborne, 2017) have predominantly focused on the displacement or replacement of jobs that have already been identified and captured in an occupation list (Statistics, 2010). Job creation is a key factor when exploring the future workforce, Dachs & Peters (2014b) presented a dual theory that considered two possible outcomes, '*displacement*' and '*compensation*.' Proposing that innovation can have an '*employment-reducing effect,*' which supported the theory of displacement and also an '*employment-creating effect.*' The dual theory is similar to that of White (1931) and also Schumpeter (1942) both claimed that there were economic gains linked to technology or innovation. The research conducted by Dachs and Peters did not extend to exploring what kinds of jobs would be reduced or created, the focus was on proving that innovation generated a growth factor for the workforce, rather than what roles would be needed to drive such growth and innovation.

As part of Dachs and Peters (2014) research they cited a significant gap in existing literature around job creation citing the sizeable economic growth (Dachs and Peters, 2014b) in the Service Industry, which had generated new jobs. Dachs and Peters acknowledged the paucity in existing literature and stated further research is required to understand how job creation, an area of employment growth, could be affected by further technical change, a key part of the future workforce. Dachs and Peter's dual effect theory strengthens Schumpeter's (1942) theory of '*creative destruction,'* highlighting the changing structure of the workforce as a result of technology. The next subsection, 2.8.3.6 Creative Destruction reviews the literature in relation to Schumpeter's theory.

2.8.3.6 Creative Destruction

Exploring further the claim of a dual effect (Dachs and Peters, 2014b) The National Bureau of Economics Research (NBER) (Vladislav and Svetlana, 2016), utilised data to predict what professions could be replaced by "*machines, automated systems and robots*" (p.2). The research predicted 30% of professions would be replaced. The research went further than Frey and Osborne (2013), clarifying which specific professions would be replaced. The research looked at four areas: i). Roles required up to 2020; ii). Roles that would be required after 2020; iii). Roles that would be retired and iv). A requirement for new approaches. The research identified several forecasted professional skills and sector specific areas which would require "*New Specialties*" (p.4). The research supported Levy and Murnane's (2004) theory of displacement. However, it is unclear whether the predicted 30% of professions replaced by automated systems or robots was mitigated or displaced as part of a creative secondary or dual effect, that created new roles (Dachs and Peters, 2014b; Acemoglu and Restrepo, 2018a). The significance of the research carried out by Vladislav and Svetlana (2016) is that it presented a predicted list of professions that they believe would be in high demand. An observation of the research is that it was unclear from the literature how the top ten professions were determined. The focus of the research targeted management challenges and assumed a future requirement to automate that area of the workforce. The research supported the view that machines and technological change would produce a dual effect across the professions. Retiring and creating jobs. Vladislav and Svetlana (2016) did not review or confirm the net effect. It is unclear from the literature whether the overall impact was positive, negative, or neutral to job volumes. It was also unclear whether specific professions or jobs would be better placed to be fulfilled by people. A key contribution by the paper is a list of suggested future skills, see Figure 2-29. The skills captured support the earlier views of others (Polanyi, 1966; Simon, 1969; Billings, 1991), confirming areas of flexibility and adaptability and understanding the wider context. In addition, interpersonal skills and the ability to work with others are highlighted along with more specialist skills, '*system engineering'* and '*programme management*.' The skill areas highlighted a need for further research, to corroborate the findings given the lack of literature on future skill consideration.

1. Systemic thinking (System engineering);
2. Intersectoral communication skills;
3. Ability to manage projects and processes (IT programming- Solutions/management of complex automated complexes/work with artificial intelligence);
4. Customer (ability to work with customer's requests);
5. Multilingual and multiculturalism (free languages of business communication, understanding of the NationalThe national and cultural context of the partner countries, understanding the specifics of the work in the industries in other countries);
6. Ability to work with teams, groups and individual people;
7. Ability to work in a mode of high uncertainty and fast change of conditions of tasks (skill Quickly make decisions, react to changes in working conditions, ability to allocate resources and manage your time);
8. Ability to artistic creativity, presence of aesthetic taste;
9. Lean production.

Figure 2-29 Identified skill areas for future work (Vladislav and Svetlana, 2016, p.4)

Understanding the areas of employment growth is a key part to exploring the future workforce. There is agreement that technology displaces work (Levy and Murnane, 2004; Arntz,Gregory and Zierahn, 2016). Displacement can stretch across industries as jobs reduce in one area and increase in another. Previous industrial revolutions have greatly displaced the agricultural and manufacturing sectors (Bloem *et al.*, 2014). Over time the service and knowledge sectors have been established with technology underpinning these sectors through innovation (Mainardes,Funchal and Soares, 2017). Application of technology varies across sectors and whilst technology can replace human tasks (2010; Acemoglu and Autor, 2012) it also complements them. In the Service industry the observed impact is one of creation and not unemployment (Mainardes,Funchal and Soares, 2017) and the result is that technology enhances the industry, encourages innovation and "*complements the use of human capital*" (p.37). Supporting the theory of creative destruction (Schumpeter, 1942), Mainardes, Funchal and Soares (2017) acknowledged the historical negative effect on jobs from automation; which had replaced jobs that involved manual repetitive tasks. An important contribution was they captured the creation of Service jobs. Highlighting that they see two ways in which technology can be applied, one of replacement and substitution and the other to augment and complement. Mainardes, Funchal and Soares claimed that the growth in the Service industry is a result of human tasks complementing the technology, that discrete areas of innovation had impacted the task makeup of human work in the service sector and this had resulted in a change to the structure of work. They further claimed innovation triggered a change in service products and processes; accentuating that major innovation affected both the products and processes within the service industry. Understanding the type of innovation provided insight into the effect on the workforce. Mainardes, Funchal and Soares (2017) referred to process innovation as being a key driver to displacement of jobs which impacted the task makeup. The study referred to how the innovation increased the demand for additional skills which created a higher set of skills from people to complement the technology. Whilst the study supported the view of others (Schumpeter, 1942; Sirilli and Evangelista, 1998; Bogliacino and Pianta, 2010; Dachs and Peters, 2014b) it was limited to a single economic geography, Brazil and data collection was at two points in time, 1994 & 2002. It also did not take into consideration the advancements in AI and other innovation in the last fifteen to twenty years. The research made recommendations for further study, acknowledging the limitation of a single sector within the Service Industry, recommending further research is required to look across multiple Service Sectors. Building on the key contribution from Mainardes, Funchal and Soares (2017) in relation to areas of human advantage and growth in the work force. Huang and Rust (2018) explored the Service industry and specifically the impact of AI within that sector. Conversely, they referred to innovation within the industry and identified AI as a threat to the workforce.

Huang and Rust provided new insight on stages of intelligence, claiming four stages in relation to tasks that are carried out as part of a job. Distinguishing between "*a job, a task*" along with "*labour*" (p.6) which led to "*AI job replacement*" (p.1). The model (see Appendix 8.6) presented four types of intelligence that run sequentially and also in parallel once achieved. As part of the development of their model they defined AI as being "*manifested by machines that exhibit aspects of Human Intelligence (HI)*" (p.1). The four stages of intelligence captured were mapped to the tasks of a person's job to predict when a machine could complete the tasks to the advantage of the business over a human. Huang and Rust's 2018 model considered key skills that AI would need to master consistently to replace people, examples of these skills included "*communication, relationship building, leadership, advocating and negotiating, work–life balance, social, teamwork, cultural diversity, and charisma*" (p.5). Huang and Rust cited Sophia (Robotics, 2017) a robot that that had been developed and created by Hanson Robotics to be like a human, emotionally and visually. Whilst the literature provided fresh insight by presenting a framework of intelligence, it was limited in that it does not describe the types of jobs associated with the intelligence levels. Further research is required to understand the comparative advantage of technology and people, to understand the future workforce and how they could augment. An observation is the model assumed a linear adoption and capability of intelligence and suggested that singularity is just a matter of time. Presenting levels of intelligence, where technology replaces people and that the fifth and final stage will result in "*total replacement*" (p.12) there is no research to support this view currently available. A significant take away from the research is that the skill examples captured represent existing human comparative advantage areas for humans over the existing technological capability. This is important as it informs the areas that are required for humans to fulfil in the workplace and do well alongside technology. Reaffirming that there are key areas of comparative advantage (Simon, 1969) that should be developed within human workers.

A more recent article by Acemoglu and Restrepo (2019b) captured that AI has potential to drive two outcomes. The first through automation, '*displacing*' activities carried out by humans and the second being more '*complementary*' adding value to work fulfilled by humans. This dual effect supports the view of '*creative destruction*.' Acemoglu and Restrepo stressed that there is a need for intervention through policy controls to safeguard employment and growth to ensure that these two factors are balanced. The significance of the article is that it acknowledges that technological change, such as AI has potential to complement and displace work. Acemoglu and Restrepo (2019b) captured the importance and provided a handful of examples of task creation in Healthcare and Education sectors. They also cited augmented reality as an area that could complement human labour. Further research is required to explore the complementary nature of AI and the human workforce to balance the automation drive.

This sub-section has reviewed the dual effect driven out of technological change, where the impact is twofold, one of replacement, substitution or destruction which is then offset by a growth effect, that complements and creates. Schumpeter (1942) referred to this as '*Creative Destruction*' and others (Dachs and Peters, 2014b; Acemoglu and Restrepo, 2019a) have built on this theory referring to an employment-creating or re-instatement effect. Understanding the theories and claims on how technology has and may impact workers is key to exploring future work. The dual effect supported the view of job displacement (Levy and Murnane, 2004) presenting the claim that technology displaces work into new job roles as well as existing roles.

This concludes sub-section 2.8.3 which has reviewed the key claims relating to workforce impact since the 1990s, before summarising section 2.8 the literature highlighted an area that raised an important consideration when adopting technological change and that is the potential societal impact and how this will be addressed. The linkage to the future workforce relates to the job roles that could be affected by changes driven through responsible adoption of the emerging technological change. The existing views and literature on the ethical considerations will be discussed in the next sub-section.

2.8.4 Ethical considerations

Stahl et al (2017) evaluated a potential comparative advantage for humans in the workforce over technology, they reviewed eleven technological areas (see Table 2-2 in section 2.5.1). Claiming that these will have substantial effect between, 2028-2033 on how we live. Whilst it is acknowledged that AI is not a recent discovery, the more recent developments in this area have raised the question of what the potential impact could be for people in the future. The eleven areas were highlighted in relation to investigating ethical considerations for informing future policy setting and the potential implications of such technology. Stahl et al. (2017) highlighted further understanding is required on how people will interact with intelligent technologies and machines and additional research is required around the existing work that is carried out by people. The article drew attention to areas that should be considered from an ethical standpoint, it did not provide a potential viewpoint or response to any of the consideration areas. The report invited further analysis to be carried out to explore answers and potential scenarios relating to future workforce considerations and what relationships people will have with the intelligent technology. Supporting the view that there is a significant gap in existing literature on how intelligent technology could integrate and complement the workforce.

Continuing the ethical angle and the need for further research declared by Stahl et al. (2017) The European Commission invested in a ten-year research initiative (Aicardi *et al.*, 2018) which was called '*The Human Brain Project (HBP).*' Aicardi et al. explored Kurzweil's 2005 AI claim of "*existential risk,*" referencing the need for further research projects, such as the HBP. They argued against Kurzweil's (2005) claim that '*singularity*' was near. Declaring that the realisation of machine intelligence being greater than that of people, is not in the near future, stating that there is little evidence to support a view that AI is a threat to the existence of humanity. Whilst singularity was not supported, Aicardi et al. (2018) presented five areas that do pose societal risk. The first being interaction between people and intelligent machines and groups of people who require care, "*vulnerable populations (the elderly, people with disabilities, children)*" (p.4). This specific identification supported the view that some jobs are more suited to humans than intelligent machines due to emotional considerations, and that there is a clear *'comparative advantage'* (Simon, 1969) for people. Another area of interest when exploring future work, is the potential impact on the wider global workforce, which highlights the associated economic effect. As part of the recommended action points, a need for '*human centric approaches*' was highlighted. Advising that people should be at the heart of any technology and not to be "*designed out*" (p.4). This ethical recommendation is fundamental to the shape of the future workforce and understanding the delineation between human job activities and machine-driven activities. The recommended follow-on actions captured by Aicardi et al. (2018) denoted a gap in literature in relation to emerging technologies and the technical change that affects the future work force, which supported the aim of this thesis. Understanding the relationships and interactions between technology and people (Aicardi *et al.*, 2018) was one gap identified, the literature also presented an understanding of the impact technological advancements have had on data and how key this is to machine learning and artificial intelligence. Aicardi et al. accentuated the importance of new job roles which have already started to emerge to address the new requirements alongside the technology, capturing job areas focused on d*ata privacy and protection risks.* Other roles were also identified such as a "*Data Protection Officer*" and a dedicated "*Data Governance Working Group*" (p.4). The research flagged the need for focus and hiring of these roles, which is an example of new jobs being created because of technological change and human augmentation rather than substitution. However, what is not yet understood are whether there are additional types of jobs that will be created or required. Aicardi et al provided a limited view, identifying key new roles around data that are required alongside the technological change.

In 2017, concerns were raised (Zanzotto) in relation to the adoption of AI, advising that AI solutions need to be transparent and that they were stealing knowledge from workers which they will come to replace if appropriate steps are not taken. Zanzotto highlighted the potential of AI whilst also acknowledging the implications, setting out a recommendation of establishing responsible AI through the concept of Human in the loop AI (HIT-AI) establishing guidelines and transparency on the knowledge sharing and life cycle processing involved in machine learning. This raised a further consideration for organisations when adopting technological change, around ethical controls and the governance skills and job roles required in these areas. A limitation of Zanzotto's article is that whilst the findings captured a list of areas organisations should invest in to drive responsible AI, it is unclear what job roles or job activities and tasks would be affected by the guidelines. Further research is required to explore the impact the emerging compliance requirements would have on future job roles and skill demands.

Dwivedi et al. (2019) further supported the importance of humans alongside technology, the group presented an opinion paper following a focused workshop to gather insight on AI, the opportunities, the challenges and the implications for practice and research. The paper provided timely, balanced insight and opinion on this emerging area of technological change. One of the opportunity areas captured the integration between humans and AI technology. Stipulating an approach of '*human in the loop'* and not human substitution by AI solutions. The human in the loop activities that were captured included: '*design, analysis and interpretation based on AI processing and outputs*' (Dwivedi *et al.*, 2019, p.7) Dwivedi et al. referred to the human in the loop as a positive approach to AI technology and humans complementing each other, through the comparative advantage each party provided to work. (Comparative advantage alongside technology was discussed in section 2.8.3.1). Similarly, to Zanzotto, the Dwivedi et al. opinion group on AI captured concern of existing public policy not being fit for purpose and additional consideration is required to ensure AI is adopted responsibly and does not lead to a negative humanitarian impact. They highlighted the need for practitioners within public policy to have the appropriate tools for evaluating the public use of AI, acknowledging further research is required to unify this key area alongside the emerging technological change. The opinion paper provided a practical model for future consideration capturing six challenges that need to be addressed going forward in relation to the adoption of AI, see Figure 2-30 which outlines the '*TAM-DEF (Transparency & audit (T), Accountability & Legal issues(A), Misuse protection (M), Digital Divide & Data Deficit (D), Ethics(E), Fairness & Equity(F))*' (Dwivedi *et al.*, 2019, p.30) proposed model.

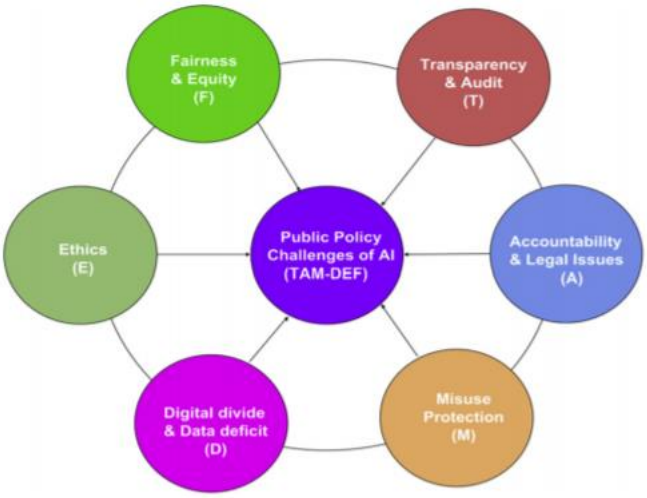

Figure 2-30 Proposed public policy framework for responsible AI (Dwivedi et al., 2019a, p.30)

Each of the areas in the framework raises implications for the future workforce. Earlier in this section Aicardi et al. (2018) described the need for new roles that included data governance and privacy roles as a result of the emerging technology, Dwivedi et al. support this claim by highlighting the areas such roles would need to consider and control through public policy. Further research is required to explore and build on these recommendations and suggested new roles to help inform education and organisational policies to ensure training and readiness is provided on these key areas of ethical compliance and governance.

The next sub-section will summarise section 2.8 along with the previous sections in Chapter 2 and set out the identified gap in literature and how this supports the research aim set out in this thesis.

2.8.5 Summary of technological impact on the workforce

This section, 2.8 has built on the literature reviewed in the preceding sections to 2.8 in Chapter 2. Figure 2-31 summarises the literature areas reviewed. This section will summarise the existing literature and the key theories and focus of research to date, along with the identified gaps and areas that require further research.

There is a consensus (White, 1931; Levy and Murnane, 2004; Autor, 2010; Autor and Acemoglu, 2010; Acemoglu *et al.*, 2014; Bessen, 2016b; Huang and Rust, 2018; Bessen *et al.*, 2020a) that work carried out by people has been impacted as a result of technological '*change*.' Technology is now able to execute routine, codifiable, repeatable activities and tasks, through technological change known as '*automation*.' The seminal work of Frey and Osborne (2017) created much debate (Arntz,Gregory and Zierahn, 2017; Goos, 2018) and demonstrated the lack of consensus on whether technology will completely replace jobs and drive '*technological unemployment'* in the future as declared back in the 1930s (Keynes, 1933). The literature presented a claim of '*inequality'* as a result of technology displacing workers (Levy and Murnane, 2004). This displacement effect presented two further claims; one of '*skills bias*' (Piva,Santarelli and Vivarelli, 2005; Autor and Acemoglu, 2010; Bennett, 2016), which presented a view that there was an increased demand for higher skilled and paid workers. The second claimed, that demand had increased for both high-skilled and low-skilled workers, creating a '*polarisation*' of work (Goos and Manning, 2007; Goos,Manning and Salomons, 2014; Murphy and Oesch, 2017). This polarisation carved out the middle layer of work. The existing literature predominantly focused on the socio-economic inequalities of the displacement effect. An area which demonstrated paucity in the literature was related to the skills and work carried out by the high skilled workers claimed to be in demand. Limited research (Polanyi, 1966; Billings, 1991; Autor,

2015) has been conducted on the area of technology driven skills bias. The demand for further research on the area of skilled work bias is heightened through existing literature, which has highlighted the growing skills shortage that exists for high skilled work. The literature suggested a comparative advantage (Simon, 1969) that human workers have over the emerging technology, areas of '*emotional intelligence, flexibility and adaptability, collaboration, creativity and critical thinking'* (Autor, 2015; Vladislav and Svetlana, 2016; Hess and Ludwig, 2017; Stahl,Timmermans and Flick, 2017; Aicardi *et al.*, 2018; Huang and Rust, 2018). Further research is required to explore the possible comparative advantage skills for people alongside the evolving technology.

The literature supported the view that technological change drives *'creative destruction*' (Schumpeter, 1942), a '*dual effect*' (Dachs and Peters, 2014b; Acemoglu and Restrepo, 2019a) which included a compensation effect where new jobs are created, compensating against the roles that have been removed, the displacement effect. Limited attention has been given to exploring what roles (Aicardi *et al.*, 2018) could be created in the future supporting the theory of comparative advantage in higher skilled workers.

This thesis addresses the identified gap in the literature, exploring the theory of comparative advantage and the impact of technological change on future high skilled professional work.

The original high-level research aim was to explore the impact of technological change and future work. Following the literature review a gap emerged in relation to higher skilled work. The claim of job polarisation and skills bias technical change theory confirmed that there is a demand for higher skilled, professional, managerial, and associate professional work. Limited research has been conducted that considers the human comparative advantage of such workers alongside technological change. There was consensus that technology has and is disrupting the workforce and the significant focus has been allocated to the inequality and polarisation effect with minimal attention or research in how policy and workforce strategy can ready workers to secure the jobs and occupational groups that are in high demand. Figure 2-31 captures the literature areas reviewed, the light green box on the bottom right-hand side represents the areas where there is limited literature. These relate to future job creation and the area of high skilled work, along with understanding the comparative advantage that the high skilled workers may have over the captured emerging technological change areas. The areas of technological change are captured in the top section of the figure 2-31 and were reviewed in section 2.5.

The gap in literature raised several questions relating to the impact of technological change on future high skilled work, the questions raised were:

- What are the technological change areas impacting the workforce? Is there clarity on the evolving technological areas?
- Is there a set of skills that high skilled workers have an advantage over technology?
- Should training courses and programmes be focused on specific skill areas to integrate and complement the maturing technology?
- Do these skill areas drive a requirement for new job roles to be created or for existing roles to be updated to align with the technological change?
- Aspects of existing literature suggests there is a negative perception relating to technological change and future work. Is this view shared amongst existing professional workers who are working in high skilled areas?
- What considerations should educational and corporate organisations be adopting when planning and scoping training and readiness courses for students and workers to meet future high skilled workforce demands?

These questions emerged from the gap in literature are the foundations for the research objectives that underpin the research aim set out in this thesis. The next section articulates the research aim and objectives.

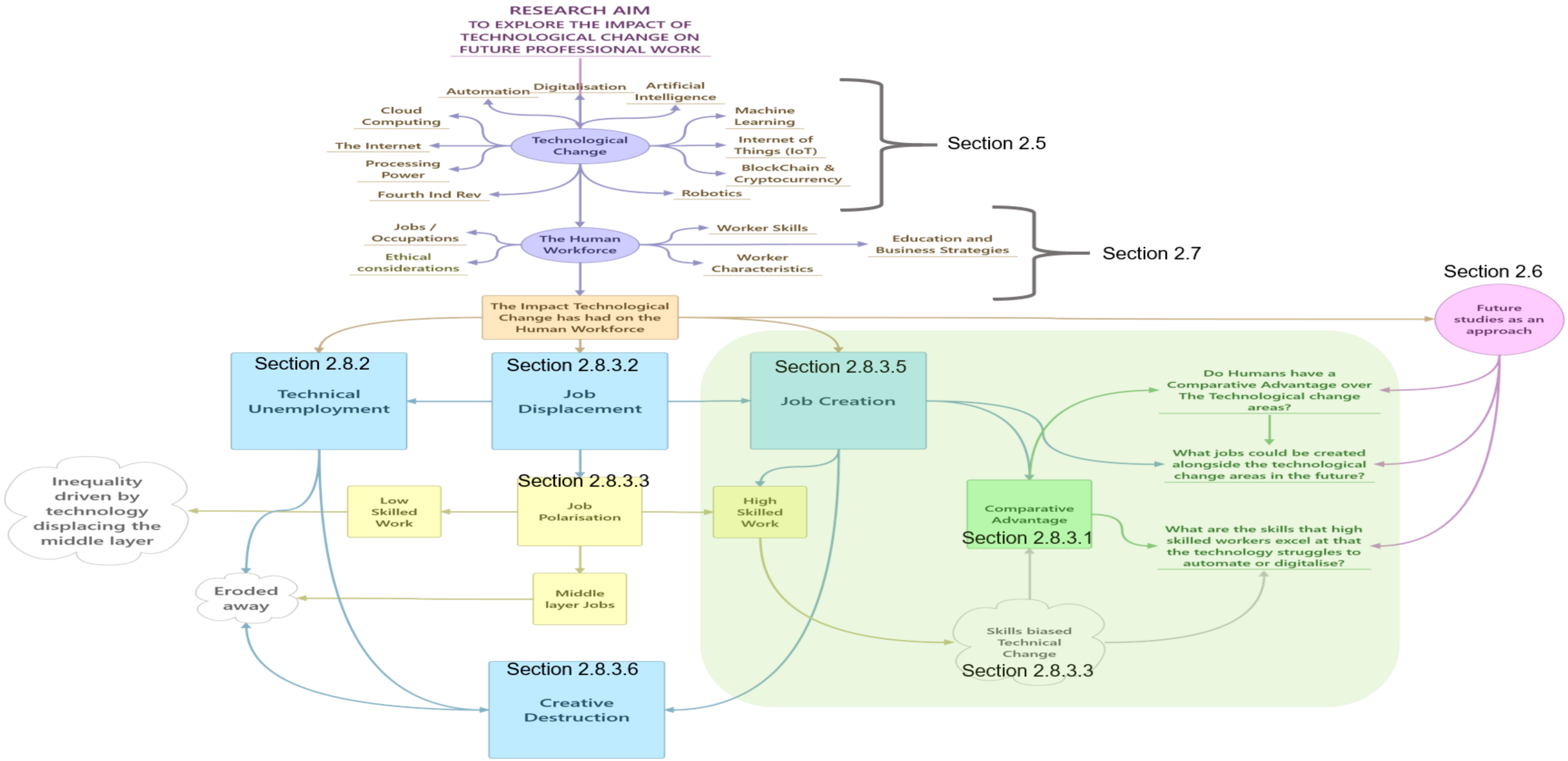

Figure 2-31 Literature Review Summary

2.9 Research Aim and Objectives

This research aim and objectives that have been achieved through this thesis are captured in Figure 2-32, the research aim and objectives address the gap in literature highlighted in the green box in figure 2-31.

Research Aim

To explore the impact of technological change on future high skilled professional work.

Objective 1: To explore human centric skills, skills that are not easily replaced by technology

Objective 2: To explore potential future professional occupations

Objectives 3: To explore existing professional worker's view on future work

Objective 4: To explore the key considerations for organisations, workers and students in relation to future professional, high skilled work.

Figure 2-32 Research Aim and Objectives

The next chapter, 3 sets out the methodological considerations that were followed to achieve the research aim and objectives captured above. The chapter is broken into thirteen sub-sections, the structure of the chapter will be described in section 3.1 Methodological structure.

3 Methodology Chapter

3.1 Chapter Structure

The purpose of this chapter is to describe the methodological choices and rationale behind the research design adopted in this thesis. Including the research approach, method, strategy and timescales. The chapter also explains the philosophical foundations that underpin the research. A fundamental goal of determining the most appropriate research design, approach and method in response to the research aim and objectives is to select an approach and method that will yield credible findings (Reiter, 2017). The chapter is structured to provide an overview of the various philosophical considerations, both the epistemological and ontological, followed by an explanation of how those considerations map to the research aim and objectives. The chapter then sets out the research approach and methods that were adopted, with a section on the Research Design which explains the steps and process followed in conducting the research. The chapter concludes with a description of the analysis approach and research control considerations such as, Ethics, timescales and limitations.

3.2 Research Philosophy

When embarking on a research journey a key consideration is the philosophy that underpins the research and the justification by the researcher on the approach being taken. Understanding how the researcher and research participants see the world around them is a part of that process. Saunders, Lewis and Thornhill (2012) summarised the various components through the analogy of '*an onion,*' see Figure 3-1 which captures the different layers as constituent parts that underpin a researchers approach and what shapes their research choices.

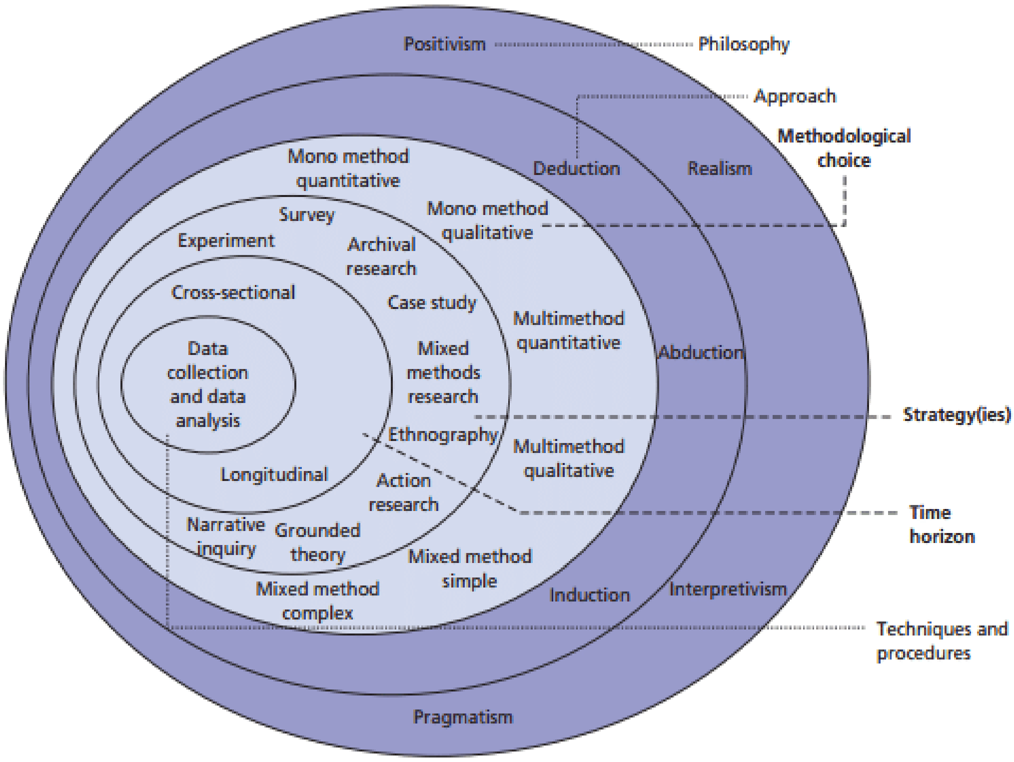

Figure 3-1 The Research Onion (Saunders, Lewis and Thornhill, 2012, p.126)

The research data techniques are at the core, the model captures the various choices researchers make to reach that founded position. Saunders, Lewis and Thornhill's (2012) onion highlights the significance the layers have to the researcher's decision making. The literature stressed the importance of understanding the assumptions taken by the researcher when determining the layers, starting on the outside with two key philosophical notions, '*ontology*' and '*epistemology*.' These research assumptions will be set out in more detail in the following sections.

3.2.1 Epistemology

"The study of the nature of knowledge and ways of enquiring into the physical and social world," (Easterby-Smith,Thorpe and Jackson, 2015, p.69). Saunders, Lewis and Thornhill (2012), referred to knowledge, stating that epistemology epitomises

"acceptable knowledge," within the research area. At a high-level epistemology according to Saunders, Lewis and Thornhill (2012) relates to two considerations; firstly, whether the research is driven by real tangible things, and these *'real'* objects or resources constitute the research reality, as they are real the research is far more '*objective.*' It is important to capture that the researcher is independent and external to the research objects, and this strengthens the claim the research is '*objective*' and less susceptible to researcher prejudice and sits within the philosophical position called '*Positivism.*' The alternative consideration is whether the research is founded on '*feelings*,' which are intangible and *'subjective*.' Researchers that follow this position argue that the world and reality is complicated and cannot be understood through rigid rules. Acknowledging that the research is grounded in people, rather than objects, and the roles people play in society is important, the lens in which this is viewed is dependent on individual views and the reality is not external to the research objects and the individual views and perceptions do affect the interpretation of the world, this falls under the philosophy of *'Interpretivism*.'

In addition to the two epistemological positions above there are two others set out by Saunders, Lewis and Thornhill (2012); where the research question affects the observed significance, the interpretation is based on different perspectives, which are considered and the research centres on, "*practical applied research*" (p.140) and this position falls under the philosophy known as '*Pragmatism.'*

3.2.2 Ontology

Derived from, "*Ontologia*" (Killam, 2013, p.91) meaning '*to be*' in Latin. Killam captures key questions relating to how the researcher views the World and the belief they have around reality; is the World *"context-free and can be discovered?"* (p.100) or is it made up of "*Multiple mental constructions bound by context?"*

(p.100). These two questions lead onto different approaches and guide and affect how the World is perceived. Saunders, Lewis and Thornhill (2012) also referred to reality and defined ontology as a philosophical area of study into reality. Ontology considers '*reality*' and what the disposition of that reality is. Saunders, Lewis and Thornhill (2012) captured this reality as a, "*multidimensional set of continua*" (p.129) and see the '*nature of reality'* being, '*external'* and therefore '*objective*' or is it '*socially constructed*,' thus '*subjective*' in nature. This '*continua*' is supported by others (Easterby-Smith,Thorpe and Jackson, 2015) and Guba and Lincoln (1994) refer to these beliefs as '*metaphysics*,'(p.109). The following table, 3-1 consolidates the various ontological positions and captures the various positions set out by the seminal authors.

Author/s	Ontological position 1	Ontological position 2	Ontological position 3	Ontological position 4
Easterby-Smith, Thorpe & Jackson (2015) See Appendix 8.7 for the 4 Ontological truths (p.67)	**Realism** The world exists and is not affected by observations made about it and does not change	**Internal realism** Assumes that the world is locked however, it cannot be observed directly	**Relativism** How we observe the world and our perspectives affects the nature of reality, reality varies depending on the observer's perspective	**Nominalism** Reality is generated through perception and the way in which experiences are perceived and captured.
Guba & Lincoln (1994)	**Realism or Naive realism** Does not change with added context, an absolute	**Critical realism** Reality is not perfect and cannot be captured or comprehended logically due to the limitations of human rational	**Historical realism** A reality that was captured and changed over time due to a disarray of factors that were deemed as real but are no longer valid	**Relativism** A reality that is constructed through individual or group, an informed reality that can be adjusted through construction
Saunders, Lewis & Thornhill (2012)	**Objectivism**	**Pragmatism**	**Subjectivism**	
	Realism That reality is external and objective & social actors do not influence this	Where interpretation of reality varies and acknowledges that depending on the research question a different	**Social Constructionism** Reality is created through social interaction (*'intersubjectively,' p.137)*	**Nominalism** Reality is driven completely by the social actors and how they perceive and take action

Author/s	Ontological position 1	Ontological position 2	Ontological position 3	Ontological position 4
		ontological position maybe required		

Table 3-1 Ontological position comparison

3.2.3 Summary of Philosophical positions

Saunders et al. (2019) in a revision to their previous literature simplify the three philosophical considerations as assumptions. Acknowledging that whether the researcher knowingly makes these assumptions or not they exist in the process of developing knowledge. To summarise the assumptions that underpin research are, firstly; "*the realities you encounter in your research*" (p.130) the ontology, secondly the epistemology "*about human knowledge"* (p.130) and lastly "*the extent and ways your own values influence your research process*" the axiology (p.130). Saunders et al. (2019) claimed that the philosophical assumptions made by researchers informs the research goals, selected methodology and how the researcher conducts interpretation with the results to determine research findings and provide a comparison of five philosophies that are applicable to "*Business and Management Research*" (Saunders,Lewis and Thornhill, 2012, p.140) see Figure 3-2.

To assist researchers with the process of '*reflexivity*' (Bristow and Saunders, 2014) to understand the values and beliefs that underpin research assumptions Bristow and Saunders created and published a questionnaire called "*Heightening your Awareness of your Research Philosophy (HARP)*" (Saunders *et al.*, 2019, p.162) to help researchers score and obtain an indicator for their research philosophical position. See Appendix 8.11 for a copy of the questionnaire that was completed by the researcher to capture the responses in relation to the proposed research. As an initial indicator, the *HARP* questionnaire presented a high score for, '*Interpretivism*,' followed by '*Pragmatism,*' and a high negative score for a philosophical standing of ‘*Positivism*’ and neutral (0) and near neutral score (1) for ‘*Critical Realism.*’

Ontology (nature of reality or being)	**Epistemology** (what constitutes acceptable knowledge)	**Axiology** (role of values)	**Typical methods**
	Positivism		
Real, external, independent One true reality (universalism) Granular (things) Ordered	Scientific method Observable and measurable facts Law-like generalisations Numbers Causal explanation and prediction as contribution	Value-free research Researcher is detached, neutral and independent of what is researched Researcher maintains objective stance	Typically deductive, highly structured, large samples, measurement, typically quantitative methods of analysis, but a range of data can be analysed
	Critical realism		
Stratified/layered (the empirical, the actual and the real) External, independent Intransient Objective structures Causal mechanisms	Epistemological relativism Knowledge historically situated and transient Facts are social constructions Historical causal explanation as contribution	Value-laden research Researcher acknowledges bias by world views, cultural experience and upbringing Researcher tries to minimise bias and errors Researcher is as objective as possible	Retroductive, in-depth historically situated analysis of pre-existing structures and emerging agency Range of methods and data types to fit subject matter
	Interpretivism		
Complex, rich Socially constructed through culture and language Multiple meanings, interpretations, realities Flux of processes, experiences, practices	Theories and concepts too simplistic Focus on narratives, stories, perceptions and interpretations New understandings and worldviews as contribution	Value-bound research Researchers are part of what is researched, subjective Researcher interpretations key to contribution Researcher reflexive	Typically inductive. Small samples, in-depth investigations, qualitative methods of analysis, but a range of data can be interpreted
	Postmodernism		
Nominal Complex, rich Socially constructed through power relations Some meanings, interpretations, realities are dominated and silenced by others Flux of processes, experiences, practices	What counts as ‘truth’ and ‘knowledge’ is decided by dominant ideologies Focus on absences, silences and oppressed/repressed meanings, interpretations and voices Exposure of power relations and challenge of dominant views as contribution	Value-constituted research Researcher and research embedded in power relations Some research narratives are repressed and silenced at the expense of others Researcher radically reflexive	Typically deconstructive – reading texts and realities against themselves In-depth investigations of anomalies, silences and absences Range of data types, typically qualitative methods of analysis
	Pragmatism		
Complex, rich, external ‘Reality’ is the practical consequences of ideas Flux of processes, experiences and practices	Practical meaning of knowledge in specific contexts ‘True’ theories and knowledge are those that enable successful action Focus on problems, practices and relevance Problem solving and informed future practice as contribution	Value-driven research Research initiated and sustained by researcher’s doubts and beliefs Researcher reflexive	Following research problem and research question Range of methods: mixed, multiple, qualitative, quantitative, action research Emphasis on practical solutions and outcomes

Figure 3-2 Saunders et al. Five Philosophical positions (2019, p.144)

The following sub sections provides further details on the philosophical positions and a review of how they map to the research.

3.2.4 Positivism

This is the position adopted by physical and natural sciences (Gill and Johnson, 2010) who believed that reality is independent, and the researcher is external to any reality. The reality relates to fact and generalisations that are rule based and fixed. A structured approach, which usually follows a deductive approach and quantitative methodology (which will be described in the next section). Guba & Lincoln (1994) described the limitations of this inquiry, in that it excludes context and does not allow for a rich picture to be portrayed due to lack of *"meaning and purpose"* (p.197). In addition to these limitations, they also claimed that it does not lend itself well to the creation of new theory and over generalises, through quantitative means to demonstrate a level of confidence and level of significance against a specific hypothesis or set of hypotheses. This approach does not align to the research aim and objectives due to the reality being variable and the researcher not being external to the phenomenon of technological change, furthermore there is insufficient quantitative data available on this research topic as a result of the exploratory and futurology (Sardar, 2010; Um, 2019) due to the aspects not yet being fully documented.

3.2.4.1 Interpretivism

"*Contextualized meaning involving a belief that reality is socially constructed, filled with multiple meanings and interpretations, and that emotions are involved"* (Hurworth, 2011, p.210). It is subjective and because of human meaning, different people will see the world in a different way, unlike the positivist view that there is a consistent single view of the world, it varies depending on the values, knowledge and experience of those observing it, namely '*social actors.*' This position typically follows a qualitative methodology. Saunders et al. (2019) highlighted a challenge of an interpretivist is the ability to stay impartial and seek to gather understanding from the lens of the participants, rather than their own axiological and epistemological assumptions. Saunders et al. acknowledged within the field of business research, where the environment and context are complicated an interpretivist position which furnishes empathy and understanding with participants is advantageous. This approach, in line with the HARP questionnaire maps to the exploration of the reality of technological change, an area that is socially constructed and also due to the social implications with the working environment establishes human meaning and the variability of jobs and technological mapping resonate with this philosophical position.

3.2.4.2 Pragmatism

Where '*subjective*' and '*objective*' ontological views come together to achieve a practical contribution. Evaluating reality through multiple lenses, "*facts and values, accurate and rigorous knowledge and different contextualised experiences*" (Saunders *et al.*, 2019, p.151). Utilising a *'reflexive'* inquiry practice to derive a rich picture of reality. Within business and management, a pragmatist view enables acknowledgement of a complicated reality which changes depending on the experiences and views of those involved. It can help address specific problems identified through the literature. It supports a range of methods to be utilised tailoring the methodology to the specific research questions being addressed which is also known as '*triangulation*' (Easterby-Smith,Thorpe and Jackson, 2015). The challenges may include collating multiple views to interpret the world due to it not being possible to understand through a single view.

AI and other maturing technology that beget current and future technological change is an area of phenomenon, debate and interpretation (Sarmah, 2019). Exploring this phenomenon requires a pragmatic approach to enable credible insight of the technological aspects to consider the potential future workforce landscape. A flexible and adaptable approach is required with field expertise and knowledge to explore the growing and emerging area (Stahl,Timmermans and

Flick, 2017). Saunders, Lewis and Thornhill (2000; 2012) highlighted that the importance of exploratory study is, "*to discover what is happening and gain insights about a topic of interest*" (p.171). This is pertinent to the future workforce when considering the technological phenomenon that is emerging (Um, 2019). There is a lack of literature, as outlined in Chapter two relating to emerging technological change and the future workforce for humans and this influences the methodological options available. The philosophical considerations are driven by the need for exploration through pragmatism and a degree of interpretivism.

To summarise, exploration of the future is a subjective ontology, Saunders, Lewis and Thornhill (2012) refer to a, "social phenomena, created through the perceptions and consequent actions of affected social actors" (p.131). Given the lack of quantitative data associated with future projections of technological advancements, such as digitalisation and automation of tasks on the workforce which is attributed to the emerging nature of the technology that is still being realised (Mohideen and Evans, 2015; Bildosola *et al.*, 2017; Kyebambe *et al.*, 2017). The views and experiences of those that have encountered the technology in the last three to five years is crucial to building a picture of what is unfolding and having an informed view of the art of the possible to make predictions through foresight scenarios (Rhisiart,Störmer and Daheim, 2016). Understanding the social construct through those that have experienced the social phenomenon of technological change such as AI and specifically their experiences in relation to the working environment is essential. This research seeks to understand and interpret the experiences put forward by the selected social actors, who will be deemed '*experts*' (Dalkey and Helmer, 1963) that fulfil a set criterion which is set out later. The ontological assumption taken by the researcher is that the future work alongside the maturing technological change has an element of variability when exploring the potential effect, and therefore the experiences of multiple research participants is required to build this picture and create a social construct, considering the situational differences that the social actors, or experts may have. These differences will be relative to the sector or industry that the experts have experienced and it is this variability that supports a subjectivist ontology (Saunders, Lewis and Thornhill, 2012) over one of objectivism, which would present a view that all experts or social experts would have the same prescriptive view which is not the case given the variance of scenarios for adoption (Bhat and Cain, 2018, Jarrahi, 2018).

In addition to the ontological considerations which are founded on individual experiences and observations, this research is grounded in how people and organisations not only adopt and use technology but also their role within the workplace, this interpretation of the world supports an interpretivist philosophy. Due to this research building on "*practical applied research*" (Saunders,Lewis and Thornhill, 2012, p.140), through participant's knowledge and scenarios, this research philosophy is one of interpretivism and pragmatism.

The epistemological position for this research follows a pragmatist stance, due to this research looking to explore different perspectives of future scenarios. These perspectives could vary depending on observations and experiences of those asked. This research required interpretation of the multiple perspectives gathered acknowledging the complexity of reality and the world of AI and other technological change, an exploration of the future would be limited through a positivistic, objective quantitative or hypothesis led approach. The next section will look at the research approach building on the philosophical foundations and revisit Saunders, Thornhill and Lewis's Onion analogy (2012).

3.3 Research Approach

The philosophical ontological, epistemological and axiological assumptions are the foundations of the research approach and methodological choices (Easterby-Smith,Thorpe and Jackson, 2015; Saunders *et al.*, 2019). There are three approaches to developing research theory (Saunders *et al.*, 2019); '*Deductive', 'Inductive'* and *'Abductive'* and these are defined below along with how they align to the Philosophical positions of the previous section.

3.3.1 Deductive

Killam (2013) captured a deductive approach as starting with a broad view and then narrowing it down to something more specific, with detailed data. This approach aligns to the positivist epistemology grounded in an objective realism ontology (Saunders,Lewis and Thornhill, 2012; Easterby-Smith,Thorpe and Jackson, 2015; Saunders *et al.*, 2019). This approach aligns to the natural sciences (Gill and Johnson, 2010) and determining a level of confidence and significance against a set of hypotheses.

3.3.2 Inductive

If approaches were on a scale inductive would be at the opposing end of deductive. There is consensus that inductive reasoning, has subjective ontology of *'relativist'* or *'social constructivism*' (Guba and Lincoln, 1994; Saunders,Lewis and Thornhill, 2012; Killam, 2013; Easterby-Smith,Thorpe and Jackson, 2015; Saunders *et al.*, 2019). Where observations and experiences are utilised to research phenomena. '*Interpretivist'* or '*Pragmatist*' philosophical positions map to inductive theory. This approach is applied within social sciences as opposed to the natural sciences and analyses meaning and words over statistical analysis which is developed through deduction.

3.3.3 Abductive

This approach combines both '*deductive*' and '*inductive*' (Saunders,Lewis and Thornhill, 2012) and involves moving between the two as part of the research theory development approach. The '*abductive reasoning'* begins with an idea or feeling that requires further exploration. This approach is also known as '*pragmatic reasoning*' (Rivas, 2017) and is often used in management research. Another term used interchangeably is '*retroduction*' (Saunders *et al.*, 2019). Abductive theory seeks to create new or update a theory that has been identified or developed through '*inductive*' reasoning and through '*deductive*' iteration further looks to test any findings or consistencies identified. '*Critical realism'* aligns to an '*abductive*' or '*retroductive*' approach, where a focus may be on historical data to feed a discovery to be progressed for example.

Evaluating the three research approaches and acknowledging the social constructivism ontology of this research and the exploratory nature of this research and the pragmatist philosophy this research approach is one of abduction and is highlighted on the 'Research Onion' below, Figure 3-3 (Saunders,Lewis and Thornhill, 2012, p.126). The next section will look at the Research Method, followed by the Research design.

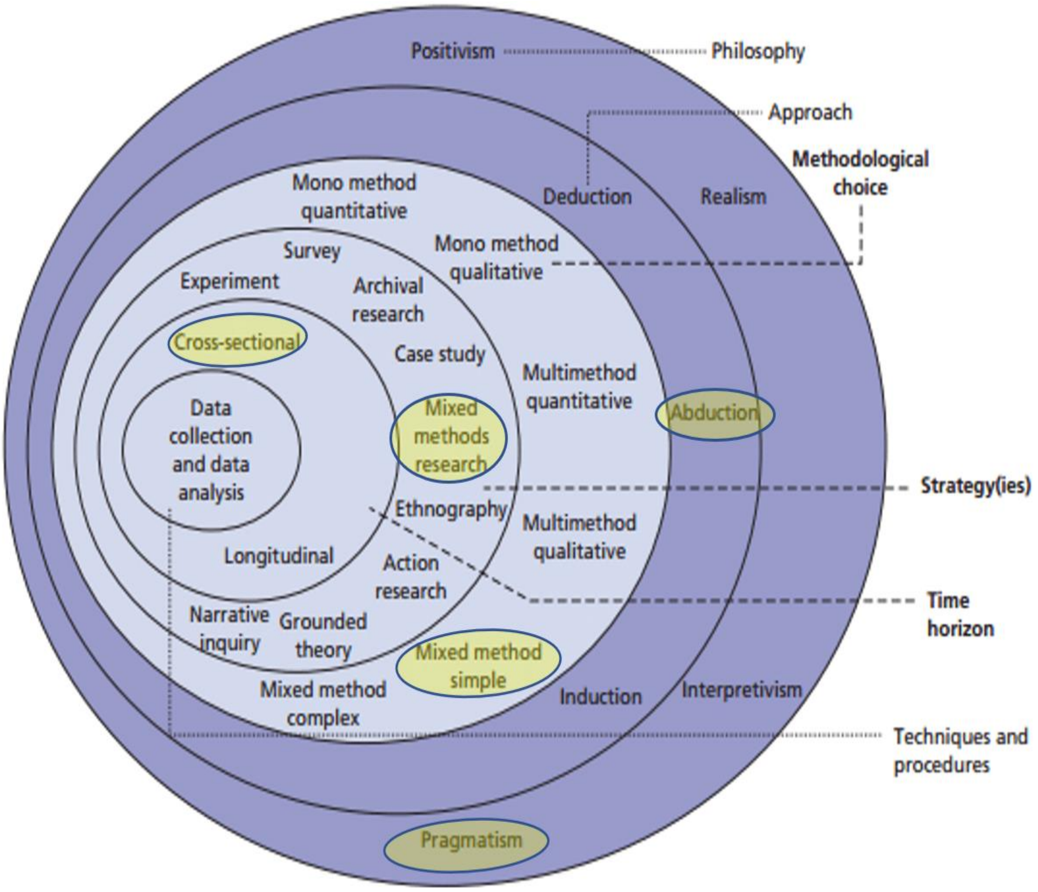

Figure 3-3 Updated Research Onion (Saunders, Lewis and Thornhill, 2012, p.126)

3.4 Research Method

The previous sections explained the philosophical aspects and the research approaches, these are the foundations of the research and influence the research methodological choice. Saunders onion analogy (Saunders,Lewis and Thornhill, 2012) captured six choices which are made up of variations of two high level methods; '*Qualitative*' and '*Quantitative.*' The following table (3-2) compares the characteristics of each high-level methodology

	Quantitative	**Qualitative**
Philosophy	Positivistic	Interpretivist
Approach	Deductive to validate theory through data or Inductive where theory is being developed through data	Inductive or Abductive (where researcher utilises Deductive and Inductive approaches)
Features	Driven by numbers and statistics. Standardised and repeatable. The research is external from the research.	Driven by words and meaning, non-standard approach which can be amended depending on questioning, researcher is involved in the research
Strategies	Experiments, Structured interviews, Structured Observations, Surveys etc.	Case studies, action research, ethnography, grounded theory etc.

Table 3-2 Quantitative & Qualitative Methods

Not all research fits a single method, or *'mono method*,' a '*mixed method'* or '*multiple method*' (Saunders,Lewis and Thornhill, 2012) depending on the research questions may be more appropriate (Jick, 1979). A mixed or multiple method approach is driven through a '*realist*' ontological belief. A multi-method could be either multiple quantitative or multiple qualitative. Another option is a combination where the methods are mixed and utilises both quantitative and qualitative. A mixed method approach would follow a '*Pragmatist'* philosophy and could have a varying approach, Deductive, Inductive or combined through abductive. The chosen methodological decisions need to align, with the quantitative and qualitative elements complementing one another. Research strategies that fall under mixed methods would be combining those listed in Table 3-2.

There are various benefits and limitations associated with the different methods, Creswell (2014) summarises the advantages of qualitative research as it allows views, opinions to be collected, along with listening to research participants, it enables a story and context to be captured in detail from limited numbers of participants. The disadvantages are that it is not quantitative and therefore cannot be statistically analysed, it involves a high level of subjectivity and can be time consuming due to the participant overhead. Similarly, quantitative research has advantages and disadvantages; the positives are that generalisation from large numbers of people is feasible, statistical evaluation is achievable, examination of relationships, cause and effect scenarios are possible along with the ability to mitigate bias. The limitations of quantitative research are that there is minimal context or understanding, there is the risk of the research being influenced by the researcher and their motivations, no rapport built with participants or respondents and it rules out context. Lastly, building on Creswell's advantages and disadvantages above, the following captures the advantages and disadvantages of a mix methods approach, or the method of '*triangulation'* (Jick, 1979).

The mixed methods approach if aligned correctly can leverage the benefits outlined by Creswell (2014) of both approaches along with the benefits of validation and synthesis of results. Jick (1979) captured the advantage of '*triangulation'* as *"it can stimulate us to better define and analyse problems*" (p.610). Creswell (2014), highlighted key factors when considering the research methodology, which would constitute the research design and the research strategy being whether an experiment or fieldwork would be conducted to explore the social world, how the data would be collected and from where or who, the tools that would be utilised to collect the data and how the collected data is to be analysed and validated for reliability reasons. Creswell articulated three designs for a mixed method, namely *"Convergent design, Explanatory sequential design and Exploratory sequential design*" (Creswell, 2014, p.6).

The aim of the first design, convergent design is to utilise both quantitative and qualitative data that has been collected and treat them as a single result set and validate or converge through comparison. The second design, explanatory sequential design starts with quantitative and seeks to provide explanation through qualitative means adding context and understanding. Lastly, the third, exploratory sequential design is the reverse of the second and starts with qualitative data to help explain a phenomenon or area of interest and through quantitative methods to measure and analyse further. When evaluating what would constitute an appropriate method several factors were considered:

1. How can I access the data to explore the phenomenon of technological change and future work?
2. How have others approached futuristic type studies?
3. What will yield appropriate insight?
4. What type of data would help address the research aim and objectives?

After reviewing the philosophical elements as set out in section 3.2 and building on the literature that emerged from the literature review (chapter 2) and assessing what data already existed, which is limited in relation to future skills and potential job creation alongside theories of displacement (Mainardes,Funchal and Soares, 2017), some quantitative data exists on historical employment trends and theories presented on components of historical work impact. Due to the exploratory nature of the research, which seeks insight, which is much more interpretivist and grounded in pragmatism, qualitative data is required to build a picture of meaning when considering the research aim and objectives. Whilst the majority of the data was expected to be qualitative, previous studies (Brandes, 2009; White, 2017) have sought insight from a panel of experts and have evaluated group insight from a descriptive statistical standpoint to help assess agreement across a group which provides further insight to the maturity of a specific area or topic being studied. Therefore, looking at data in a quantitative way as well as qualitatively would derive a mixed method approach.

This research utilised existing data that was available to present an initial picture, the initial data feeds were:

1. Standard Occupation Classification (SOC) Data from the Office for National Statistics (Statistics, 2010b)
2. Research carried out by the World Economic Forum (Forum, 2016; 2018)
3. From online occupational profiling data (LinkedIn, 2018)

To gather insight on an area that is still emerging and developing an expert panel (Brandes, 2009, Webler *et al.*, 1991) approach was utilised. An expert panel would enable exploration into the most recent wave of technological change, acknowledging it is an area which is still maturing and has sporadic adoption and varying maturity levels (Huang and Rust, 2018). Expert insight would also explore how work is carried out by humans in practical terms over theoretic modelling, providing an empirical view of existing and potential forecasting of required skills that are emerging or are necessary alongside the technology. A proven method of soliciting expert insight when evaluating areas that are not widely adopted or established is by administering a Delphi approach (Linstone and Turoff, 1975). The Delphi approach will be discussed in more detail in the next sub section.

A Delphi study enabled access to expert participants through a questionnaire model, to inform the compilation of the data collection questionnaire several data sources were evaluated, these are summarised below in Table 3-3. This research method was dependent on accessing the appropriate data in line with the research aim and objectives, a key aspect of this was determining what constituted an expert. This is discussed in more detail in the next section. To help establish credibility data validation was recommended (Jick, 1979; Torrance, 2012), this research method included a phase of triangulation with additional data, both quantitative and qualitative to help validate themes that emerged from the Delphi study which was the initial phase to enable data collection for analyses. To help further validate the patterns and themes that emerged follow up interviews with selected panel experts were incorporated as part of this research method, these were conducted post analysis of the Delphi and triangulation with additional data sources to further validate the rich picture that emerged and to benefit from respondent validation (Bazeley, 2013). The components of the research method will be elaborated through the subsequent sections.

#	Type of Data	Data Name	Owner	Date published or accessed	Link
1	Occupational Data	Standard Occupational Classification (SOC2010)	Office for National Statistics *(UK)*	2010	https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010
2	Industry/ Sector Data	Standard Industry Classification	Office for National Statistics *(UK)*	2007	https://www.ons.gov.uk/methodology/classificationsandstandards/ukstandardindustrialclassificationofeconomicactivities/uksic2007
3	Occupational Data	International Standard Classification of Occupations (ISCO08)	United Nations Agency *(187 Member states)*	2008	http://www.ilo.org/public/english/bureau/stat/isco/isco08/
4	Occupational Data	Standard Occupational Classification (SOC2018)	United States Bureau of Labor	2018	https://www.bls.gov/soc/2018/home.htm
5	Occupational Data	Occupational Information Network System (O*NET)	United States Department of Labor (US)	2019	https://www.onetonline.org/
6	Trending jobs	The 33 most recruited jobs	LinkedIn Talent Solutions	2018	https://business.linkedin.com/content/dam/me/business/en-us/talent-solutions/cx/2018/pdf/33-most-recruited-jobs.pdf
7	Future of Jobs Report	The Future of Jobs	World Economic Forum (WEF)	2016	http://reports.weforum.org/future-of-jobs-2016/?doing_wp_cron=1520706369.1438820362091064453125 (Forum, 2016)
8	Future of Jobs Report	The Future of Jobs	World Economic Forum (WEF)	2018	https://www.weforum.org/reports/the-future-of-jobs-report-2018 (Forum, 2018)
9	Panel Participation List	Panel Sample List	Claire Clement	2019	LinkedIn Network - https://www.linkedin.com/in/claire-clement-0054079/

Table 3-3 Data Sources

3.5 The Delphi Approach

When evaluating the research aim and questions numerous research strategies (Saunders,Lewis and Thornhill, 2012), were eliminated due to the research strategies being founded on positivistic and deductive grounds. This research is of exploratory nature, whilst technological change has been experienced previously, the latest wave of emerging technological advancements are of a different nature (Atkinson, 2016; Bostrom, 2017), this reduced the applicability of traditional natural science strategies (Gill and Johnson, 2010) which are validating or determining a level of confidence against specific or set of hypotheses (Saunders,Lewis and Thornhill, 2012). Another key feature of quantitative research which is grounded in positivism and a deductive reasoning approach is explained by Saunders, Lewis and Thornhill (2012) as being where, *"research examines relationships between variables, which are measure numerically and analysed using a range of statistical techniques"* (p.162). Such research strategies would be structured and experimental in nature. Data collection would be through structured observations, surveys or experiments. This research does not complement an observational or experimental approach due to the study exploring a future effect of an emerging phenomenon; how developing technological change could impact future high skilled professional work, which cannot easily or consistently be observed at the current time. Structured surveys through questionnaires are used in explanatory or descriptive research. As previously stipulated this research is exploratory and a Delphi strategy utilised questionnaires through an inductive approach to understand opinion (Mitchell, 1992) this explorative design follows an interpretivist and pragmatist philosophy, interpreting and analysing words over numerical data.

The Delphi technique dates back to the 1950s (Linstone and Turoff, 2011) where the US Air Force utilised it to capture expert input in a controlled way. A key component of the approach was the anonymity of participants and the application of iterative surveys. Two considerations when utilising the Delphi technique are:

a. "*Experts focused bias*" – Engineers and scientists are prone to be too optimistic in the short term and too pessimistic in the long term (p.1715) a view also supported by Amara's Law (Amara, 1984).

b. "*Creating a shared reality*" (p.1716). This is looking at the various characteristics across the three perspective types, Technical (T) Organisational (O) and Personal (P).

The approach brings together a panel of experts, with experience, knowledge and insight of technical change such as AI and other cloud computing driven technologies, both from an applied and theoretical perspective. The panel included experts from a people management perspective to build on the technological change knowledge and experience from a people development perspective to consider potential future skills and experience requirements. The panel also had representation from Industry aligned experts (customer and supplier perspective) and academic experts, to cover the three perspective types T, O & P (Linstone and Turoff, 2011). For the full participant breakdown see Section 4.1.1.

The Delphi approach is a significant strategic methodological tool within forecasting research (Wigginton, 1979; Mitchell, 1992; Rowe and Wright, 1999; Bradley and Stewart, 2003; Scholl *et al.*, 2004; Huang,Wu and Chen, 2013; Gary and Heiko, 2015). The terminology is claimed by Loo (2002) to have linkage to Greek Mythology, where the Oracle in Delphi was approached to foresee the future to help with decision making. The term, '*Delphi*' was allotted by Kaplan (Kaplan,Skogstad and Girshick, 1950), a Researcher at the RAND Corporation. The approach was developed by the RAND Corporation (Dalkey and Helmer, 1963; Loo, 2002) through experimentation of expert opinion to reach a *"consensus of opinion"* (Dalkey and Helmer, 1963, p.468). The controlled experiment was to elicit expert opinion to help inform and shape policy and strategic decisions within the military. Utilising carefully selected participants with knowledge of the subject matter being explored, the approach developed and expanded outside of the military into other areas and sectors of interest, where through expert knowledge and experiences, researchers were able to gather insight into future areas of interest and concern that may not have been substantiated fully or, where limited quantitative data was available to carry out predictive probability modelling. Delphi as a method has been applied where research was exploring issues that could impact social well-being, examples within business and management, aligning with healthcare aspects such as predicting worker mental health in relation to workplace stress scenarios (Loo, 2002). Along with evaluating technological advancements and future applications within Business, such as 'Blockchain' (White, 2017) and other studies which looked at predicting future impact (Wigginton, 1979; Mitchell, 1992; Rowe and Wright, 1999; Bradley and Stewart, 2003; Scholl *et al.*, 2004; Huang,Wu and Chen, 2013; Gary and Heiko, 2015). There are five key aspects to a Delphi study (Loo, 2002, p.763):

1. A '*panel*' of representative experts, that have a broad range of '*opinion*' on the topic or issue being reviewed.
2. Anonymity of participants.
3. Series of structured questionnaires and corresponding feedback reports prepared by the researcher for the panel.
4. Iterative rounds soliciting feedback through the questionnaires from the panel.
5. Delphi output report, capturing the results.

Loo (2002) built on the work of Rowe & Wright (1999) who concisely captured the key aspects of a Delphi study into four areas; *"anonymity, iteration, controlled feedback and the statistical aggregation of group response*" (p.354). The original aim of Delphi studies (Dalkey and Helmer, 1963) was to reach "a *reliable opinion consensus"* (p.458). Overtime as the approach has matured and recognised the social complexities inherent in exploratory research (Loo, 2002), where the philosophical grounding is interpretivism or pragmatism, the research reality is constructed through individual observations and perspectives (Easterby-Smith,Thorpe and Jackson, 2015; Saunders *et al.*, 2019). Delphi studies have an ontological relativism, which collates the experiences and views of selected participants, the researcher evaluates through a '*reflexive*' inquiry supported by the *"contextualised experiences"* (Saunders *et al.*, 2019, p.151) of the panel and therefore adopting a pragmatist philosophy, through abductive reasoning to explore the research aim and address the research objectives of this thesis.

Turnoff (1970) captured a variation to the original *'consensus'* approach, the *'Policy Delphi*,' where consensus was not the aim of the panel, instead the objective was to examine, *"a major policy issue*" (p.80) where Turnoff claimed there are no '*experts*' and the panel are, *"informed advocates and referees.*" Highlighting that input or supporting quantitative information may be called upon as part of the study. Turoff distinguishes between the two Delphi approaches, stipulating that the Policy Delphi is an analysis tool rather than a tool for decision making through consensus, strongly suggesting that consensus should be avoided to support exploration of key organisational and social challenges. Adopting a '*policy delphi'* approach can achieve one or more of the following (Turoff, 1970):

1. *"To ensure that all possible options have been put on the table for consideration,*
2. *to estimate the impact and consequences of any particular option,*
3. *to examine and estimate the acceptability of any particular option"* (p.83).

This research aim and research objectives align to all three of the above objectives in relation to technical change and future work. A key advantage noted by Ray and Sahu (1990) of utilising a delphi study is, *"as an information gathering process, delphi is likely to provide more information on an issue than any other process"* (p.26), due to the exploratory nature of this research, information gathering is an essential component to achieving the research aim and objectives and gathering information through the expert panel helps explore the phenomenon of 'technical change' and future work.

The Delphi approach was selected after careful consideration to allow for expert insight to be gathered in a structured way whilst allowing participants freedom to share their professional insight without peer pressure as is sometimes the case in focus groups or more open data collections methods. The Delphi method also allowed for data to be collected electronically aiding both the respondent and the researcher in the capturing and then later analysis.

The next sections articulate the key considerations for a Delphi study. There are several important features to evaluate when embarking on a Delphi study, this section looks at the number of rounds in more detail, the required number of panel participants along with the associated advantages and also criticisms of the approach. Starting with the number of rounds.

3.5.1 Number of rounds

There is much debate over the optimal number of Delphi rounds required to achieve optimal results (Rowe and Wright, 1999; Hsu and Sandford, 2007; Skulmoski,Hartman and Krahn, 2007; White, 2017). Studies range from two to four rounds, a key factor is '*saturation'* (Speksnijder,Mank and van Achterberg, 2011) when the results or theory (Skulmoski,Hartman and Krahn, 2007) start to repeat or there is no new data being presented, then a sufficient number of rounds have been run. A consideration when determining the number rounds is also panel participation. The study requires time from knowledgeable and experienced individuals, who are professional people with limited time available. Increased Delphi rounds present a research risk of increased dropout rates and low responses if the study is elongated to allow for multiple rounds. For this reason, there is a valid claim that two Delphi rounds are optimal (Speksnijder,Mank and van Achterberg, 2011; von der Gracht *et al.*, 2015; White, 2017). Acknowledging this the research design which will be covered in more detail in section 3.8, planned for two rounds, although the option for a third round was not completely ruled out should there be a lack of saturation or data presented through the two rounds.

The Delphi questionnaire consisted of fifteen questions for round one, see Appendix 8.15 and sixteen questions for round two, see Appendix 8.17. The questionnaire was compiled to extract as much insight from the expert participants as possible. Table 3-4 captures the questions that were compiled along with the information that the question was exploring in line with the research aims and objectives. The table also captures which specific research objective the question supports. To reiterate the research, aim and objectives they are captured below in figure 3-4.

Figure 3-4 Research aim and objectives

The next sub-section will look at what constitutes the right number of participant numbers and how is an 'expert' defined.

Qu. #	Questions Round 1 & 2	Rationale for Question Against the Research Aim & Objectives
1	Please provide your name so that responses can be tracked across each round. Please note that you name will not be shared or published as part of this research and a participant number will be allocated to anonymise responses.	Control question for tracking across rounds
2	What Industry or Sector do you or have you worked in? Select all that apply.	Control question to review the experience landscape and to establish a picture of the experience across the panel and to track any limitations of this research if a gap emerged
3	How many years work experience do you have? (This is the cumulative experience in the sectors captured in Question 2).	Control question, to validate experience against the expert criteria and to establish a picture of the experience across the panel.
4	What is your existing or last Occupation/Job Title	Control question to evaluate whether role is a professional role – triangulated with the SOC, to establish a picture of the expertise
5	What professional or technical occupations do you think could be created over the next decade as a result of AI related technological change? (List all or state not sure if applicable)	To explore future roles and compile a list of specific jobs or occupations, research objectives: 2; 3 & 4
6	Looking at the next few years - Please rank the following job role groupings - in order of importance alongside technological change between now and 2025; (1 - the top being most important and 10 - the bottom being the least out of this list). See Briefing paper for more information (page 5). Drag the role grouping in order of importance.	To explore research objectives: 2; 3 & 4 the job roles that could be in higher demand and also in conjunction with question 7 whether there could be a change in the demand as technology matures. This question also was to help measure whether there was agreement across the panel on the types of roles that would be in higher demand
7	Looking further ahead - Please rank the following job role groupings - in order of importance alongside technological change post 2025; (1 - the top being most important and 10 - the bottom being the least out of this list). See Briefing paper for more information (page 5). Drag the role grouping in order of importance.	To explore research objectives: 2; 3 & 4 the job roles that could be in higher demand and also in conjunction with question 6 whether there could be a change in the demand as technology matures. This question also was to help measure whether there was agreement across the panel on the types of roles that would be in higher demand
8	Do you think there is a key professional job role missing in the list? If yes, please state the job role/s or state Not Sure	This was to explore research objectives: 2; 3 & 4 and also validate the job roles presented in question 6 & 7
9	Have any of your job roles been affected by technological change? If yes please describe the impact and when that was. If No, please state No in the box	This was to support research objective 3 & 4. Also provided a further control question with question 10 if there had been an adverse impact it could influence response to 10. Also, an important consideration for participant well-being if there has been historical emotional impact. (See section 4.7)

Qu. #	Questions Round 1 & 2	Rationale for Question Against the Research Aim & Objectives
10	On a scale of 1-10 (1 being negative and 10 being positive) rate how you feel about the impact technological change will have on professional occupations in the future?	To explore professional workers views on future work, research objective 4 and to a control question for further validation/exploration if negative answers were received and not linked to question 9.
Qu. #	**Questions Round 1 Only**	**Rationale for Question Against the Research Aim & Objectives**
11	What do you think are the key skills required by people in the future alongside technological change? Please list	To explore the human centric skills research objective 1 and objective 3 & 4 to help build a picture of potential future demand for skills and worker readiness and training.
12	Which sector/s do you think will be affected the most technological change?	To explore whether there were any industries or sectors that could drive a demand for workers and skills ahead of others, and whether there are any specific industry requirements that emerge. All research objectives, 1, 2, 3 & 4.
13	Is there anything you would like to add in relation to technological change and the human future workforce? Is there anything that concerns or excites you about the future workforce?	This was to incite further insight from the participants and to ensure that the questionnaire was not too prescriptive. A catch all type question to invite a serendipitous revelation (Kefalidou and Sharples, 2016) from the expert panel. In support of all the research objectives 1, 2, 3 & 4.
14	Would you be happy to be contacted by the researcher to take part in a follow up interview?	This was a control question for respondent validation and as an option to explore further any responses provided
15	If you are happy to be contacted by the researcher for a follow up 30-60 min interview, please provide your email address:	As above - This was a control question for respondent validation and as an option to explore further any responses provided
Qu. #	**Questions Round 2 Only**	**Rationale for Question Against the Research Aim & Objectives**
11	Rank in order of importance the key skills required by people in the future alongside AI related technological change. (1 - the top being most important and 10 - the bottom being the least out of this list). See Briefing paper for more information (page 5). Drag the role grouping in order of importance.	This built on the responses from the first round and was for research objective 1, 3 & 4. It also was to evaluate whether the panel were in agreement of the prioritisation or ranking of those skills as a group.
12	Do you think there are any key skills missing from the list in question 11? If yes list below.	This was to validate whether any key skills had been omitted from the question 11, & to test saturation in relation to skills. Research objectives 1, 3 & 4.

Qu. #	Questions Round 2 Only	Rationale for Question Against the Research Aim & Objectives
13	Which sector/s do you think will be affected the most technological change?	To explore whether there were any industries or sectors that could drive a demand for workers and skills ahead of others, and whether there are any specific industry requirements that emerge. All research objectives, 1, 2, 3 & 4.
14	Is there anything you would like to add in relation to technological change and the future workforce for people? Is there anything that concerns or excites you about the future workforce?	This was to incite further insight from the participants and to ensure that the questionnaire was not too prescriptive. A catch all type question to invite a serendipitous revelation (Kefalidou and Sharples, 2016) from the expert panel. In support of all research objectives, 1, 2, 3 & 4.
15	Would you be happy to be contacted by the researcher to take part in a follow up interview?	This was a control question for respondent validation and as an option to explore further any responses provided
16	If you are happy to be contacted by the researcher for a follow up 30-60 min interview, please provide your email address.	As above - This was a control question for respondent validation and as an option to explore further any responses provided

Table 3-4 Delphi Questions mapped to Research Aim and Objectives

3.5.2 Panel numbers

Similarly, to the debate over the optimal number of rounds (Hsu and Sandford, 2007; White, 2017; Strohmeier, 2018) the number of participants also varies in Delphi studies. The key consideration for panel experts is the ability to achieve a level of knowledge and expertise (Linstone and Turoff, 1975; Rowe and Wright, 1999; Kosow and Gaßner, 2008; White, 2017) within the study area to aid understanding and valuable contribution against the research aim and objectives. Rowe and Wright (1999) conducted key analysis on a number of Delphi studies reviewing the multiple factors, including the group size. Numbers varied greatly from four to ninety-eight, however a key finding from their study was that whilst there were individual examples of high group numbers most of those reviewed had low participant numbers of below ten. This supports the view that the aim of a Delphi approach is one of quality rather than quantity. This research design focused on having a representative panel of expertise and knowledge in the study area over participant volume.

Technological forecasting and futurology are key to achieving this research aim. The Delphi technique (Mark et al., 2000) utilises a group or panel of people who are interested or have interest in this research area. The Delphi approach has been utilised in studies (Turoff, 1970; Koskiala and Huhtanen, 1989; Ray and Sahu, 1990; Skulmoski,Hartman and Krahn, 2007; Keller and von der Gracht, 2014; White, 2017) where there is limited knowledge or understanding of a particular area or where the technology is new. White (2017) by applying a two round Delphi technique gained future insight through an expert panel, of relevant scholars and business practitioners on "*how blockchain may be expected to change the future of businesses*" (p.6). A Futures study (Gary and Heiko, 2015) utilised the Delphi technique, 1226 people were invited to participate in a survey that looked at projections for 2030, 142 out of the 1226 participated, 11.6% of the target participants.

This thesis had an initial target population of 170 experts. For Round one, 72 responses were received and for the second round this increased to 82. The level of consistency across the two rounds was high, 81% of first-time responders participating in the second round. Given the expertise available across the target population, experts were invited to respond to the second questionnaire even if they had not completed the first, this was to support the broad collation of expert views for evaluation given the lack of quantitative data available on this research area and rate of adoption of the technical change. Section 4.1.1 provides further details on the response rates. The next section will describe how the target population was identified and the expert criteria that was part of that process.

3.5.3 Participant identification and Selection approach

The research focused on the exploration of two key areas: the phenomenon of Technological Change and the landscape of high skilled professional work. As already highlighted a Delphi study requires, "*expertise*" and or "*knowledgeability*" (Rowe and Wright, 1999, p.371). Hsu and Sandford (2007) acknowledged the need for participants to have appropriate experience relevant to the topics being studied. For this research participants needed a reasonable level of understanding of technological change, specifically some or all of the areas described in section 2.5, experience and knowledge of how it has and could be further adopted across industry and sectors is a key area for the panel participants. Another area that that requires insight and '*knowledge*' is the area of professional work and what constitutes an occupation. The participate briefing paper contained background information with definitions of any terminology used for consistency, so that a range of knowledge could be leveraged across the panel (Strohmeier, 2018). Some participants may have in-depth knowledge of technological change scenarios but limited knowledge of specific occupational naming conventions and will be required to review the briefing document in more detail for the occupational information. Conversely some participants may have more knowledge and experience of occupation role makeup and training requirements and through reviewing the technological definitions be better placed to express an opinion on potential impact or requirements. Across the rounds participants will have the ability to review their previous responses to shape and review their opinions, therefore synthesising and triangulating (Loo, 2002) their knowledge across the two areas to provide an informed opinion. Another consideration when selecting participants is linked to the values and beliefs of participants, an ability to reflect on the feedback is required and to be open to revisiting previous opinions and "*judgements*" (Hsu and Sandford, 2007, p.3) considering the wider environment and reality around them. To assist with participant and panel selection a participant criterion was drafted that needed to be met and was used as a validation check as part of the selection process. The checklist criteria was based on reviewing key studies that have used expert insight (Richey,Mar and Horner, 1985; Needham and de Loë, 1990; Rhisiart,Störmer and Daheim, 2016) and informed by the researcher's twenty years business and technological experience and see Figure 3-5 below:

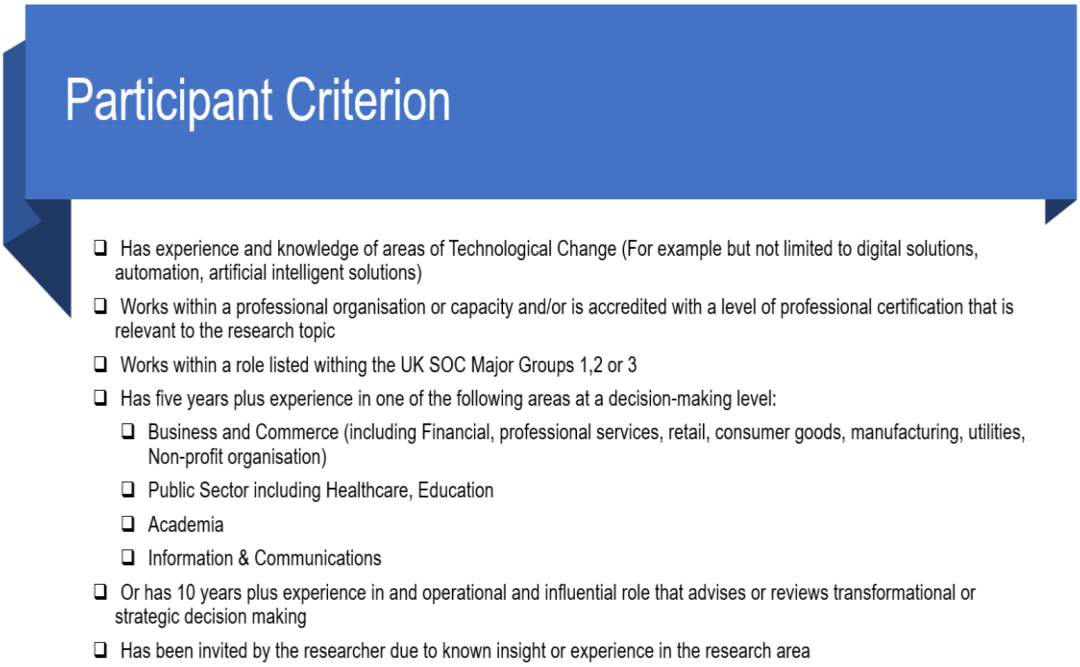

Figure 3-5 Panel participation criteria

Section 3.8 will describe in detail this research design and steps taken, prior to that the Delphi stages are summarised below setting out the selection of participants across the initial pilot phase, followed by the first round and then the second phase, along with the updates that were administered to acknowledge the feedback loop as this research was conducted. Furthermore, this section concludes with an explanation of the triangulation and interview considerations that along with the Delphi rounds make up the end-to-end research method.

3.5.4 Delphi Pilot participant selection and invitation approach

Participants were identified through the professional network of the researcher, over two decades working across multiple sectors such as retail and consumer goods and products, Financial Services and various Public Sector areas the researcher has established a multi-industry network which contains professionals in a diverse range of roles, for example; doctors, nurses, senior lecturers, senior police officers, technical specialists, commercial directors, financial advisors, company CEOs and executive level directors, managers and many more. A target list of potential panel participants was drafted. This was compiled based on, perceived openness and reliability to participate by the researcher, tenure and experience in their professional field, their potential exposure to technology historically, currently and in the future. The participants the researcher met through various professional meetings were verbally asked whether they would like to participate in this research whilst others were contacted via private message through the professional networking platform '*LinkedIn*[2].' A small number of participants were identified as potential pilot participants to help test the briefing paper and the questionnaire before sharing with the wider target group of 170 participants. The pilot participants were selected from the 170 based on their willingness to participate and openness to share constructive feedback to the researcher on the material shared. The feedback from the pilot captured the need for three changes:

1. *Participant name not captured for quality checks by researcher on the questionnaire, this was addressed by adding a field to the updated questionnaire*
2. *Wording of question 6 & 7 updated for additional clarity on the ask*
3. *Minor typo identified and addressed*

After the updates had been made the Round 1 invitations were initiated with the updated questionnaire and briefing paper. See Appendices 8.14 and 8.15.

3.5.5 Delphi Round 1 participant selection/invitation approach

The 170 participants were contacted through two channels, one email if the email address was known to the researcher or the second route was through a LinkedIn private message. Both provided a synopsis of this research and a copy of the

[2] https://www.linkedin.com/

briefing paper along with the link and QR code to the online questionnaire. The QR code enabled participants to easily complete the questionnaire on a mobile device giving the participant multiple options acknowledging that as professional people their time is limited. Microsoft Forms [3] was used to compile and share the questionnaire. It was selected due to its ease of use in compiling the questionnaire and also the interface for participants was straight forward. Another advantage of using Forms was the access to the data once questionnaires had been submitted. The data set was easily exported to excel where analysis could be carried out, see section 4 for further details on the analysis techniques applied.

3.5.6 Delphi Round 2 participant selection/invitation approach

Following the analysis of the first-round responses, the 170 participants were contacted again to invite them to take part in the second questionnaire. The same mechanism from Round one was used for the distribution of the updated briefing paper and updated questionnaire, the updates were based on round one responses. The changes made to the Round 2 questionnaire and briefing paper were:

1. *Questions 6 & 7 – Job grouping updated to capture feedback from question 8 in Round 1.* Updates captured in source column in Table 3-5 below.
2. *Questions 11 – introduce a new question building on the responses from question 11 in round 1, see table 3-6 overleaf.*
3. *Questions 12-15 then moved on a digit due to the introduction of the new question 11.*

[3] https://forms.microsoft.com/

#	Grouping	Job Role	Source	Potential variants or roles included in this grouping
1	Industry Specialists	Financial and Investment Advisers	WEF 2018	Business Specialists /Advisors/Analysts
		Senior Tax Advisor	LinkedIn 2018	Supply Director
		Supply Chain and Logistics Specialists	WEF 2018	
		Agricultural Specialists	Round 1 responses	Farmers
		Specialist - Scientist	Round 1 responses	
		Environmental Specialists	Round 1 responses	
		Chemical Processing Plant Operators	WEF 2018	Specialist Operations
		Petroleum and Natural Gas Refining Plant Operators	WEF 2018	Specialist Operations
		System Administrators	LinkedIn 2018	Specialist Operations
2	Legal/Compliance/Regulator/Ethical roles	Compliance Officers	WEF 2018	Financial Analyst
		Information Security Analysts	WEF 2018	
		Risk Management Specialists	WEF 2018	
		Ethical Specialists and evaluators	Round 1 responses	
		Enforcement Officers	Round 1 responses	Police Officers
		Legal Specialists	Round 1 responses	Solicitors, Lawyers, Barristers, Judges etc
3	Creativity roles	Innovation Professionals	WEF 2018	
		Interaction Designers	WEF 2018	
		Service and Solutions Designers	WEF 2018	
		User Experience and Human-Machine Interaction Designers	WEF 2018	
		Culture Specialists	WEF 2018	
4	Data Specialists	Big Data Specialists Digital	WEF 2018	Data Scientist
		Chief Data Officer	US SOC 2018	
		Data Analysts and Scientists	WEF 2018	
		Algorithm/ Mathematical Specialists	Round 1 responses	
5	Healthcare Professionals	Medical Doctors/Surgeons & Professionals	UK SOC 2010	
		Nurses, Dentists, Radiographers, Physiotherapists	UK SOC 2010	
		Health care professionals	Round 1 responses	
		Health care professional - Psychologists	Round 1 responses	
6	Human Resources and Learning & Development roles	Human Resources Specialists	WEF 2018	Recruiting Coordinator
		Technical Recruiter	LinkedIn 2018	
		Training and Development Specialists	WEF 2018	
		Transformation Specialists	WEF 2018	
		University and Higher Education Teachers	WEF 2018	
		Career/ Personal Coaches	Round 1 responses	
		Teachers	Round 1 responses	
		Educational/ Learning Specialists	Round 1 responses	
7	Leadership, Management Roles & Organisational Specialists	Management Roles	WEF 2018	General and Operations Managers
		Delivery Manager	LinkedIn 2018	Managing Directors
		Management and Organization Analysts	WEF 2018	
		Organizational Development Specialists	WEF 2018	
		Government & Political Official	Round 1 responses	Civil Servants/ Politians
8	Sales Specialists and Marketing Specialists	Sales Professionals	WEF 2018	Account Managers/ Directors
		Account Executives	LinkedIn 2018	Sales Development Representative
		Digital Marketing and Strategy Specialists	WEF 2018	Sales Engineer
		Product Marketing Manager	LinkedIn 2018	Brand Manager
		Ecommerce and Social Media Specialists	WEF 2018	
9	Technical Specialist & Specialist Engineers, Developers	Electrotechnology Engineers	WEF 2018	Front-End Engineers
		Energy and Petroleum Engineers	WEF 2018	Dev Ops Engineers
		Robotics Specialists and Engineers	WEF 2018	Solution Architects
		Software Engineer	WEF 2018	Solution Consultants
		Software and Applications Developers and Analysts	WEF 2018	
		Database and Network Professionals	WEF 2018	
		AI and Machine Learning Specialists	WEF 2018	
		Technology Specialists	WEF 2018	
		Information Technology Services Process Automation Specialists	WEF 2018	
		Cloud Architect	LinkedIn 2018	
10	AI Integration and human augmentation roles	AI Integration/ Mediation	Round 1 responses	
		Human Integration - Speech Specialist	Round 1 responses	
		Human Integration Specialists - Biological	Round 1 responses	
		Human Integration Specialists - Gaming	Round 1 responses	
		User Experience and human integration specialists	Round 1 responses	

Table 3-5 Round 2 updates following Round 1 responses Questions 6 and 7.

In addition to the updates for question 6 and 7 as shown in table 3-5, a new question was introduced based on the responses from question 11 in round 1. The ten skill groups that participants were asked to stack rank are captured in Table 3-6.

Question 11: **Rank in order of importance the key skills required by people in the future alongside AI related technological change** (1 - the top being most important and 10 - the bottom being the least out of this list)
Ability to change & learn (Including resilience, motivation & Tenacity
Analytical, Interpretation, Problem solving & Critical thinking
Business value analysis, mapping & strategizing
Creativity, Innovation & & Curiosity
Empathy & EQ (Emotional Intelligence
Envisioning, Business value analysis & mapping
Ethical adoption, Compliance & Legal
Maths/ STEM. Specialist technical skills
Relationship Mgr, Collaboration, Decision Making, Communication & Mgt
Specialist in depth knowledge – non-technical

Table 3-6 Round 2 updates following Round 1 responses Question 11.

This section has covered the considerations for deploying a Delphi method, the number of rounds and how participants were identified and invited to participate along with capturing the updates that were made across the rounds. To conclude this Delphi sub-section the final component will summarise the advantages and criticisms of the delphi method before moving into sub-sections which discuss the triangulation and interview approaches taken.

3.5.7 Advantages and criticisms of a Delphi method

3.5.7.1 Advantages of a Delphi Approach

The key advantages of following a Delphi method over a focus group or committee (Turoff, 1970) include; preventing consensus through individual domineering views. Enabling all participants to share their insights and perspectives freely and without fear of professional challenge or peer bias and domination, enables other views to be shared back to the panel in confidence. Wilson (1997) supported this view and referred to how people's responses may differ depending on whether they are deemed 'public' or 'private.' Other advantages of utilising a Delphi approach over other '*Nominal group techniques (NGT)*' (Loo, 2002) are; the removal of the logistical overhead of co-location to seek panel feedback, personality conflicts are avoided among panel, the researcher can build on previous round information to ensure research focus, enables mixed method approach to be used, which can increase validity and reliability through triangulation (Dootson, 1995; Loo, 2002; Bryman, 2006). Lastly it enables insight and data to be analysed on areas that are still maturing and lack historical data (Mitchell, 1992; Kosow and Gaßner, 2008). Whilst there are advantages to the Delphi Method, like all approaches there has been some criticism of the approach which are captured next.

3.5.7.2 Key criticisms of a Delphi approach

This section captures the key drawbacks along with mitigation for the identified criticism:

i. Panel Selection is small compared to Positivist approaches

   a. This criticism is addressed by aligning the Panel selection to the Research aim and objectives and having intentional and informed panel selection. The focus is on qualitative data and responses rather than high volume quantitative data which can over generalise. Due to the nature of this research a positivist approach was not appropriate due to the lack of quantitative data available and as presented above the focus is on quality of data rather than quantity.

ii. Panel consistency and response rates across the multiple rounds can be low

    a. This has been addressed through clear participation expectation setting and was presented through the briefing documentation which highlighted and communicated the criteria and commitment requirements for participants.

iii. Participation pressure to conform across rounds with other responses

    a. This was mitigated through the participant briefing notes and selection criteria to encourage participants to share their insight based on their own experiences and knowledge and personal opinion, furthermore the experts all had extensive working experience which typically provides a maturity of thinking and less likely to be swayed by group opinion (Taylor, 1975) and also the anonymity of participants removes pressure to conform, by being able to provide 'private' answers (Wilson, 1997).

iv. Validity concerns and challenges on results

    a. This criticism is addressed through the method of triangulation' *(Loo, 2002; Bryman, 2006)*. Utilising secondary data to inform the panel and follow up validation interviews after the Delphi study to clarify results and to enable respondent validation (Bazeley, 2013).

The details of the triangulation phase are set out in the next sub-section followed by a section on the interview approach that was adopted.

3.6 Triangulation phase

The triangulation strategy as part of a research method is to help validate the data and the interpretations taken from that dataset. Validating research is not a new recommendation, Campbell and Fiske (1959) stressed '*validity*' was key to accepting research, with it being, "*convergent, a confirmation by independent* *measurement procedures*" (Campbell and Fiske, 1959, p.81). This has been supported by the views of Mathison (1988) who advised that when evaluating the outcomes from a phase of triangulation there are three potential conclusions: '*convergence, inconsistency or contradiction*' (p.15). Along with providing validation of inferences from the data, triangulation helps build a rich picture which is advantageous when conducting exploratory research. Ussher (1999) highlighted the benefit of triangulating data through applying multiple methods, stating that, "*It demonstrates the limitations of taking a unilinear approach, be it qualitative or quantitative, as it is only when we put the different pieces of the jigsaw puzzle together that we see a broader picture and gain some insight" (Ussher, 1999, p.43)*. The application of triangulation as part of this research method is to help validate in line with Mathison's suggested outcomes and also to broaden the picture as described by Ussher.

When analysing the datasets from the Delphi rounds, a pattern emerged that triggered further questions, see section 4 for further details and a phase of triangulation was administered to check whether the data did indeed, '*converge,*' '*contradict*' or flag any '*inconsistencies*' (Mathison, 1988). In addition the validation outcomes triangulation was applied to build a picture of the participant demographic for this research and this was achieved by triangulation with the Standard Occupation Classification (SOC) (Office for National Statistics, 2010; 2020c), which validated the expert criteria against professional, technical and managerial roles established through the SOC. This is covered in more detail in section 4.1.3.

The triangulation activities looked at both qualitative and quantitative data sets and the follow up interviews were scheduled to validate the patterns that emerged from the analysis conducted. Due to the exploratory nature of the study and to help understand and interpret the responses (Huang,Wu and Chen, 2013) this research design included follow up interviews with participants. The interviews were part of the triangulation strategy and will be described in more detail in the next sub-section. When the second-round responses were reviewed a theme emerged which raised a further research question around the historical impact of technological change, one of technical unemployment. Keynes (1933) and Frey and Osborne (2017) captured that they believed technology would substitute and create unemployment across the workforce. The comments provided by some of the experts (question 13). prompted the need for validation, triangulating (Jick, 1979) the views presented of unemployment to date with the ONS Labour Force Survey that recorded the employment numbers across the United Kingdom. The findings of the triangulation phase are captured in section 4.2. When evaluating the Labour Force Survey data and specifically the employment rates further triangulation was required against the technological timeline. There was limited literature available that presented the technological advancements in chronological order, to understand the timings of the emergence of key technological change see appendix 8.26, which was created to enable further triangulation against the employment data to explore whether there were any trends aligning to the chronology of key technological changes, see section 4.2. Torrance (2012) articulated the benefits of triangulation as a key advantage to administering a mixed method over a single method approach,

> "*The assumption is that different perspectives can be generated, which will give a fuller and more informative picture of what is going on: Such fuller pictures will be more rounded, nuanced, and valid than that produced by a single method" (p.113).*

Acknowledging the value triangulation offers, further phases were administered as part of the analysis stage. To help establish a broader picture the future skills presented back in the questionnaires by the expert panel were triangulated with the US O*NET[4]. The O*NET is a US online database which provides open access to US occupational data including a '*Content Model*' which is described on the online O*NET site as being the, "*Anatomy of an occupation. Every occupation requires a different mix of knowledge, skills, and abilities, and is performed using a variety of activities and tasks. These distinguishing characteristics of an occupation are described by the* O*NET Content Model" (US Department of Labor, 2019). The US O*NET data was used to triangulate the skills data provided by the expert participants due to it being recognised as the global exemplar in occupational data (Peterson *et al.*, 2001). The O*NET provided information on the components of work, as depicted in Figure 3-6.

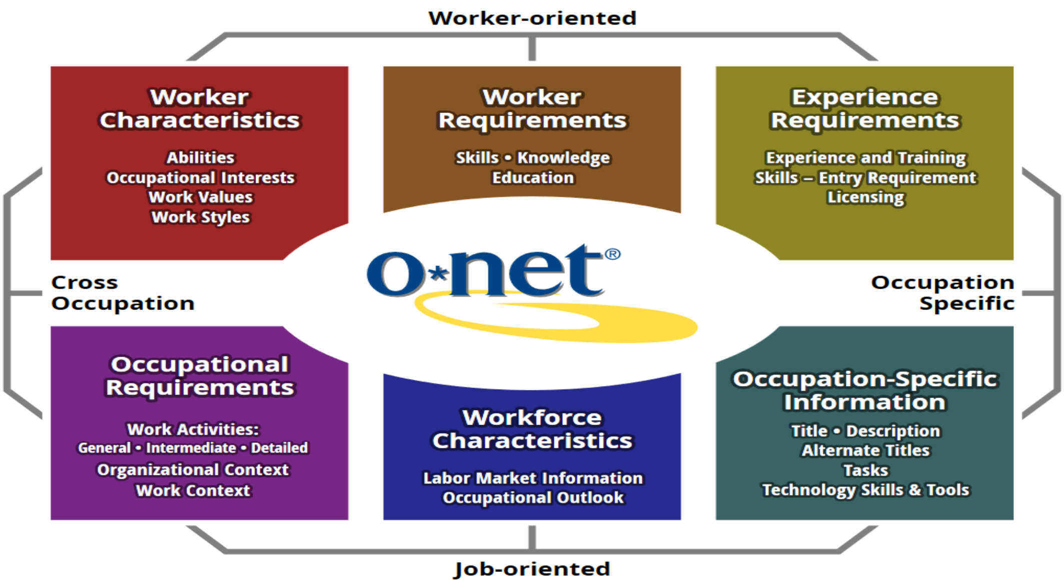

*Figure 3-6 The O*NET Content Model (US Department of Labor, 2019)*

Similar to the future skills, the questionnaires asked the expert participants their views on future jobs or occupations, the responses were triangulated with the UK Standard Occupational Classification (SOC) both the 2010 and 2020 version. This was completed to help establish whether the job roles presented by the experts were 'new' or whether they already existed within the existing UK standard. The

[4] https://www.onetcenter.org/content.html

findings of this triangulation activity can be found in section 4.2. The 2010 version was the active standard at the time of data analysis. The 2020 Standard was released for review and comment during the analysis stage. The Researcher was part of that review group and as part of that early draft triangulation was completed against the relevant components of the 2020 SOC in addition to the 2010 active version (Office for National Statistics, 2010; 2020c). Once published fully the 2020 Standard was further reviewed for any changes that may have affected the triangulation against the expert's responses, no further updates were required.

3.7 Interview Approach

As mentioned in the triangulation segment, follow up interviews were utilised to further validate and also explore further the emerging themes. The interviews were semi-structured in nature (Saunders,Lewis and Thornhill, 2012) to build on the data received from the delphi rounds. The objective of the interviews was to elicit further insight and opinion on the themes that emerged from the analysis conducted thus far and to help validate the researcher's findings from the previous stages. The benefit of using semi-structured interviews, over un-structured or structured interviews is that the interviewer/researcher can build and triangulate the information received through the delphi phase, whilst also enabling the expert interviewee freedom to share any additional thoughts and insights that they may have had. It also provided a mechanism for '*respondent validation*' (Bazeley, 2013), validating the patterns and themes from the previous stage of the research. The interviews were a mixture of in person and over video conferencing. All interviews were recorded from an audio perspective to assist with accurate transcription and to minimise distraction from the interviewer by excessive note taking. All interviews were transcribed and analysed as an individual data set (see 3.10 which describes the analysis approach). All data extracts were then analysed as a single data set. Following on from the analysis of the data collated from the

Delphi rounds and the triangulation activity, a theme of augmentation emerged. To further validate the emerging themes the semi-structured interviews (Saunders,Lewis and Thornhill, 2012) were scheduled with experts who had participated in the delphi study to explore and validate further the findings presented. The interview objectives identified and shared with the experts were as follows:

"*The Research aim is to explore future high-skilled professional work alongside Technological Change. The research interview objectives of this thesis are to explore:*

1. *The area of 'augmentation' where technology and the human worker could or do complement one another*
2. *The potential human capabilities/skills and requirements that would support future technological and human augmentation as part of future professional roles."*

Semi-structured interviews were utilised as they provided a 'non-standardised' approach (Cassell and Symon, 2004) which enabled the interviewer/researcher to vary the questioning based on responses given to help explore and drill into the discussion area. The interview approach acknowledged that expert interviewees would have different experiences and opinions based on their epistemology, working environments and experiences. The informal nature attributed to semi-structured interviews provided a relaxed environment and encouraged the interviewee to be open and share their views (Saunders,Lewis and Thornhill, 2012). The Semi-structured approach enabled the interviewer to set the scene with the interview objectives and structure the discussion at a high level in the two areas: augmentation and skills. Both are broad topics, so the interviewer listened carefully to responses provided and used exploratory questioning to expand on discussion points raised. Saunders, Lewis and Thornhill (Saunders,Lewis and Thornhill, 2012) confirm that "*Semi-structured and in-depth interviews provide you* *with the opportunity to 'probe' answers, where you want interviewees to explain, or build on their responses* " (p.378).

After the interviews, the interview recordings were transcribed using free software, 'Otter.ai[5].' The Software package was the basic free option, more advanced transcription options were available, for frugality the researcher utilised the basic package, which reduced the transcription time significantly. The Software transcribed the majority of the content accurately and the researcher manually went through the transcripts updating any transcription errors made by the software to validate and assure the transcripts. A list of the transcription updates is captured in the appendices (see 8.24). To further validate the interviews, the interviewees were sent a copy of their interview transcripts and asked to review and confirm that it was an accurate reflection that captured their views and opinions. This was carried out to further validate the information being captured which is seen as good practice (Torrance, 2012).

3.7.1 Interviewee selection/invitation approach

Interviewees were selected by evaluating the responses of the delphi rounds, specifically comments provided by the experts in relation to skills and augmentation type activities. The participants were flagged in an excel spreadsheet for potential follow up. One of the control questions in the delphi questionnaires was whether participants were happy to be contacted for a follow up interview. One of the limitations was the responsiveness of participants due to the professional demands on their time, whilst participants had flagged, they were happy to be contacted the response rate was particularly low. Out of twenty identified potential interview candidates', half responded and scheduling still proved challenging. Eight interviews were conducted and themes started to repeat

[5] https://otter.ai/

after the third interview. Rather than cancel the remaining five these took place to further evaluate saturation and no new themes emerged.

The target interview candidates were emailed thanking them for their participation in the Delphi rounds and asked whether they were still happy to participate in a follow up interview. Those that responded confirming their participation were then sent an Interview briefing paper, see appendix 8.22, and a link to an online Consent form, See appendix 8.23. All interviewees were asked to complete a consent form prior to their interview taking place. The consent form not only documented the required consent it also provided a mechanism to validate the level of experience and the industry exposure in line with the expert criteria previously captured in figure 3-5 (see section 3.5.3). The consent form also advised the interviewee that the interview would be recorded and transcribed and that they would be sent a copy of the transcription for validation and confirmation post the interview.

The next section provides a diagrammatic view of the end-to-end research design, the subsequent section describes the individual process steps in greater detail.

3.8 Research Design

The mixed method approach involved multiple phases to inform, collect, analyse, validate and interpret the data in accordance with the research aim and objectives. Figure 3-7 depicts the research design by phases, this is followed by table 3-7 that walks through the steps.

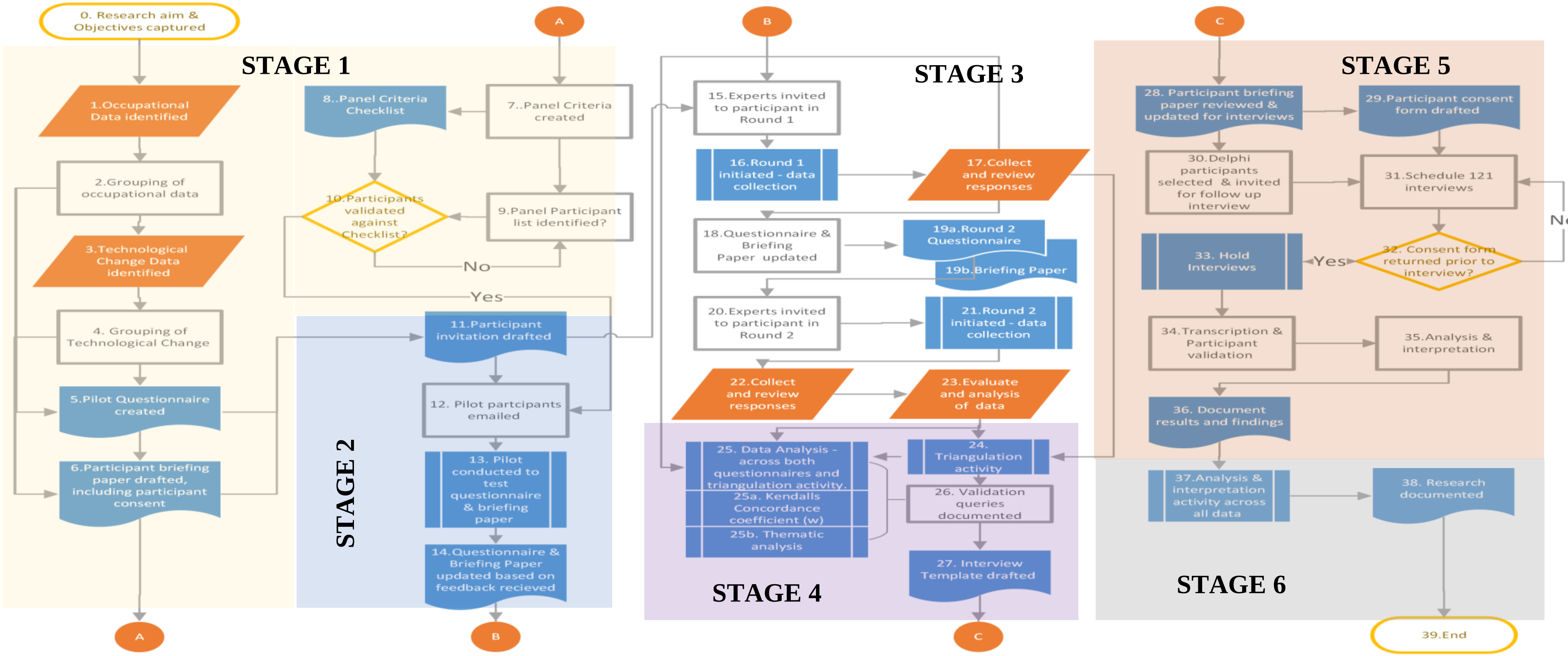

Figure 3-7 Research Process Flow

3.9 Design Procedure steps

Step #	Step title	Description	Inputs	Outputs
0.	Research aim & objectives captured	Through completion of an extensive literature review the research aim and objectives are capture	Literature Review	Step 1
STAGE 1 – Research Preparation activities				
1.	Occupational Data identified	With the assistance of the Data sources standard occupational data is identified for input into the Delphi questionnaire and to ensure occupational consistency	Data Sources (See Table 3-3)	Step 2
2.	Grouping of occupational data	Due to the volume and variability of occupation data, the data is grouped to a manageable number by placing occupations into job groups as an input to the Delphi Study and inclusion in the briefing paper	Step 1	Step 5 & 6
3.	Technological change Data identified	Collating output from the Literature review on technological change areas and identifying the technology areas and terminology	Data Sources (See Table 3-3)	Step 4
4.	Grouping of Technological Change	Key terms are documented to help clarify the term technological change as part of this research and is captured in the briefing document and initial questionnaire	Step 3	Step 5
5.	Pilot Questionnaire Created	The Delphi Questionnaire is created for an initial pilot stage, using Microsoft Forms. To test the flow and content of the questionnaire with a small number of pilot volunteers – validated against the panel criteria checklist (step 11)	Step 2 & 4	Step 6 & 11
6.	Participant briefing paper drafted, including participant consent.	Briefing paper for participants is created incorporating the pre-requisite information, participation instructions and required timescales along with a section on Data & Consent	Step 2, 4 & 5	Step 11
A				
7.	Panel criteria created	Due to Delphi study requiring knowledge and expertise on the area relating to the research question and objectives there is a level of experience/knowledge required to participate in the study – the criterion is captured. See section 3.5.3 for further information on panel selection	Step 6	Step 8 & 9
8.	Panel criteria checklist	A checklist document is created to drive consistent participation selection & validation	Step 7	Step 10

Step #	Step title	Description	Inputs	Outputs
9.	Panel participant list identified	A sample list of potential panel participants is drafted. This is compiled through professional and academic networks and where appropriate utilising social professional networking site, LinkedIn. A small number of participants are identified as potential pilot participants.	Step 7 See section 3.5.3 for further details on selection inputs	Step 10
10.	Participant validated against checklist?	The sample list is validated against the Panel checklist to ensure appropriate level of experience and knowledge for the target panel invitations	Steps 8 & 9	If yes Step 11 If no step 9 for the list to be updated
STAGE 2 – Pilot Delphi				
11.	Participant Invitation drafted	A draft message is compiled to invite a small number of identified people to participant in a pilot questionnaire. The draft message contains a request to take part in research exploring Future Professional Work and Technological Change through expert opinion. The message explains that the recipient has been identified as having expert insight and professional expertise that this research would like to collate for academic research and that this research would be confidential and anonymised. A copy of the briefing paper is attached to the message and a QR Code and hyperlink for them to access the Research Questionnaire if they would like to participant.	Step 5 & 6	Step 12
12.	Pilot participants emailed	Once participant validation, against the checklist (Step 10) is passed, a small target group of participants are invited via email to take part in an initial pilot phase. The email or LinkedIn private message is sent using the draft (step 11) for consistency.	Steps 10 & 11	Step 13
13.	Pilot conducted to test questionnaire & briefing paper	Participants in the pilot are asked to provide details on how they found the questionnaire and the briefing document. The feedback is collated, and the required updates made before issuing to a wider target	Step 12 Questionnaire results through	Step 14

Step #	Step title	Description	Inputs	Outputs
		audience for Round 1 completion. See section 3.5.4 for further details	MS Forms	
14.	Questionnaire & Briefing Paper updated based on feedback received	The documentation is updated in readiness for the Round 1 Delphi stage, see Appendices 8.14 & 8.15	Steps 13, 6 & 5	B Stage 3 – Delphi Study
B. STAGE 3				
15.	Experts invited to participate in Round 1	Following the tested approach in the pilot stage, participants are validated against the checklist (step 10) and invited to take part in the multi round Delphi Study. The standard message is utilised for consistency with an updated link, QR code and briefing document. The message also includes a request to complete the questionnaire within the response window. If they have any queries, they are asked to contact the researcher for clarification.	Steps 10 & 11	Step 16
16.	Round 1 initiated – data collection	The first round of the Delphi study is run. Participants are asked to complete the questionnaire and return by a target date; gentle reminders are sent to the panel to encourage completion against the timeline	Step 15	Step 17
17.	Collect and review responses	Responses are reviewed and the response rate monitored. MS Forms provides export to excel functionality so that data can be easily reviewed. The Tool also provides some basic analysis on quantifiable questions – response rates, against industry selections and a breakdown of the respondent demographic by experience. See Chapter 5 for further details	Step 16	Step 18 & 25
18.	Questionnaire & the Briefing Paper are updated	Incorporating the responses from round 1 the questionnaire is updated in the readiness for second round, this is in-line for standard Delphi practice – see section 3.5 for further clarification The Briefing paper is also updated to help participants with the updated Groupings See Appendix 8.16	Step 17	Step 19a &19b
19.	a. Round 2 Questionnaire &	Following the updates from Round 1 both the Round 2 Questionnaire & Briefing Paper both require updates.	Step 18	Step 20

Step #	Step title	Description	Inputs	Outputs
	b. Briefing Paper	The Questionnaire, See Appendix 8.17 made available through a new QR code and hyperlink is create and the Briefing paper is circulated to participants in the invitation for Round 2		
20.	Experts invited to participate in Round 2	The standard message from Round 1 is updated to thank them those that responded to Round 1 and inviting those that did not to have the opportunity to participate. The updated hyperlink, QR code and briefing document are included in the message. The message also includes a request to complete the questionnaire within the response window and if they have any queries, they are asked to contact the researcher for clarification.	Steps 19a & 19b	Step 21
21.	Round 2 initiated – data collection	The second round of the Delphi study is run. Participants are asked to complete the online questionnaire by a target date and gentle email reminders are sent to the panel to encourage completion against the timeline	Step 20	Step 22
22.	Collect and review responses	Responses are reviewed and the response rate monitored	Step 21	Step 23
23.	Evaluate and analysis data	The data is exported into a spreadsheet format for manual analysis.	Step 22	Step 24 & 25
STAGE 4 – Triangulation & Analysis				
24.	Triangulation activity	Initial evaluation of the Delphi rounds data presented a flag that historical impact was one of unemployment. The UK Labour Force Survey data was analysed alongside a technology timeline to triangulate across data received from the Delphi participants to validate the theme that was presented. Further triangulation was carried out to support the analysis of question 11 response in round 2 of the Delphi study – which focused on future skills, see section 4.1.10	Steps 17 & 23 Labour Force Survey Employment Data (See Section 4.2 for further details)	Steps 25 & 26
25.	Data Analysis – across both questionnaires & triangulation activity	The data analysis followed a mixed methods approach see section 3.4 which was primarily broken down into; 1. Quantitative analysis – Kendall's coefficient of concordance,	Steps 17, 23 & 24	Step 26

Step #	Step title	Description	Inputs	Outputs
		known as Kendall's W – See 25a and 2. Qualitative analysis – Thematic Analysis – See 25b A number of responses across the 2 Delphi rounds contained data that was more appropriate for quantitative analysis (see section 4 for further details) namely questions; 1,2,10,12(Round 1 only) 14(Round 1 only) & 15(Round 2 only)		
25a.	Kendall's Concordance Coefficient (W)	Questions 6 & 7 in the Delphi Round 1 questionnaire were suitable for analysis along with questions 6,7, & 11 in the Round 2 questionnaire		
25b.	Thematic Analysis	Responses for questions 5,8,9 & 13 for both Delphi Rounds along with question 11 in the Round 1 questionnaire required qualitative analysis, this was conducted using a Thematic Analysis approach see section 5 for details on the findings		
26.	Validation Queries documented	As a result of the analysis and triangulation a series of queries presented themselves which warranted further validation with the research participants – these were documented (See appendix 8.20) and fed into the follow up interviews	Steps 24 & 25	Step 27
27.	Interview Template drafted	The semi-structured interviews (See section 3.7) are initially led by the validation queries which form a high-level interview format for the researcher to follow as a guide. See Appendix 8.20).	Step 26	C – STAGE 5
C – STAGE 5 – Interviews				
28.	Participant briefing paper & reviewed & updated for interviews	The Briefing paper that was used for the Delphi Study is reviewed and updated to help brief the interviewees. (See Appendix 8.22 for a copy of the document).	Steps 27 & 18	Steps 29 & 30
29.	Participant consent form drafted	A consent form is drafted using Microsoft (MS) Forms – See Appendix 8.23	Step 28	Step 31
30.	Delphi participants selected & invited for follow up interview	Interview candidates are evaluated based on responses provided and whether they gave permission to be contacted for a follow up interview. Potential interviewees are contacted by the researcher asking them if they are still happy to be interviewed and what availability they have.	Step 28	Step 31

Step #	Step title	Description	Inputs	Outputs
31.	Schedule 121 interviews	In-depth one to one interview scheduled with selected Delphi participants (dependant on the data received). These are scheduled via email by the researcher. See section 3.7.1 for further details).	Step 29, 30 & 32	Step 32
32.	Consent form returned prior to interview	To ensure appropriate consent is in place and to check that interviewees understand the scope of the interview and also consent to be recorded for transcription purposes, it is mandated that the online consent form is completed and submitted to the researcher prior the interview.	Step 31	If Yes Step 33 If No Step 31 for reschedulin g
33.	Hold interviews	Interviews are held and recorded (with written consent from the participants see step 32) to clarify the theme of augmentation that was presented in the Delphi rounds along with exploring with the interviewees the key skills.	Step 32	Step 34
34.	Transcription & participant validation	All interviews are transcribed, and a copy sent to the interviewee for review and validation and confirmation requested that the transcript is a true reflection of the discussion that took place.	Step 33	Step 35
35.	Analysis & interpret results	The interview transcript data is analysed by following the thematic analysis approach and interpreted along with the Delphi data extracts.	Step 34	Step 36
36.	Document results & findings	The results from the multiple data extracts are documented	Step 35	Step 37
STAGE 6				
37.	Analysis & interpretation activity across all data	Further analysis is carried out on a single data set, which is made up of all the data extracts that have individually been analysed – bringing them together for a further analysis stage	Step 36	38
38.	Research documented	The research is documented as a doctoral thesis	37	39
39.	End	End of the Research data collection and analysis phase	38	-

Table 3-7 Research design process steps

The next section documents the overall analysis approach and the specific practices followed. The analysis techniques are determined by the data type, being a mixed method research study the data to be analysed is varied, the following section describes the data types and the corresponding analytical method.

3.10 Analysis Approach

A key consideration when determining an appropriate analysis approach is the type of research method adopted. A mixed method approach required multi-faceted analysis, the delphi study returned both quantitative and qualitative data, the triangulation activities similarly evaluated both quantitative and qualitative data and the validation interviews provided qualitative data through the transcripts. The type of research conducted is also a key factor, as an exploratory study a key goal is captured by Reiter (2017), "*by observing and analyzing reality from a new and different angle, we can expect to unveil previously hidden facets*" (p.139), this was achieved by critically evaluating and determining meaning from the data corpus or corpuses containing expert opinions and views. The data provided two high-level data sets for analysis, quantitative and qualitative.

Saunders, Lewis and Thornhill (2012) highlighted that "*Quantitative data in a raw form, that is, before these data have been processed and analysed, convey very little meaning to most people*" (p.472). The process of analysis Antaki et al. (2003) described as "*a close engagement with one's text or transcripts, and the illumination of their meaning and significance through insightful and technically sophisticated work*" (p.10). Table 3-8 captures the different data types returned by experts through the Delphi Questionnaires (see appendices 8.15 and 8.17 for the full list of questions) and the validation interviews along with how they were analysed.

The next sections describe the analysis methods captured in Table 3-8 in more detail. To help determine the data type the Saunders, Lewis and Thornhill (2012) quantitative decision tree was utilised and is depicted in figure 3-8. If the data was not quantitative it was classified as qualitative data which is more text based, commentary provided by the experts either through the Delphi questionnaires or the follow up interviews.

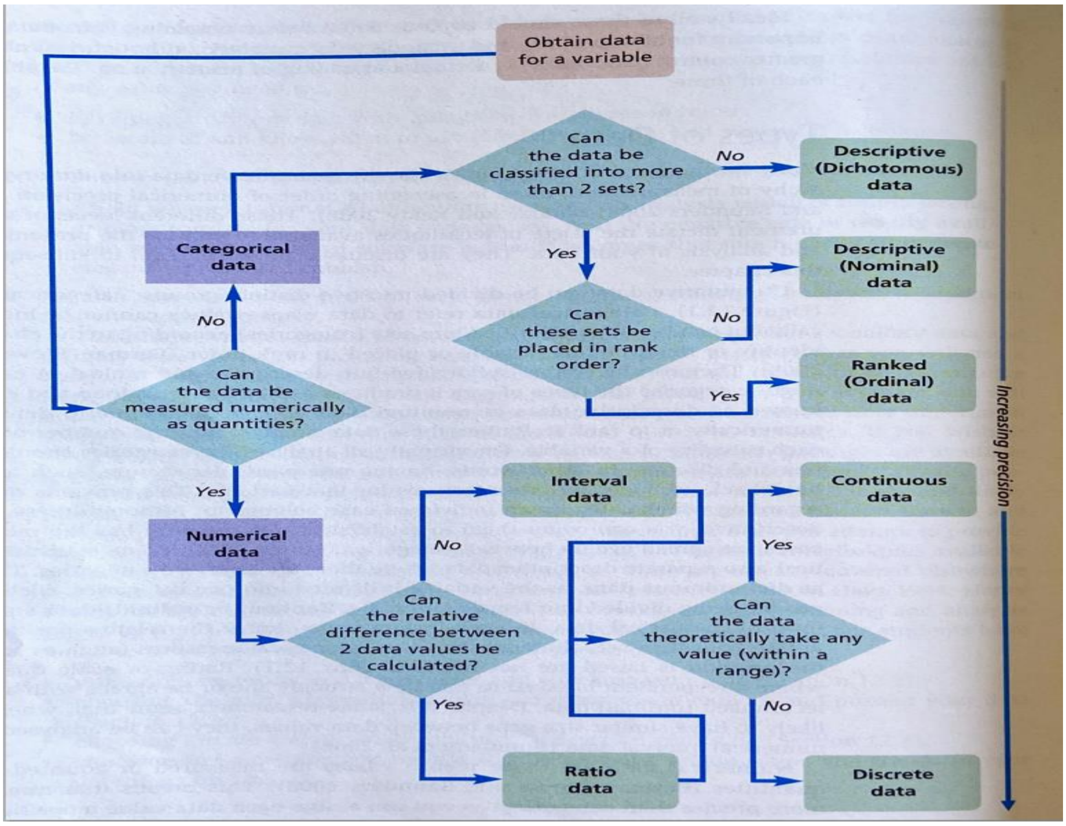

Figure 3-8 "Defining the data type" (Saunders, Lewis and Thornhill, 2012, p.476)

Research Area		Area being analysed	Data type	Data Analysis	Area being analysed	Data type	Data Analysis
⬇	**Specific Question or area**	**Round 1 Question / or data being analysed**	**Round 1- Data type**	**Round 1- Data Analysis**	**Round 2 Question / or data being analysed**	**Round 2 - Data type**	**Round 2 - Data Analysis**
Delphi Questionnaire number	N/a	Overall Participant breakdown	Quantitative, Numerical, discrete data	Calculated Central tendency & Dispersion	Participant breakdown	Quantitative, Numerical, discrete data	Calculated Central tendency & Dispersion
	1	Name - control question	N/a	N/a	Name - control question	N/a	N/a
	2	Industry or Sector	Quantitative – Categorical, descriptive, nominal data	Calculated Central tendency & Dispersion	Industry or Sector	Quantitative – Categorical descriptive Data	Calculated Central tendency & Dispersion
	3	Years work experience	Quantitative – Categorical ordinal data	Calculated Central tendency & Dispersion	Years work experience	Quantitative	Calculated Central tendency & Dispersion
	4	Existing or last Occupation	Qualitative	Control question	Existing or last Occupation	Qualitative	Control question
	5	Occupations created over the next decade	Qualitative	Thematic Analysis	Occupations created over the next decade	Qualitative	Thematic Analysis
	6	Ranking of Job role groupings up to 2025	Quantitative – Categorical, descriptive, Ranked (or ordinal) data	Kendall's W	Ranking of Job role groupings up to 2025	Quantitative – Categorical, descriptive, Ranked (or ordinal) data	Kendall's W
	7	Ranking of Job role groupings post 2025	Quantitative – Categorical, descriptive, Ranked (or ordinal) data	Kendall's W	Ranking of Job role groupings post 2025	Quantitative – Categorical, descriptive, Ranked (or ordinal) data	Kendall's W
	8	Any professional roles missing?	Qualitative	Thematic Analysis	Any professional roles missing?	Qualitative	Thematic Analysis
	9	Have any of your jobs been affected by TC?	Qualitative	Thematic Analysis	Have any of your jobs been affected by TC?	Qualitative	Thematic Analysis
	10	Scale of 1-10	Quantitative, Numerical, discrete data	Calculated Central tendency & Dispersion	Scale of 1-10	Quantitative, Numerical, discrete data	Calculated Central tendency & Dispersion
	11	List key skills	Qualitative	Thematic Analysis	Rank the key skills groupings	Quantitative – Categorical, descriptive, Ranked (or ordinal) data	Kendall's W
	12	Which sectors affected?	Quantitative – Categorical, descriptive, nominal data	Calculated Central tendency & Dispersion	Any skills missing?	Qualitative	Thematic Analysis
	13	Anything to add?	Qualitative	Thematic Analysis	Which sectors affected?	Quantitative – Categorical, descriptive, nominal data	Calculated Central tendency & Dispersion
	14	Follow up contact consent?	Quantitative – Categorical, descriptive, dichotomous data	Calculated Central tendency	Anything to add?	Qualitative	Thematic Analysis
	15	Email details for follow up	N/a	N/a	Follow up contact consent?	Quantitative – Categorical, descriptive, dichotomous data	Calculated Central tendency
	16				Email details for follow up	N/a	N/a
		Area being analysed		Data type		Data Analysis	
Triangulation Data	Employment Data	Last 15 years of Employment data by SOC Major Group triangulated with a timeline of technological events		Quantitative, Numerical, discrete data		Calculated Central tendency & Dispersion	
	SOC	Triangulation with Question 4 & 5 responses		Mixed		Thematic analysis to analyse the skills presented & Dispersion	
	O*NET	Triangulation with Question 11 (Round 1) & Question 12 (Round 2)		Mixed		Thematic analysis to analyse the skills presented & Dispersion	
Interview Data	Interview Transcripts	Interview transcripts		Qualitative		Thematic Analysis	

Table 3-8 Research analysis breakdown

3.10.1 Quantitative Data analysis

Quantitative analysis was utilised to create an initial picture of responses and to evaluate whether there was a level of agreement across the expert panel. The Delphi approach is a reliable and proven approach to glean expert opinion and insight to technological phenomenon, (Van de and Delbecq, 1974; Ray and Sahu, 1990; Ronde, 2001; White, 2017). Table 3-8 above sets out the types of data collated, to summarise under quantitative data there was numerical and categorical data collated. Descriptive statistics were used to calculate 'central tendency' and 'dispersion' (Saunders,Lewis and Thornhill, 2012) for comparison views along with Kendall's coefficient of concordance (w) to measure agreement across the expert panel responses.

3.10.1.1 Kendall's coefficient of concordance

Using the statistical formula in Figure 3-9 where 'W' provides a measure of 'concordance' which is a "*test of the agreement among sets of rankings,"(Vogt and Johnson, 2005, p.165).* This was applied to responses for questions 6 and 7 in both rounds and for question 11 in round 2.

$$W = \frac{12S}{m^2(n^3 - n)}.$$

W = *Coefficient of Concordance*

S = *is the sum of squared deviations,*
m = *is the number of expert responses*
n = *is the total number of objects being ranked*.

Figure 3-9 Kendall's 'W' Statistic (Coefficient of Concordance) (Legendre, 2010)

When analysing 'W' the following confidence interpretation was applied, see figures 3-10 and 3-11.

W	Interpretation	Confidence in Ranks
.1	Very weak agreement	None
.3	Weak agreement	Low
.5	Moderate agreement	Fair
.7	Strong agreement	High
.9	Unusually strong agreement	Very high

Figure 3-10 Kendall's 'W' interpretation table (Schmidt, 1997, p.767)

Schmidt's interpretation levels (figure 3-10) are similar to the values presented by Saunders, Lewis and Thornhill (2012). See figure 3-11 below.

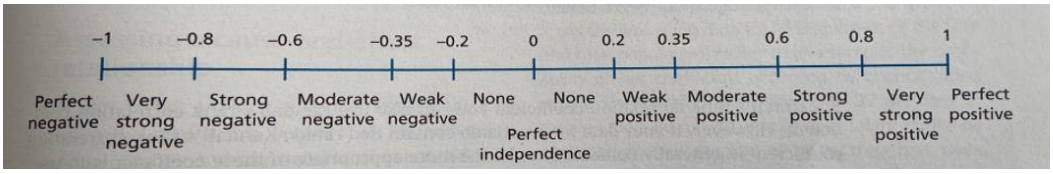

Figure 3-11 Values of correlation coefficient (Saunders, Lewis and Thornhill 2012, p.521)

In addition to applying Kendall's 'W' additional quantitative analysis was conducted on the Delphi data corpus. Descriptive statistics were calculated on the numerical data such as the '*Mode, Median and Mean'* to evaluate the '*central tendency*' along with analysis of data 'dispersion' (Saunders,Lewis and Thornhill, 2012). See Chapter 4 for further details.

3.10.2 Qualitative Data Analysis

As explained at the start of this section (3.5) some of the data captured was qualitative, across the delphi questionnaires, the triangulation and interview phases data were presented in multiple qualitative formats. These included:

i. Free format text responses through open questions in the questionnaires to elicit expert opinion on future foresight into potential occupations,
ii. Free format text responses through open questions in the questionnaires to elicit expert opinion on foresight into future skills,
iii. Free format text capturing of historical impact from participants,

iv. Free format text with general responses on the research topic for further insight gathering,

v. Comparison of responses from i. against the SOC data,

vi. Comparison of responses in ii. against the O*NET data

vii. Interview transcripts

The previous sub-section focused on representing the 'quantities' captured by this research data this sub-section is focused on the '*quality*' (Bazeley, 2013) and looking for themes from the expert responses from the qualitative data. Miles, Huberman and Saldana, (2018) captured that,

> "*Good qualitative data also lead to serendipitous findings and interrelationships. They help researchers get beyond initial conceptions and generate new understandings"* (Miles,Huberman and Saldana, 2018, p.3)

This approach is pertinent to meeting the research aim and objectives of exploring technical change and future work. This research design returned a large amount of unstructured qualitative data and to help interpret this a 'thematic analysis' approach (Braun and Clarke, 2006; Clarke,Braun and Lane, 2014) was followed to help understand the context and views of experts who had and were experiencing the technological change phenomenon. The following sub-section provides an overview of the approach.

3.10.2.1 Thematic Analysis

Thematic Analysis is an analytical qualitative method that has been extensively applied to qualitative research (Braun and Clarke, 2006; Thomas,White and Samuel, 2018; Throuvala *et al.*, 2019; Adekola and Clelland, 2020). The method through six steps aids the researcher to explore their dataset, exploring for themes in a flexible and immersive way. The six sequential steps are:

1) *"Familiarising yourself with the data and identifying items of potential interest*
2) *Generating initial codes*
3) *Searching for themes*

4) *Reviewing potential themes*
5) *Defining and naming themes*
6) *Producing the report"*

(Braun and Clarke, 2006, p.87)

The method's flexibility makes it ideal for exploratory research that follow a constructivist and interpretivist epistemology. '*Experiential Thematic Analysis (TA)*' "*Focuses on the participants' standpoint – how they experience and make sense of the world*" (Braun and Clarke, 2013, p.175) this matches the exploratory nature of the research aim and objectives set out in this thesis.

The data corpus contained a number of data sets. The data sets were the individual delphi responses to specific questions, such as questions 5, 8, 9, 11, 13 for round one and for round two they were, 5, 8, 9, 12 and 14. The interview transcripts also made-up discrete data sets. Following the TA process the data extracts were then re-evaluated as one additional data set and the six steps followed again to look for further themes and patterns emerging from the data. This additional data set was analysed to further explore the data as one and to look for empirical consensus or agreement across the qualitative data collected from the experts.

3.11 Ethics & Participant Well-being

Consent for the Delphi questionnaire was provided by completing the online questionnaire. Details of consent were shared with all Participants through the briefing papers (see 8.14 and 8.16) Figure 3-12 below captures the section. All participants were allocated a participant number, the participant number was allocated sequentially for Round 1 participants and this number stayed with them throughout the research. If a participant joined the research at the 2nd round, they were allocated a number prefixed with 200 based on their response number so as not to corrupt the Round 1 number allocation. Participant numbers were not shared with the Delphi participants to protect and ensure anonymity.

DATA AND CONSENT

All responses will be anonymous, any data collected will be attributed to a randomly selected participant number and no personal identifiable information will be published or shared as part of the research.

By responding to the questionnaire, you are providing consent to the researcher for your responses to be analysed and interpreted in line with the research aim and objectives.

If you have any questions about the storing or use of your responses, please contact the researcher for clarification.

Figure 3-12 Participant Consent section in Delphi Briefing paper

Due to this research asking questions relating to an individual's work, a control question, (question 9, see figure 3-13) was added to highlight whether a participant may have been affected by technological change previously.

9	Have any of your job roles been affected by technological change? If yes please describe the impact and when that was. If No please state No in the box

Figure 3-13 Question 9 Snippet from Delphi Questionnaires

This question was added to highlight whether there maybe sensitivities for the participant that should be considered if they had been impacted in a negative way, such as made unemployed or made redundant to avoid any unnecessary emotional distress to the participants, (Paul and Moser, 2009). Question ten also provided a way of gathering insight into whether participants who shared via question nine a negative experience were feeling negative about technological change. Question ten asked participants: "*On a scale of 1 to 10 to rate how you feel about the impact technological change will have on professional occupations in the future,"* see appendices 8.15 and 8.17. This information was captured to ensure that where a participant had shared a negative experience any additional distress was avoided.

For the follow-up one to one interviews additional consent was obtained prior to the interviews. This was to ensure interviewees were aware and agreed to the interviews being recorded. The consent forms also requested that participants committed to reviewing the transcript post interview to ensure accuracy and that the discussion points were captured correctly. Responses to question nine and ten were reviewed prior to any interview selection taking place to inform the interview selection process.

Appendix 8.13 contains a list of recommended Ethical Principles as defined by Saunders, Lewis and Thornhill (2012), all of which were considered and applied as part of this research. The subsequent section plots the timescales in which this research was conducted.

All data collected throughout the study was anonymised and no participant personal identifiable information shared with other participants or in any published findings. Interview transcripts were captured by Participant number and not individual names to safeguard the anonymity of participants.

3.12 Timescales

This doctoral research journey started at the beginning of 2017, with the identification of a high-level research area, the exploration of future work and advancing technology. After an initial literature review the area of future work was tailored to cover professional occupations. Initially this research aim was to focus on the area of AI however the initial literature review highlighted a picture of emerging technological change that was not isolated to AI and the research aim was clarified to include multiple emerging areas of technological advancements under the term ‘technological change.’ Technological or technical change is not a new term, although the definition of what it encapsulates does vary (Baltagi and Griffin, 1988; Acemoglu, 1998; 2002; Spitz-Oener, 2006) it is a consistent and acknowledged term, which is defined as part of the literature review chapter. Two years were spent evaluating the existing literature and understanding the methodological considerations. The output is captured in Chapters 2 and 3.

The target population was identified throughout the literature review and methodology scoping phases, utilising the researcher's professional network, which is across industry and spanning a twenty-year career in public and private sectors and working in the professional services and technology sector. In addition to the researcher's professional network LinkedIn posts were used, requesting professional volunteers to participate in a future work study. Through interactions the researcher shared the research study soliciting support and willing participants with the appropriate expertise as defined in the earlier section, 3.5.2.

The Pilot questionnaire was run in May 2019 to five willing expert participants (from the Target population) who were asked to test the format and clarity of questioning along with the online accessibility of the questionnaire. Feedback was received and the questionnaire updated, section 3.5.1 contains details of the changes made.

The Round one questionnaire was issued in June 2019 and open for one month to the target population. See Appendix 8.15 for a copy of the Delphi Round 1 questionnaire.

During July, 2019 the Round one responses were evaluated and the Delphi round two questionnaire and briefing paper updated accordingly, see section 3.5.5 for a list of updates made for Round two questionnaire.

The Round two questionnaire was issued in August 2019 and open for one month to the target population. See Appendix 8.17 for a copy of the Delphi Round two questions.

As part of the thematic analysis (TA) approach (Clarke, Braun and Lane, 2014) the first stage is to familiarise yourself with the data. Due to the volume of data collated across the two Delphi rounds this initial step took two weeks to complete, averaging approximately thirty hours per week, a total of sixty hours of initial familiarisation. (See Appendix 8.18 for a photograph of the familarisation maps). In addition to this the coding and statistical modelling using Kendall's (w) coefficient of concordance was applied to responses for questions six and seven for round one and two and also question eleven for round two, which took a further week, approximately thirty to thirty five hours of coding, modelling and analysis for these datasets.

As part of the familiarisation stage a theme of technological unemployment emerged which triggered the triangulation (Jick, 1979) of quantitative data relating to UK employment data by occupation (Office for National Statistics, 2019) to evaluate whether there had been a wave of unemployment which some participants believed had happened and emerged through responses to question thirteen. The triangulation included reviewing the last fifteen years of UK employment data by SOC major groupings and analysing for fluctuation patterns. Further triangulation was required against this data once the thematic analysis stages had been completed to conduct a holistic review of all data sources and evaluate against the research aim and objectives.

A further four weeks (thirty to thirty five hours per week) was spent building on the familiarisation of the data, thematic analysis stage one to six, with the findings report being stage six for questions five, eight, nine, twelve and thirteen alongside the analysis carried out on questions six, seven and eleven (round two). The analysis involved triangulating the responses across the questionnaire to look for further patterns and themes. Analysis was also carried out in between the Delphi rounds specifically for question eight and eleven in round one which enabled round two job groupings and skill groupings to be updated and presented back to participants, based on the insight obtained from the expert panel in round one which is in line with the Delphi approach (Rowe and Wright, 1999, White, 2017).

Question five explored what professional or technical occupations the expert responders' thought could be created over the next decade. The responses were triangulated against the SOC 2010 and the draft SOC 2020, Major grouping two (MG2) – Professional Occupations which was released to a review group in October 2019, of which the researcher is part of, the 2020 SOC is subject to change. The early visibility of the pending SOC enabled further insight into new roles recognised by the Government body since the 2010 standard was issued. A draft of Major Grouping three (MG3) which captured 'Associate professional and technical roles' was released in February 2020, the researcher reviewed the 2020 SOC when it was officially published in February 2020 and cross checked it against question five responses as part of this research analysis approach.

When evaluating the responses to question twelve in round two, the existing literature and standards on defining workplace skills were revisited. There was consensus that the US O*NET was the exemplar and recognised as an international authority on what constitutes the constituent parts of a workers occupation or job role (Bakhshi *et al.*, 2017, Dickerson and Wilson, 2017, Fowler and Siekmann, 2017). The skills presented through the expert panel responses were then coded and themed in line with the O*NET framework using Thematic Analysis (Clarke, Braun and Lane, 2014).

From September 2019 to January 2020, eight follow up interviews were conducted, these were transcribed quickly and the same day as the interviews utilising online software to expedite the transcription and shared with the interviewees as a priority following the interviews for validation and confirmation of the account of the discussion. This was also done to ensure accurate transcription whilst the discussion was clear and fresh in the mind of the interviewee and interviewer.

From January 2020 to April 2020 further analysis and interpretation was carried out on the data corpus, and further concept maps were compiled using mind mapping software to create a more holistic picture of the themes and quantitative data analysis. In parallel the thesis chapters were being compiled, capturing the methodology and an earlier literature review summary that informed the research aim and objectives.

In April through to July 2020, the literature review was refreshed, building in updates that had been published since mid-2018, 2019 and in the early part of 2020.

Figure 3-14 overleaf captures a diagrammatic view of the research timeline described above.

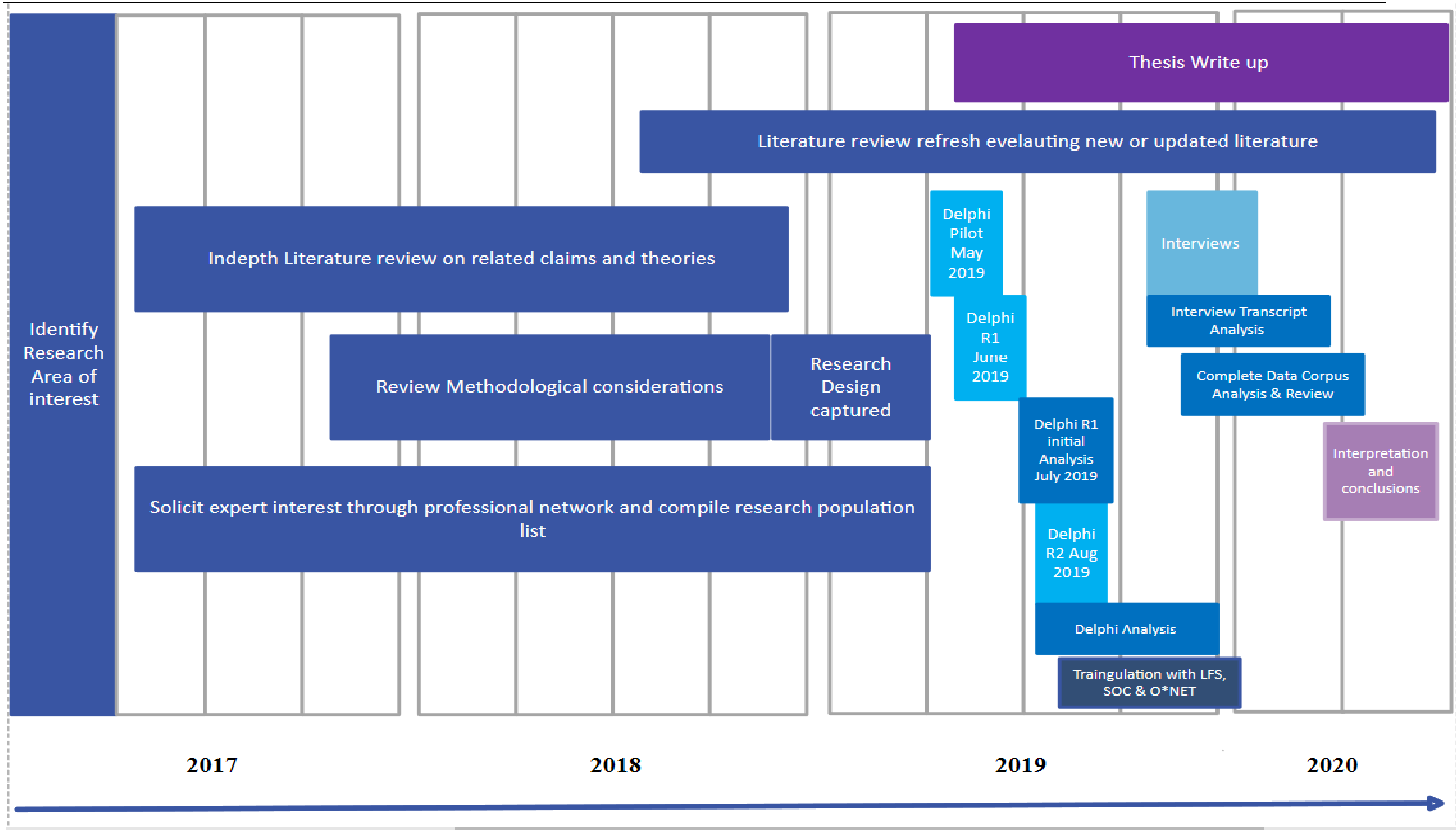

Figure 3-14 Research Timeframe

3.13 Research Limitations

The key limitations and consideration for this research were identified as follows:

3.13.1 Response rates and consistency of responses across rounds

A key consideration in a Delphi study or any survey-based research is the accessibility to participants and response rates (Turoff, 1970). White (2017) acknowledged this and highlighted the limitation and supported the view of follow-on interviews to help acquire further information from relevant participants, enabling a richer response from those that do respond. Other options to mitigate the limitation included identifying a larger sample of participants to achieve sufficient responses to enable expert insight and knowledge against the research questions being achieved.

3.13.2 Timeframe

A further consideration is the duration of the study, due to the approach requiring multiply rounds to gather data, the researcher needed to mitigate this by orchestrating and having a clear plan for executing the data collection phases which also supported the mitigation of limitation 3.13.1

3.13.3 Expert Panel Identification and selection

Experts were identified through professional channels to maximise the breadth of expertise across industry to minimise any industry bias and to acknowledge the variability across sectors. Accessibility to professional people was a limitation due to their busy schedules. This limitation was mitigated by articulating upfront with panel experts the ask of time and explaining the research aim succinctly to secure their commitment to the research and to help with prioritisation of their valuable time.

This draws an end to Chapter 3 which has set out the Methodological considerations and how and when this research was conducted. The next chapter describes the findings and analysis output from the application of the details contained in this chapter. Following on from chapter 4 Analysis and Findings, the subsequent chapter is 5 Discussion, which builds on the analysis and findings and discusses the findings for this research detailing the interpretations and linkage back to existing literature. Lastly chapter 6 concludes the thesis articulating the contribution to knowledge, theory, method and practice provided by this empirical research along with areas identified for further research and consideration.

4 Analysis & Findings

This section captures the output from the implementation of the research design outlined in section 3.8. Due to the nature of a delphi study analysis was required after round one to inform and represent back to participants in the second round. Further analysis was conducted after completion of the second round along with a triangulation activity, which was triggered by an emergent theme. The triangulation involved reviewing historical quantitative data to validate whether the workforce data corroborated an expert opinion of technological unemployment. This chapter is arranged in four sub sections; the first captures the analysis and finding from the Delphi stage; the second the triangulation analysis and findings and thirdly the analysis and findings from the follow up interviews. In addition to the three main sections there is a chapter summary which consolidates the analysis and findings and encapsulates the outcomes to feed into the last two chapters, Chapter 5, Discussion and Chapter 6, Conclusion. (For details on the analysis approach see section 3.10).

4.1 Delphi Study

The Delphi questionnaire contained fifteen questions in round one and sixteen in round two (see appendices 8.15 and 8.17 for a copy of the questionnaires) this section is broken down into a further thirteen sub-sections to articulate the results against each of the questions and the synopsis that captures the key themes and findings from the delphi stage of the research, along with areas that required further exploration. The first sub-section evaluates the participant demographic and response rates.

4.1.1 Participant breakdown

Out of a target population of 170 identified experts (see section 3.5.2) the following response rates were achieved. Round one had a 42% response rate and the second round achieved 48%. For a Delphi study these are high positive rates (Rowe and Wright, 1999; White, 2017) and the consistency of responders was encouraging with 58 of the 72 responders in the second round also contributing to the first, establishing a 81% return rate for round two. Table 4-1 below provides a summary of the response rates. An online form was used to issue and collate responses and the ease of the interface is one possible reason for the high response rate, with participants being able to respond through multiple channels: mobile device, laptop, tablet or desktop machine. The researcher adopted three stages of follow up with the target population, with two reminders being sent to all of the target population and a personalised message to those that had responded to the first round thanking them for their input and reminding them of the value of their insight through the second round. This approach is believed to have contributed to a positive response rate across the two rounds.

Participant Description	# of Experts	%
Target population - People who were asked to respond across both rounds	170	100%
Pilot Round	5	3%
Round 1 participant	72	42%
Round 2 participants	82	48%
Round 1 participants that also responded to Round 2	58	34%
Round 2 new participants (did not complete Round 1)	24	14%

Table 4-1 Delphi Response rates

Additional analysis was conducted on the gender representation within the panel. Figures 4-1 and 4-2 capture the gender split across each round.

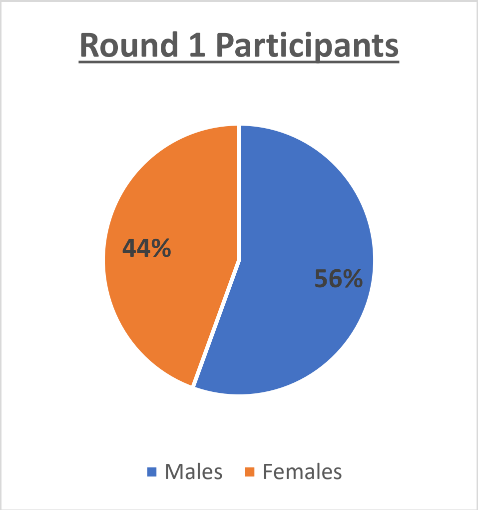

Figure 4-1 Round 1 Participant gender breakdown

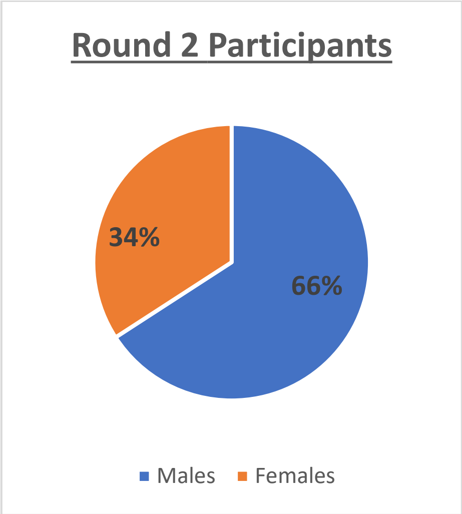

Figure 4-2 Round 2 Participant gender breakdown

Given the industry and sector gender ratios, this is a representative mix of professional experts in the current job market (Office for National Statistics, 2019) across the major occupational groups 1,2,3 & 8.

4.1.2 Control questions

The questionnaires included several control questions to help evaluate the experience and the validity of the participant's ability to be deemed an '*expert*' (Skulmoski,Hartman and Krahn, 2007) and to help provide insight into some of the responses provided. Questions two to four captured the participant's experience both in terms of duration and industry sector along with their existing job title.

Question three asked participants to select one of four experience groups that captured their cumulative work experience across all sectors. The responses showed that 90% of participants had more than ten years' experience. With 78% having more than sixteen years' work experience. The participants who had less than or equal to ten years' experience were invited by the researcher due to the professional exposure they had in their roles, they worked in a specialist area which enabled insight into technological capability for the future, such as requirement profiling with large organisations to help build out use cases for solutions driven by the latest technology, incorporating AI and machine learning for example. Figure 4-3 captures a diagrammatic view of the experience profile.

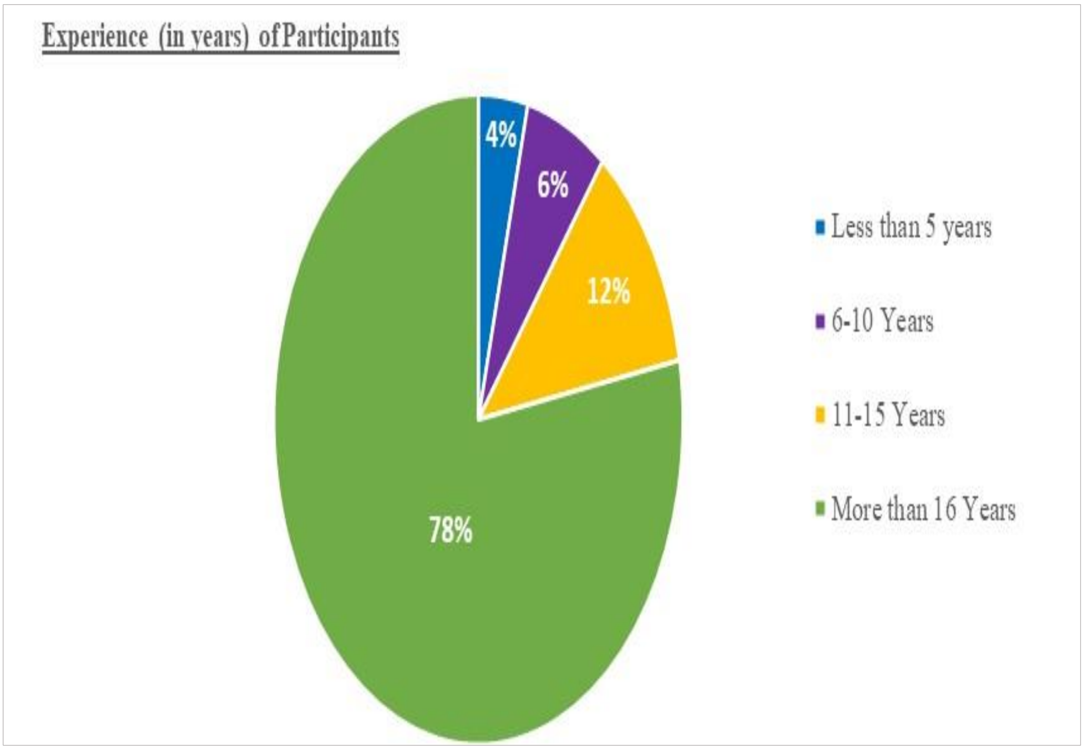

Figure 4-3 Participant experience (in years)

Across the 154 participants (for both rounds) the expertise covered multiple industries. The biggest area of expertise was in the technology sector, which was intentional to help gain insight into the emerging technological change and the adoption being observed or planned. Figure 4-4 shows the percentage breakdown provided by the participants across both rounds and participants were asked to capture all sectors that they had worked in. The multi-sector experience across the expert panel provided a broad view of knowledge in relation to the technological change adoption and use cases being explored across industry.

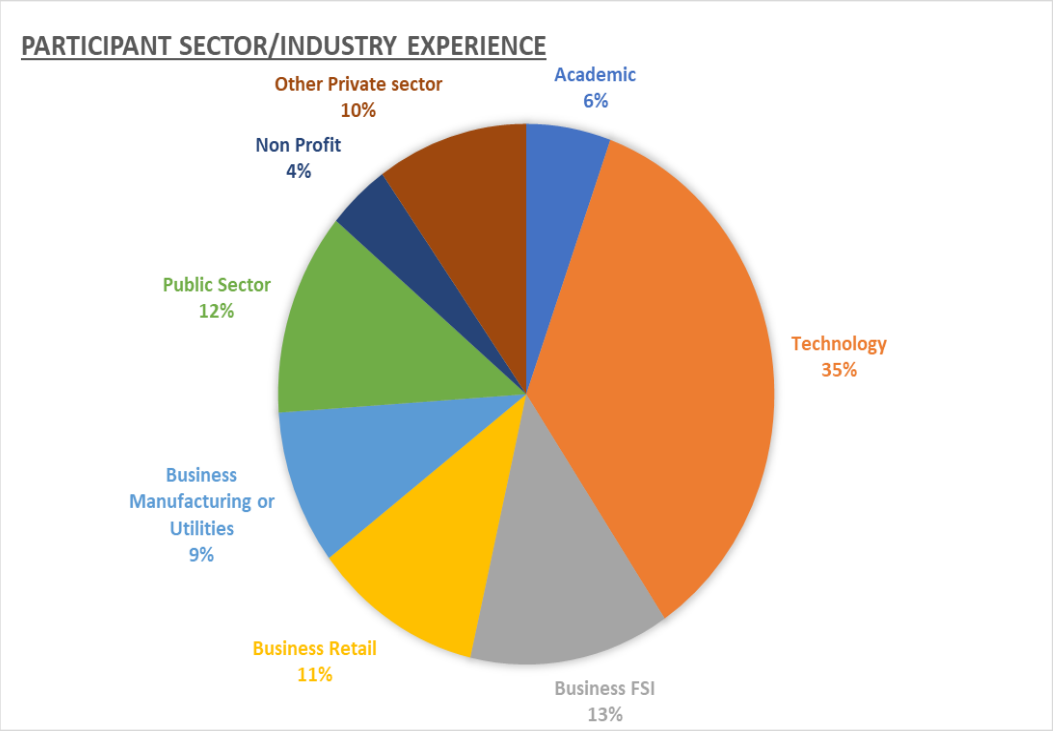

Figure 4-4 Participant industry experience pie chart

4.1.3 Question 4

Question four captured the participant's occupation, that could be their current or last occupation if they were not currently working. This was then triangulated with the Standard Occupation Classification (SOC) 2020 version (Office for National Statistics, 2020c) to validate that the panel came from the required target population, namely roles that were within the SOC Major groups 1, 2 or 3. This mapping along with question three which captured the participants work experience in years helped validate the expert credibility of the participants. Figure 4-5 below shows that all of the participants were employed or had been employed in occupations that were classified by the 2020 SOC as Major group 1, 2 or 3. The definition for each of these groups is show in Table 4-2.

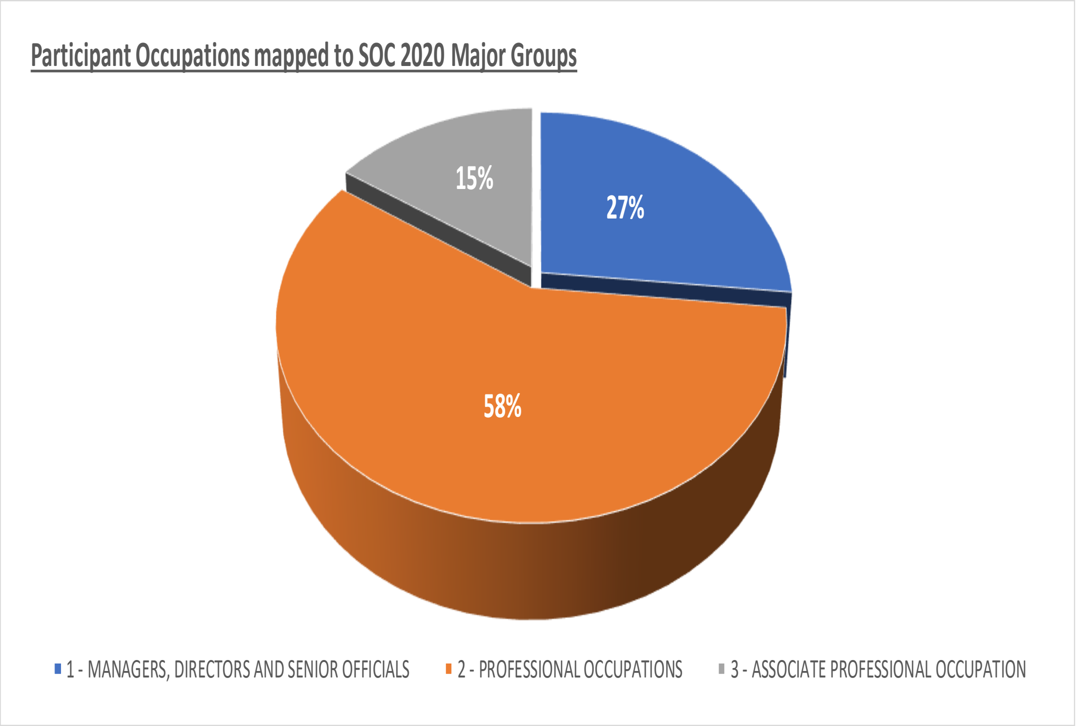

Figure 4-5 Participant occupation mapping to SOC2020

SOC 2020 Group Title	Groups Classified Within Sub-Groups	Group Description
1 Managers, directors and senior officials	Occupations in this major group are classified into the following sub-major groups: 11 Corporate managers and directors 12 Other managers and proprietors	This major group covers occupations whose tasks consist of planning, directing and coordinating resources to achieve the efficient functioning of organisations and businesses. Working proprietors in small businesses are included, although allocated to separate minor groups within the major group. Most occupations in this major group will require a significant amount of knowledge and experience of the production processes, administrative procedures or service requirements associated with the efficient functioning of organisations and businesses.
2 Professional occupations	Occupations in this major group are classified into the following sub-major groups: 21 Science, research, engineering and technology professionals 22 Health professionals 23 Teaching and other educational professionals 24 Business, media and public service professionals	This major group covers occupations whose main tasks require a high level of knowledge and experience in the natural sciences, engineering, life sciences, social sciences, humanities and related fields. The main tasks consist of the practical application of an extensive body of theoretical knowledge, increasing the stock of knowledge by means of research and communicating such knowledge by teaching methods and other means. Most occupations in this major group will require a degree or equivalent qualification, with some occupations requiring postgraduate qualifications and/or a formal period of experience-related training.
3 Associate professional occupations	Occupations in this major group are classified into the following sub-major groups: 31 Science, engineering and technology associate professionals 32 Health and social care associate professionals 33 Protective service occupations 34 Culture, media and sports occupations 35 Business and public service associate professionals	This major group covers occupations whose main tasks require experience and knowledge of principles and practices necessary to assume operational responsibility and to give technical support to Professionals and to Managers, Directors and Senior Officials. The main tasks involve the operation and maintenance of complex equipment; legal, business, financial and design services; the provision of information technology services; providing skilled support to health and social care professionals; and serving in protective service occupations. Culture, media and sports occupations are also included in this major group. Most occupations in this major group will have an associated high-level vocational qualification, often involving a substantial period of full-time training or further study. Some additional task-related training is usually provided through a formal period of induction.

Table 4-2 Standard Occupation Classification Definitions Major Groups 1,2,3 (SOC) (Office for National Statistics, 2020c)

4.1.4 Question 5

Question five in the questionnaire asked participants, "*What professional or technical occupations could be created over the next decade as a result of AI related technological change?"* The 154 responses yielded 434 job roles which were initially coded using a thematic analysis approach (Clarke,Braun and Lane, 2014), see section 3.10.2.1. The coding was then triangulated with the UK Standard Occupation Classification (SOC) 2010 and 2020 versions (Office for National Statistics, 2010; 2020a). This triangulation was carried out to explore whether the roles that the expert participants had put forward already existed as a role. Table 4-3 captures the occupational themes that emerged from the 434 job roles that were presented by the expert panel. 402 roles were derived from answers to question 5 and 32 from answers provided to question 8. There were several patterns that emerged in relation to the type of jobs presented. Specialist roles featured predominantly along with compliance type roles with a focus on Ethics and governance. Readiness, augmentation along with management and leadership roles were also recorded. The demand for specialist roles, was captured across multiple industries. The roles in relation to augmentation with technology captured the need for '*human centricity*' and a specialist need. For example, Participant 42 provided the following job roles:

> *"Customer-language tone and dialect translators, Machine learning trainers, AI Security engineers and forensic analysts, AI Explainers using techniques like LIME (Local Interpretable Model-Agnostic Explanations) Data Scientists, Ethics consultants, Context designers for AI Business use case."*

These roles are specialist roles that include technical and human centric considerations, business value contextualisation, language specialism, mathematics, engineers and developers and humanitarian compliance or wellbeing. Many of the roles identified included a focus on human centricity, augmenting the softer skills such as empathy and protecting human well-being through social care with the development or application of technology through software programs or robotics.

The majority of the 434 roles exist within the SOC2020 and were located through the coding index, it should be noted that the SOC provides groupings and the groupings have a '*catch all*' type entry, for example, under Information Technology Professionals (sub group 213) there is a unit group of, "*Information technology professional n.e.c.*" (Office for National Statistics, 2020a). One role or job grouping that stood out as not being mapped to a single entry in the SOC related to machine learning roles and augmentation or interface roles that were put forward by the panel participants.

The role themes that emerged from this data set were: '*Augmentation, Compliance, Industry Specialist, Management/Leadership, Operational, Readiness and Social Care.'* When looking across the data at the reoccurring themes, there was an element of human centricity that was captured and a pattern for specialists, along with management and leadership roles which cut across a variety of areas (see the highlighted fields in Table 4-3). These ranged from health specialists such as psychologist, surgeons and doctors to technology and data specialists across all industries. Other specialist areas were scientists and engineers. There was a theme of role merging, biologists and technologist for example, bio-engineers, mechanical engineers that utilised robotics with behavioural science such as linguistics and visual recognition programming, Nanobots and machine learning roles that bring statistician and programming roles together, and data scientists that marry up industry business knowledge with data analytical skills. Whilst many of the roles presented through the Delphi responses were captured in the SOC 2020 version, there was a pattern of context and business or industry knowledge being applied to the roles. Data Analyst or scientist could have multiple variants depending on the industry or specialism that it is being applied to. Participant 63 stated:

> "Citizen Data Scientists - people who understand how to get value out of data by understanding the opportunity that bringing data and technology together can provide."

Another area of augmentation was around the transition and readiness activities, Participant 233 quoted,

> "Social engineers, especially working on the impact of transition into an AI driven world on the workforce."

	Defined Role theme							
	Augmentation	Compliance	Industry Specialist	Management /Leadership	Operational	Readiness	Social Care	Grand Total
Initial Role Theme:								
Augmentation	2							2
Compliance		13						13
Coordinators				1	1			2
Creativity			6	3				9
Ethics		52		1				53
Governance		29		1				30
Human Centric	18		4	7	1	2	12	44
Leadership				6				6
Manager				11				11
Operations		1			5			6
Readiness	1					38		39
Specialist	16	7	167	7	12		4	213
Value Add	1		5					6
Grand Total	38	102	182	37	19	40	16	434

Table 4-3 Breakdown of coded job roles from question 5

Of particular interest was the focus on ethical compliance that emerged from the responses. Many participants captured ethical roles as being required, responses included,

> "*Ethics Officer*" (Participants, 4, 12, 35, 46, 51,59 and 233)
> "*Ethics Lead*" (Participant 222)
> "*Ethical authority roles*" (Participants, 26, 215, 20)

> *"Ethics Board roles"* (Participants, 33,50 and 60)
> *"Ethics Roles"* (Participants, 8, 27, 31, 48, 64, 220 and 238) and lastly
> *"Ethics Consultant"* or *"Specialist"* (Participants, 37, 40 and 42).

There was also a large concentration of specialist roles highlighted. These were roles that required specialist skills or training and the following graph, figure 4-6 provides further details on the specialisms captured. Key specialisms related to *'Data Specialists,' 'Programmers/Software Developers'* (which included machine learning) and *'Technology Specialists.'* Other concentrated areas included the '*Business specialist'* and '*engineering.'*

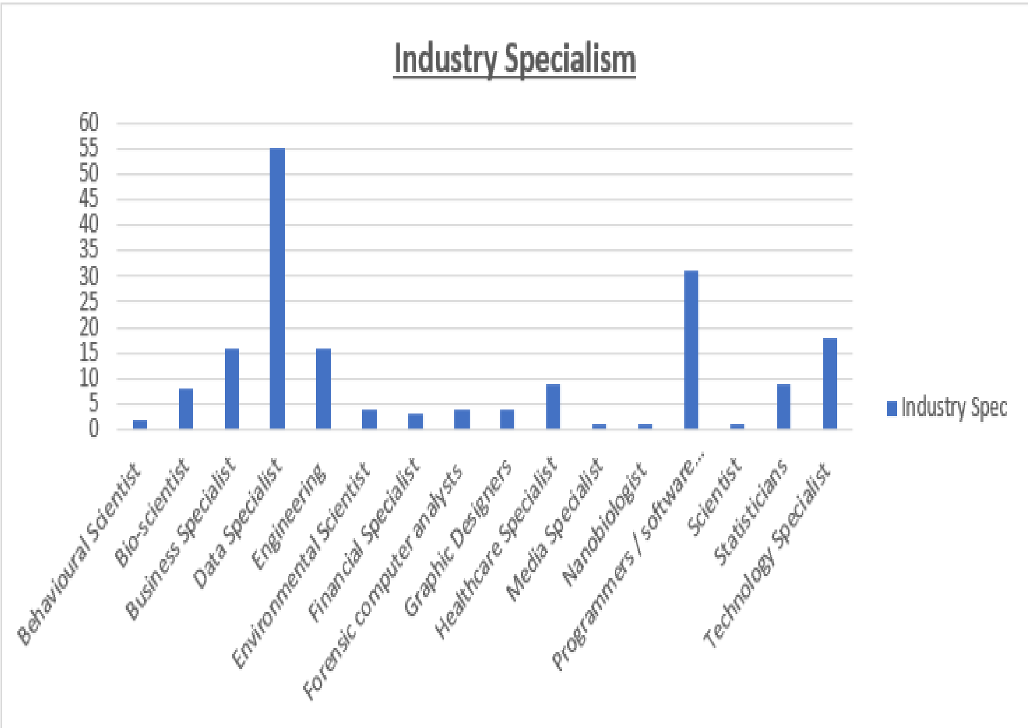

Figure 4-6 Question 5 Industry specialism details.

It was also observed that Machine Learning roles were not captured specifically in the 2020 SOC. The role of Programmer and Software developer was identified along with a Statistician. When evaluating an online a definition for a Machine Learning Specialist or Engineer (see Appendix 8.19) the role stipulates that it may crossover with other disciplines, and lists them as being: "*computational statistics;*

mathematical optimisation; data mining; exploratory data analysis and predictive analytics" (Prospects, 2020). This is an example of where a role augments across multiple occupational groups.

4.1.5 Question 6 & 7

Question six asked the expert panel, to stack rank ten occupation/job role groups and place them in order of importance alongside technological change between now and 2025. Question seven asked participants to stack rank the same list but this time considering the importance post 2025.

When analysing the concordance or consensus across the responses for questions six and seven in round one the following results were obtained, '*W*' was equal to 0.28 for both questions six and seven. There was some increase in the second round of the study supporting the view of greater consensus across the participants compared to the first round, with 'W' increasing to 0.33 for question seven, and a slight increase on question six to 0.29. A calculation of 0.1 would indicate a very weak agreement and 0.3 a weak agreement (Schmidt, 1997). Further analysis was conducted on the data to evaluate whether there was a higher level of consensus by gender. There was a higher consensus with the male participants in comparison to the females when ranking the job groupings across both question six (up to 2025) with males participants, '*W*' equaled 0.33 for round one and 0.31 for round two, in comparison to female participants with 0.26 (round one) and 0.29 (round two).

Question seven (post 2025) saw a similar gap with males and females in round one, males at 0.3 and females lower at 0.27, however there were signs of convergence in round two with males at 0.34 and females 0.33. Tables 4-4, 4-5 and 4-6 provide a breakdown of the analysis.

Round 1 Question #	6	7
Round 1 'W' calculation (All)	0.28	0.28
Round 1 'W' calculation (Males only)	0.33	0.30
Round 1 'W' calculation (Females only)	0.26	0.27

Table 4-4 Participant concordance metrics for Round 1, Question 6 and 7

Round 2 Question #	6	7
Round 2 'W' calculation (All)	0.29	0.33
Round 2 'W' calculation (Males Only)	0.31	0.34
Round 2 'W' calculation (Females Only)	0.29	0.33

Table 4-5 Participant concordance metrics for Round 2, Question 6 and 7

Changes Between Round 2 compare with Round 1	6	7
Difference All	0.01	0.05
Difference Males	-0.02	0.05
Difference Females	0.03	0.06

Table 4-6 Round 1 and 2 comparison of concordance metrics Question 6 and 7

Using Saunders, Lewis & Thornhill's scale of agreement (2012, p.521) the calculations are plotted in figure 4-7 and shows the agreement level across all participants went up slightly in the second round for both questions. With female agreement levels increasing for both question, whilst the agreement amongst male responses for question six decreased and increased for question 7.

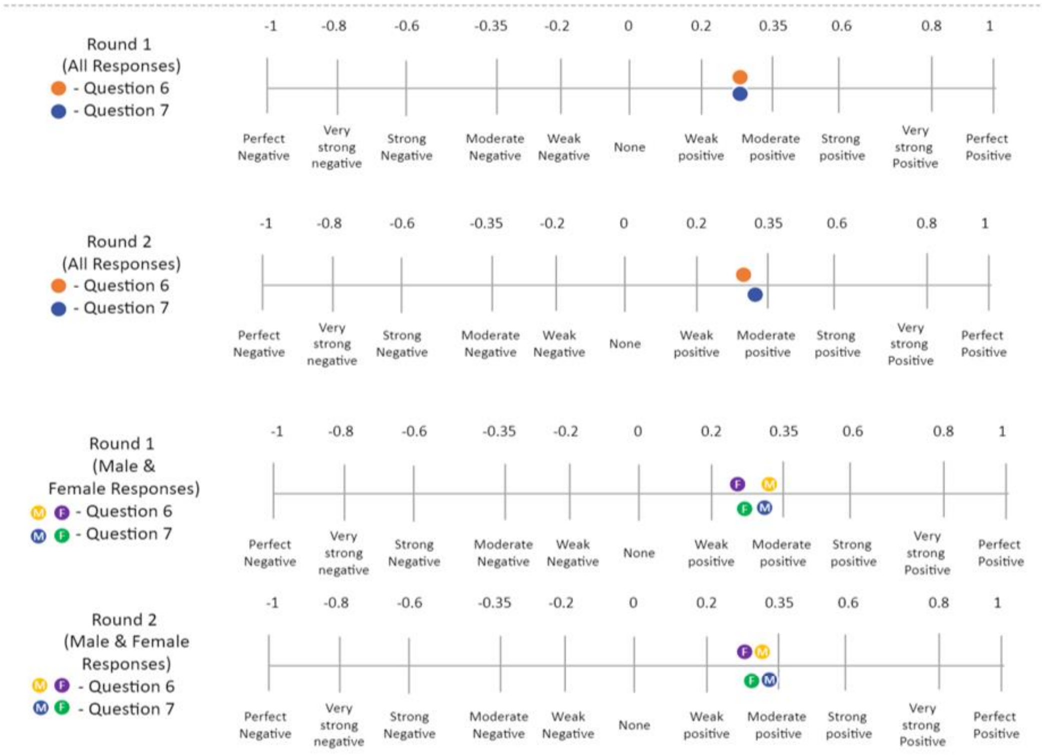

Figure 4-7 Agreement/ correlation coefficient, Saunders, Lewis and Thornhill, 2012, p.521

When profiling the changes across the rounds for questions 6 & 7 there were several changes observed. Figure 4-8 captures the changes for question 6 across the two rounds to see how the answers were stack ranked and whether there were any key fluctuations. A red arrow denotes a negative drop in the stack ranking, a yellow arrow captures no change and a green arrow highlights that the role grouping was elevated in the second round when compared with the first-round responses. Figure 4-9 captures the same for question 7 responses across the two rounds.

When looking at Figures 4-8 and 4-9, the changes in responses across the two rounds indicated a slight change in opinion in some areas but not all, for example in the first round the grouping in the highest demand was captured as being Data Specialists, this moved to second place in Round 2, with '*Legal, compliance, regulatory and ethical areas,*' moving from fourth place to first. A possible reason for this is that based on the feedback in round one the grouping was updated from '*Compliance/Regulator Specialists*' to include '*Legal and ethical areas,'* these recommended additions from the panel were supported in the Round 2 increase to first place in roles up to 2025. This was supported by verbatim provided by participants through question 13, for round 1 and question 14, for round 2. Participant number 16 shared:

> "*I believe with the advancement and pace that technology is evolving including AI, there seems to a be a 'shady' awareness with the legal stance and I anticipate there to be a steep increase in legal cases as not all organisations will (and are obliged to) follow an ethical AI approach."*

This was also supported with comments from Participant 33,

> "Ensuring the ethical use of AI is really important. AI is a powerful concept. Misinterpretation/misunderstanding of data trends or used incorrectly would be disastrous for the world. We need to ensure we are using AI correctly (whatever that is)."

Participant 224, stated that,

> "Ethics/Governance/new forms of security/regulation are certainly top of mind for me."

Another area that was updated across the rounds (See Figure 4-9) and was subsequently ranked higher, nineth place to fifth, was *'Specialist Operators*,' that was updated to be *'Industry Specialists.' Figure 4-8* and Figure 4-9 captures the changes across time, the role groupings that were captured as being in demand up to 2025 and then after 2025. Figure 4-8 captured the Round one views, and Figure 4-9 captured the Round two stack rankings. The same colour coding was used as in Figure 4-10 and 4-11 (a red arrow denotes a negative drop in the stack ranking, a yellow arrow captures no change and a green arrow highlights that the role grouping was elevated). Figures 4-10 and 4-11 show the changes in responses across the two Delphi Rounds.

The Responses highlighted the importance of '*creative roles,*' across the two rounds. The first round highlighted the importance of '*data scientists,'* and '*Business specialists'* with the second round promoting more of a focus on the *'Legal/Compliance/Regulator/Ethical roles'* along with '*AI Integration and Augmentation roles'* which was captured as business specialists in the first round. Of interest was that across both Rounds one and two there were role groups that the panel thought would remain constant in relation to the stack ranking over time. In Round one these were, '*Business Specialists/Advisors/Analysts*,' '*Compliance/Regulator Specialists,' Management (Inc Exec's) & Organisation Specialists,' 'HR & Learning & Development roles,' 'Specialist Operators,' and 'Sales Specialists & Marketing Specialists.'* For the second round the groupings that remained constant over time were, '*Industry Specialists,' 'HR & Learning & Development roles,'* and *'Sales Specialists & Marketing Specialists.'* The role grouping of *'Sales Specialists & Marketing Specialists'* was stack ranked at the bottom across all rounds and for both question 6 and 7.

Qu 6 Ranking	Round 1 Upto 2025	Round 2 Upto 2025
1	Data Specialists	Legal/Compliance/Regulator/Ethical roles
2	Technical, Engineer, Development Specialists	Data Specialists
3	Business Specialists/Advisors/Analysts	AI Integration and human augmentation roles
4	Compliance/Regulator Specialists	Technical Specialist & Specialist Engineers, Developers
5	Creativity roles	Industry Specialists
6	Healthcare Professionals	Creativity roles
7	Management (Inc Exec's) & Organisation Specialists	Leadership, Management Roles & Organisational Specialists
8	HR & Learning & Development roles	Healthcare Professionals
9	Specialist Operators	Human Resources and Learning & Development roles
10	Sales Specialists & Marketing Specialists	Sales Specialists and Marketing Specialists

Figure 4-8 Question 6 Role Stack ranking changes across rounds

Qu 7 Ranking	Round 1 After 2025	Round 2 After 2025
1	Creativity roles	AI Integration and human augmentation roles
2	Data Specialists	Legal/Compliance/Regulator/Ethical roles
3	Business Specialists/Advisors/Analysts	Creativity roles
4	Compliance/Regulator Specialists	Data Specialists
5	Healthcare Professionals	Industry Specialists
6	Technical, Engineer, Development Specialists	Technical Specialist & Specialist Engineers, Developers
7	Management (Inc Exec's) & Organisation Specialists	Healthcare Professionals
8	HR & Learning & Development roles	Leadership, Management Roles & Organisational Specialists
9	Specialist Operators	Human Resources and Learning & Development roles
10	Sales Specialists & Marketing Specialists	Sales Specialists and Marketing Specialists

Figure 4-9 Question 7 Role Stack ranking changes across rounds

Ranking	Round 1 Upto 2025 (Question 6)	Round 1 After 2025 (Question 7)
1	Data Specialists	Creativity roles
2	Technical, Engineer, Development Specialists	Data Specialists
3	Business Specialists/Advisors/Analysts	Business Specialists/Advisors/Analysts
4	Compliance/Regulator Specialists	Compliance/Regulator Specialists
5	Creativity roles	Healthcare Professionals
6	Healthcare Professionals	Technical, Engineer, Development Specialists
7	Management (Inc Exec's) & Organisation Specialists	Management (Inc Exec's) & Organisation Specialists
8	HR & Learning & Development roles	HR & Learning & Development roles
9	Specialist Operators	Specialist Operators
10	Sales Specialists & Marketing Specialists	Sales Specialists & Marketing Specialists

Figure 4-10 Round 1 comparison for role groupings in Question 6 and 7

Ranking	Round 2 Upto 2025 (Question 6)	Round 2 After 2025 (Question 7)
1	Legal/Compliance/Regulator/Ethical roles	AI Integration and human augmentation roles
2	Data Specialists	Legal/Compliance/Regulator/Ethical roles
3	AI Integration and human augmentation roles	Creativity roles
4	Technical Specialist & Specialist Engineers, Developers	Data Specialists
5	Industry Specialists	Industry Specialists
6	Creativity roles	Technical Specialist & Specialist Engineers, Developers
7	Leadership, Management Roles & Organisational Specialists	Healthcare Professionals
8	Healthcare Professionals	Leadership, Management Roles & Organisational Specialists
9	Human Resources and Learning & Development roles	Human Resources and Learning & Development roles
10	Sales Specialists and Marketing Specialists	Sales Specialists and Marketing Specialists

Figure 4-11 Round 2 comparison for role groupings in Question 6 and 7

4.1.6 Question 8

This question asked participants if they thought a key professional job role was missing from the list in question six and seven.

Post round one the responses were analysed and coded and required updates fed back into the round two questionnaire to evaluate consensus across the expert panel. See section 3.5.5 for details on the changes and Appendix 8.17 for a copy of the Round two questions.

Round two responses presented twenty-two occupations, these were cross referenced with the SOC2010 and SOC2020 versions. The updated role list from question six and seven (see section 3.5.5) and no new roles emerged from the second round, this reinforced and supported the view that data saturation had been reached (Wray,Markovic and Manderson, 2007; Fusch and Ness, 2015; Saunders *et al.*, 2018) for exploring potential new roles from the expert panel.

4.1.7 Question 9

Question nine was a control question and an ethical consideration (see section 3.11). Participants were asked whether any of their job roles had been affected by technological change. The question was aimed at identifying any participant bias, along with any sensitivity in relation to historical experience of technological change prior to any interviews to ensure this research considered the feelings and emotions of the participant and did not present any stress or anxiety to any participant if they had been negatively affected by technological change, such as redundancy and unemployment.

The responses were coded using the '*Thematic Analysis'* (TA) approach (Clarke,Braun and Lane, 2014) to explore any emerging patterns from historical and current technological change impact. Figure 4-12 captures the themes that emerged from the TA. Across the 154 responses received, 128 experts shared how technological change had and/or is affecting their job roles; 77% of responses were areas of augmentation, where technology was part of their job and had changed how they carry out their work; 13% recorded that technology had meant their job roles had evolved, they still carried out the role, however they felt that technology had changed aspects of it, such as customer discussions and their roles had evolved gradually over time rather than changed dramatically at a single point in time; 6% specifically highlighted that technological change had meant they had to re-train or learn a new skillset, that technology had displaced them from the work they were previously doing moving them into a different role; 4% confirmed that technology had completely removed the role they were doing and led to redundancy and the need to seek alternative work.

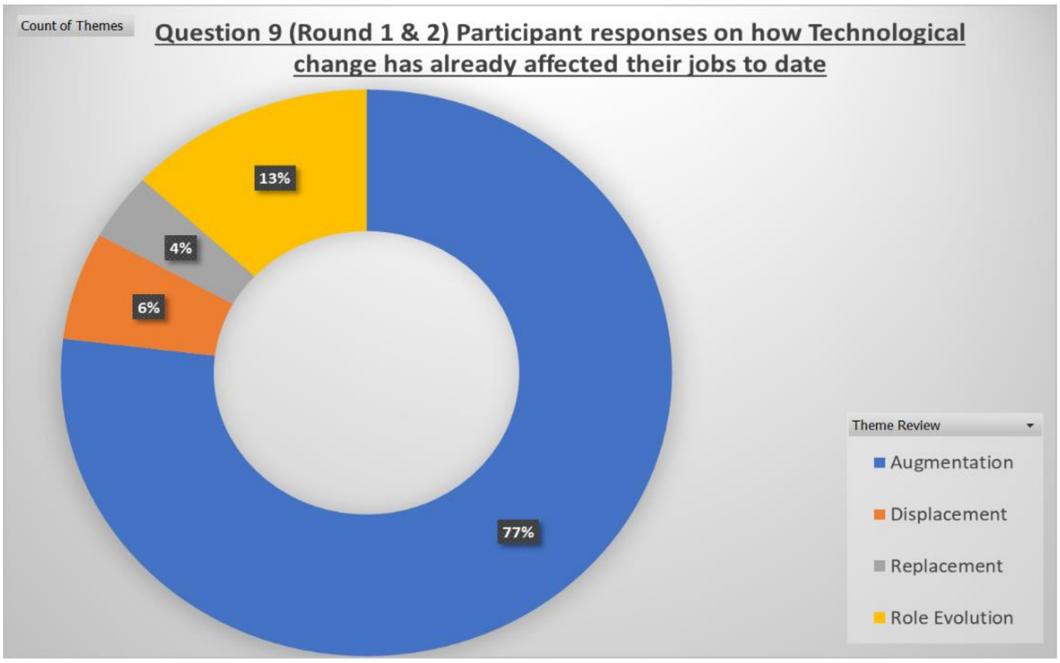

Figure 4-12 Question 9 high level themes from participant responses

The particiants provided details on how technological change had affected their jobs, Figure 4-13 captures further detail on the six areas of job disruption. Figure 4-14 breaksdown the responses behind Figure 4-13.

'*Automation*' was the main technological driver, 30% of responses pointed towards automation of existing processes, the simplification of work (Participant numbers;

2; 9; 14; 22; 27; 34; 41; 48; 52; 67; 42; 215; 240) along with the automation of specific tasks and activities, e.g. manual tasks or data collection (Participant numbers;1, 3, 9, 19, 29, 30, 33, 58, 64, 208, 224, 236, 276).

Slightly lower at 29% was '*augmentation of tooling and/or software,*' highlighting that technology had changed how they carried out their work, advancements in tooling and/or software had augmented what and how they carried out their roles. Augmentation also included mobililty as a result of technological advancements. Panel experts advised that the work itself had not changed, how it was conducted had (Participant numbers; 67; 21; 56; 14; 240; 22; 6; 18; 40; 66; 242; 46; 43; 12).

The third area was linked to the increase in data accessibility and a subset of the theme of '*augmentation'* where technological change has enabled more '*informed decision making,'* 18% of responses to question nine referred to data specifically informing their job roles, again this could be themed as automation or augmentation as the data feeds human decision making within a role or area.

Fourth out of six contributors was '*role evolution*' (13%) where participants identified that the introduction of technology meant that they had to increase their readiness and learning to adopt the change as part of their roles.

Participant 37, stated;

> "Every day my job role is evolving with the advancement in technology and changes in the market. The focus shifts to gain more knowledge to stay current and to provide specialist advice."

Participant 23 supported this view by capturing;

> "I sell advanced technology services, so it's altered the conversation and services we provide to customers."

The last two areas of role disruption related to Connectivity and Role Displacement. 6% emphasised the introduction of the internet and ability to use messaging tooling that changed how they connect with others as part of their job. Also a subset of '*augmentation*' where technology augments the human communication through technological solutions, whether that be email, video conferencing and connectivity was captured specifically by participants. The remaining 4% stressed that technology had displaced them from a role into another one and required upskilling and/or job realignment. Participant 71 articulated;

> "Most of the roles have been affected one way or another via upskilling/re-alignment of job"

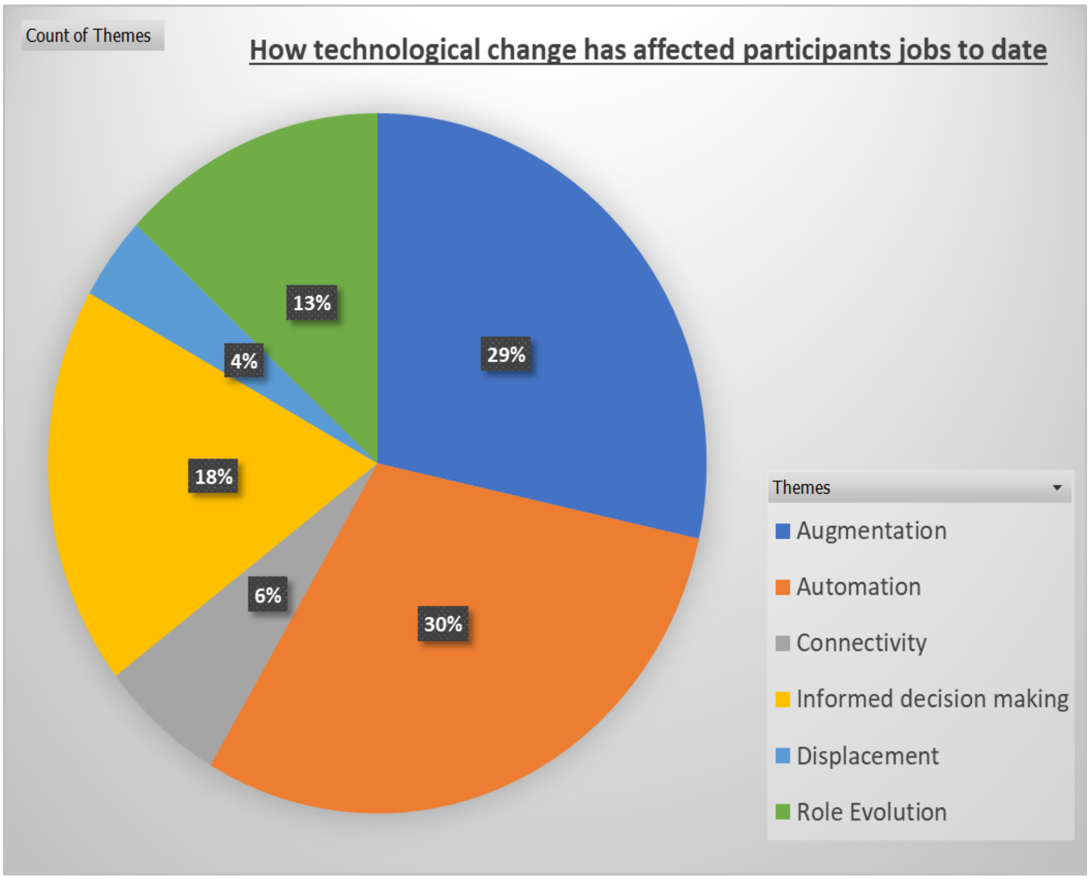

Figure 4-13 Question 9 detailed responses from participant responses

To summarise question nine, Figure 4-14, captures the four themes that emerged from the data and secondary reasons shared by expert participants that sit behind the four themes. The primary theme was '*augmentation,*' and this comprised of; '*connectivity, automation and informed decision making (data) and augmentation tooling and/or software*.' Where responses pointed to '*displacement*,' '*automation*' was also highlighted, and '*automation'* was also cited in relation to '*job replacement*.'

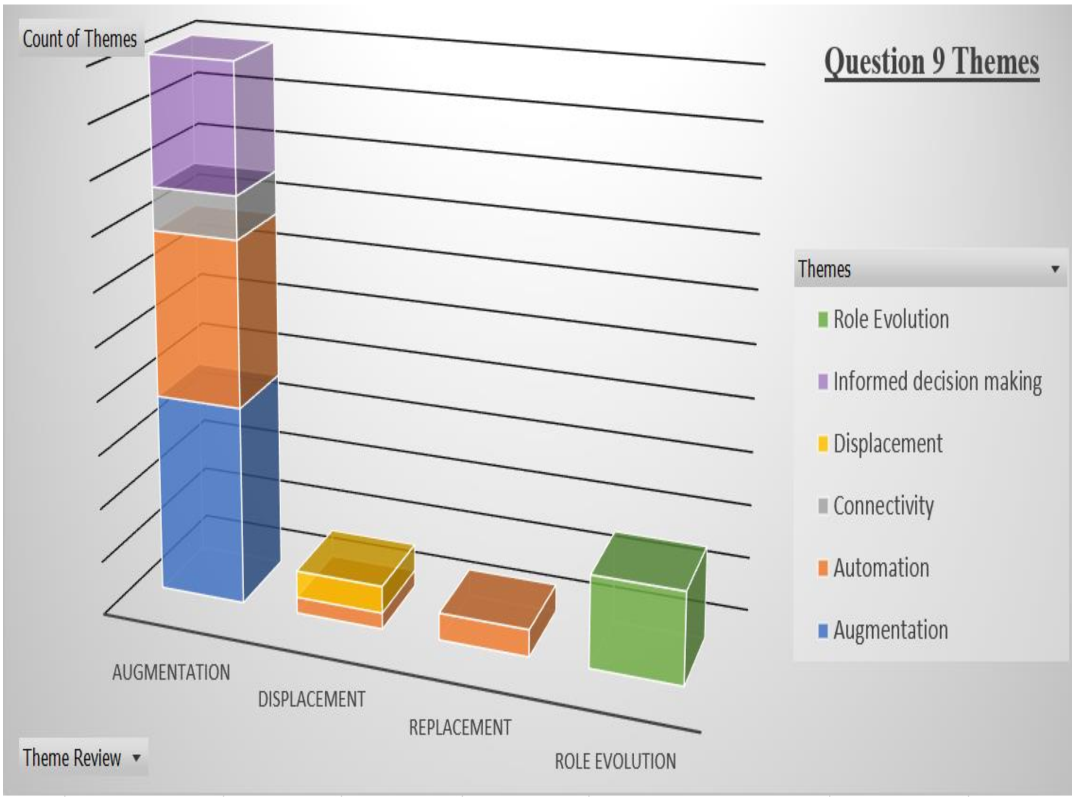

Figure 4-14 Question 9 Themes from participant responses

4.1.8 Question 10

Question ten asked participants to score between 1 to 10 (1 being negative and 10 being the positive) how they felt about the impact of technological change on professional occupations in the future. Across the two rounds the average scores were just under 8 (7.86 for round 1 and 7.9 for round 2). The scores varied slightly across males and females with the female average in both rounds being slightly higher than male participants. Round one was 8.13 for females and 7.65 for males and similarly round two was 8.29 for females and 7.7 for males. When analysing question ten there were three outliers across the 154 responses. Reviewing these, participant number 11 acknowledged that they were a '*pessimist*' and was basing their view on societal tendencies in the US and a direct quote from the Participant included; "*We will find a way to exploit people and make things worse*," although they also acknowledged that there is "*the opportunity to make it better and lives better.*" A response from participant 11 to question nine was also evaluated to check for bias to this question and the low score for question ten could be explained by historical job disruption, specifically the participant advised technological change had caused them to change career path. The other two outliers (scores below 5) were inconsistent across both rounds and these participants provided higher scores in the subsequent round.

4.1.9 Question 11 (round 1)

This question asked participants what they thought the key skills required by people in the future would be alongside technological change. The output received in round one was coded into ten skill groupings and presented back to participants in round two and they were asked to stack rank to explore consensus levels across the expert panel. Question twelve in round two then asked the same question to capture any additional skills that may have been missed in round one. The round one responses were analysed and the Delphi second questionnaire updated based on the expert participant responses. See section 3.5.5 for further details.

4.1.10 Question 11 (Round 2)

The stack ranking of the skill groupings from round one, see Table 3-6 in section 3.5.5 for the ten skill groups. Table 4-7 summarises the findings from the modelling of Kendall's (W) coefficient of concordance against question eleven. Question eleven (skills) saw the consensus levels reversed, compared with the metrics from questions 6 and 7 (See Section 4.1.5) with a stronger consensus amongst the female participants where 'W' was equal to 0.34, the consensus across the male participants was 1.1 lower at 0.23.

Round 2 Question #	**11**
Round 2 'W' calculation (All)	0.25
Round 2 'W' calculation (Males Only)	0.23
Round 2 'W' calculation (Females Only)	0.34

Table 4-7 Participant concordance metrics for Round 2 Question 11

Similar to the mapping for Figure 4-7, for questions six and seven, the calculations for question eleven in round two were mapped onto Saunders, Lewis and Thornhill's (2012) agreement scale, see Figure 4-15.

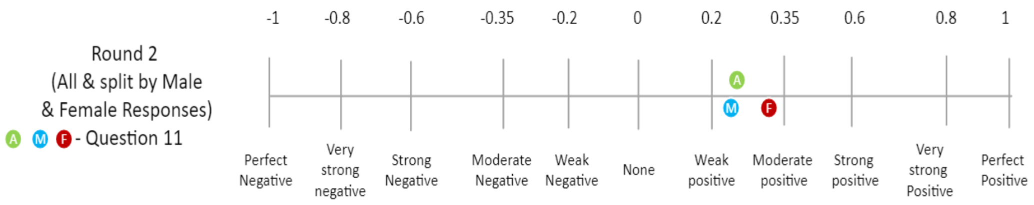

Figure 4-15 Agreement/ correlation coefficient, Saunders, Lewis and Thornhill, 2012, p.521

The Participant mix across the Delphi rounds was predominantly male which would have influenced the consensus values, out of 154 participants, across both rounds, 61% were male and 39% female. Round one had a 56% Male and 44% female mix and round two was 66% male and 34% female. The agreement measured in round 2 in line with Schmidt's (1997) rating table, see Figure 3-9 (in section 3.10.1) 0.3 represents a '*weak agreement,*' across the participants. Although agreement was recorded more strongly in females compared to the male participants.

When analysing the stack ranking of the skills, Table 4-8 captures the output from Round two responses, the top five skillsets were,

1. Ability to change and learn was top of the skills followed by
2. Analytical, interpretation, problem solving and critical thinking and
3. Creativity, Innovation, and curiosity
4. Empathy and Emotional Intelligence (EQ)
5. Ethical adoption, compliance and legal

Skillset	Ranking
Ability to change & learn (Including resilience, motivation & Tenacity)	1
Analytical, Interpretation, Problem solving & critical thinking	2
Creativity, Innovation & Curiosity	3
Empathy & EQ (Emotional Intelligence)	4
Ethical adoption, Compliance & Legal	5
Business value analysis, mapping & strategising	6
Envisioning, Business value analysis and mapping	7
Relationship Mgt, Collaboration, Decision making, Communication & Mgt	8
Maths/ STEM / Specialist technical skills	9
Specialist in-depth knowledge - non technical	10

Table 4-8 Responses from Question 11 stack ranked

4.1.11 Question 12 (round 2)

Question twelve in round two returned 210 skill recommendations from the expert panel, which were crossed referenced with the US O*NET (see section 3.6) the international authority on occupational skills (Wilson, 2013; Weng, 2015; Dickerson and Wilson, 2017; Fowler and Siekmann, 2017; Dingli and Baldacchino, 2018; Labor, 2019; 2020).

The O*NET captured a framework in relation to occupations and the '*Thematic Analysis*' (TA) (Clarke,Braun and Lane, 2014) carried out on the responses for question twelve led to, two key themes emerging;

1. Worker Characteristics (Worker Abilities, Values & styles)
2. Worker Requirements (Worker Skills & Knowledge)

Figure 4-16 shows the breakdown across the two high level themes. Worker characteristics accounted for 60% of the themed responses and worker requirements 40%. There was a single response of '*experience*' that was recorded, this is captured as below 1%

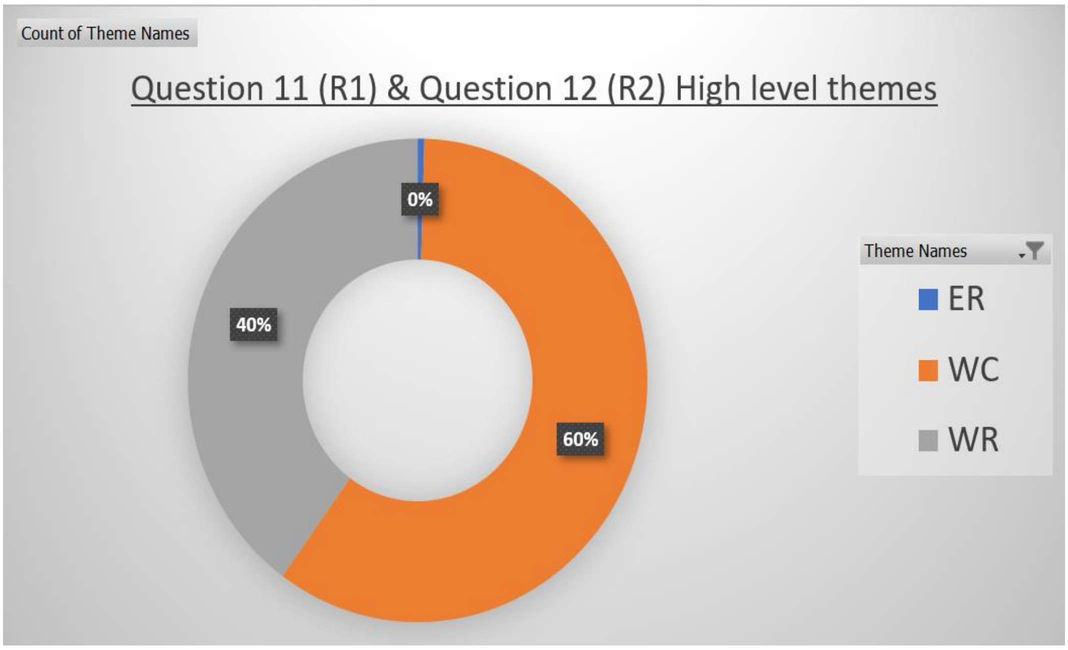

*Figure 4-16 Question 12 (Round 2) Triangulation of O*NET Framework and participant responses – High level view*

In relation to future skills, as a result of the TA and triangulation with the O*NET the theming approach was amended to include worker characteristics and requirements in-line with the US Framework rather than focusing purely on skills which are part of the '*Worker requirements*' within the O*NET. Figure 4-17 provides a view on the next level down, the detail behind the high-level themes in Figure 4-16.

The US O*NET provided a framework of components of a job role. What emerged from the data was that whilst the panel experts were asked to provide skills many of the responses related to worker characteristics, how people approach work. The abilities, occupational interests, values, and styles rather than the skills or knowledge required. Under the O*NET experience is another area. Figure 4-17 depicts that a worker's style is a key attribute for the future, based on the responses from the expert panel. Table 4-9 provides a further breakdown of the next level down, the specific attributes that were captured under the characteristic and work style theme.

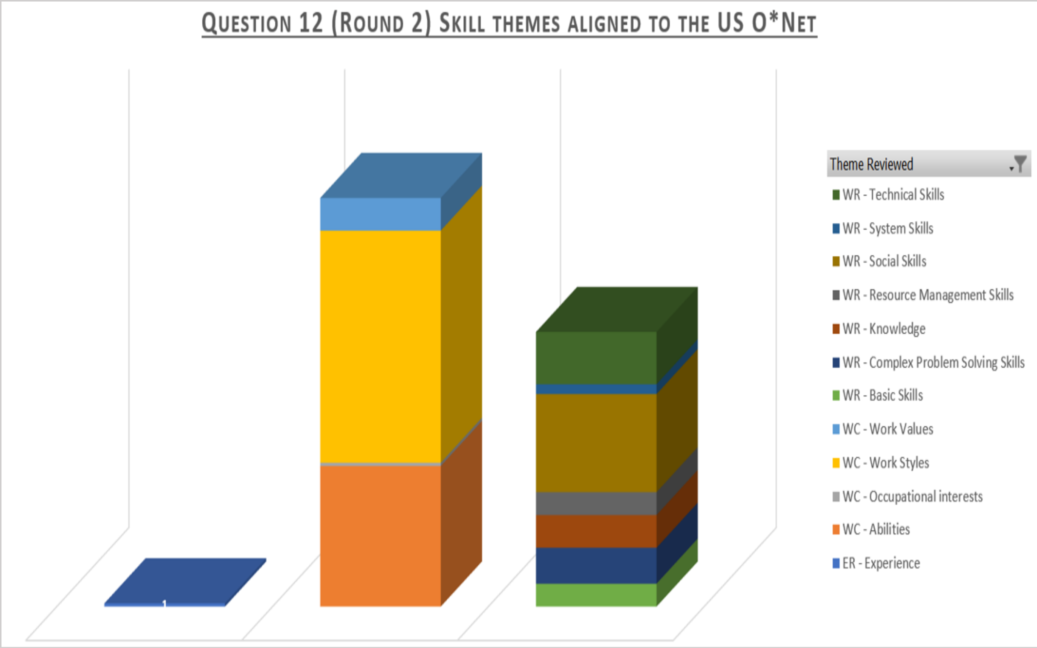

*Figure 4-17 Question 12 (Round 2) Triangulation of O*NET Framework and participant responses – Mid level*

Table 4-9 lists the themes that emerged from expert responses on "*What skills they thought were key for people alongside technological change for future work.*" The four most reoccurring themes totaling 59% of responses were:

1. The work style of '*Adjustment,*' a worker characteristic (23%)
2. The ability of '*Idea* generation and reasoning' again a worker characteristic (14%)
3. Cross functional skills, specifically '*Social skills,'* a worker requirement and (14%)
4. '*Technical skills*,' also classified as a worker requirement (8%)

Row Labels	Count of Theme
ER - Experience	1
WC - Abilities - Idea generation and Reasoning abilities	30
WC - Abilities - Quantitative abilities	6
WC - occupational Interests - Enterprising	2
WC - Work Style - Achievement orientation	9
WC - Work style -Practical Intelligence	3
WC - Work styles - Adjustment	48
WC - Work Styles - Interpersonal Orientation	9
WC - Work Styles - Social Influence - Leadership	1
WC - Work values - Support	9
WR - Basic Skills	7
WR - Complex Problem solving skills	11
WR - Cross Functional skills - Social skills	30
WR - Knowledge - Mathematics & Science	5
WR - Knowledge - Business & Management	5
WR - Resource Management Skills	7
WR - System Skills	3
WR - Technical Skills	16
WC - Abilities - Physical abilities	1
WC - Work Values - Relationships - Social Service	1
WC - Abilities - Verbal abilities	6
Grand Total	**210**

Table 4-9 Question 12 (Round 2) participant responses themed

'*Adjustment*' is a work style characteristic it was the most prominent theme that emerged from the expert panel responses and equated to 38% of the 60% of the worker characteristics shown in Figure 4-16. The full breakdown of the Worker characteristics is presented in Figure 4-18 below. Figure 4-18 captures that 55% of the work characteristics captured related to work styles as defined in the O*NET. Another significant characteristic, 24% is the ability to be able to carry out '*Idea generation and reasoning.'* This was followed with themes of having work values of '*support,'* the O*NET describes this as; *"Occupations that satisfy this work value offer supportive management that stands behind employees"* (US Bureau of Labor, 2019). Participant 70 verbatim supported this required value in future work stating,

> *"It's not really a skill but attitude and commitment to a work ethic will be important."*

Looking across the Worker characteristics that the panel provided for future work over half of these related to '*Work Style*' as already mentioned '*adjustment*' is highlighted, others included '*achievement orientation'* being driven, motivated and focused. Participant 62 captured this as,

> *"Flexibility and curiosity."*

Considering how people approach work in the future emerged as a higher consideration for the expert panel than worker requirements such as skills and knowledge.

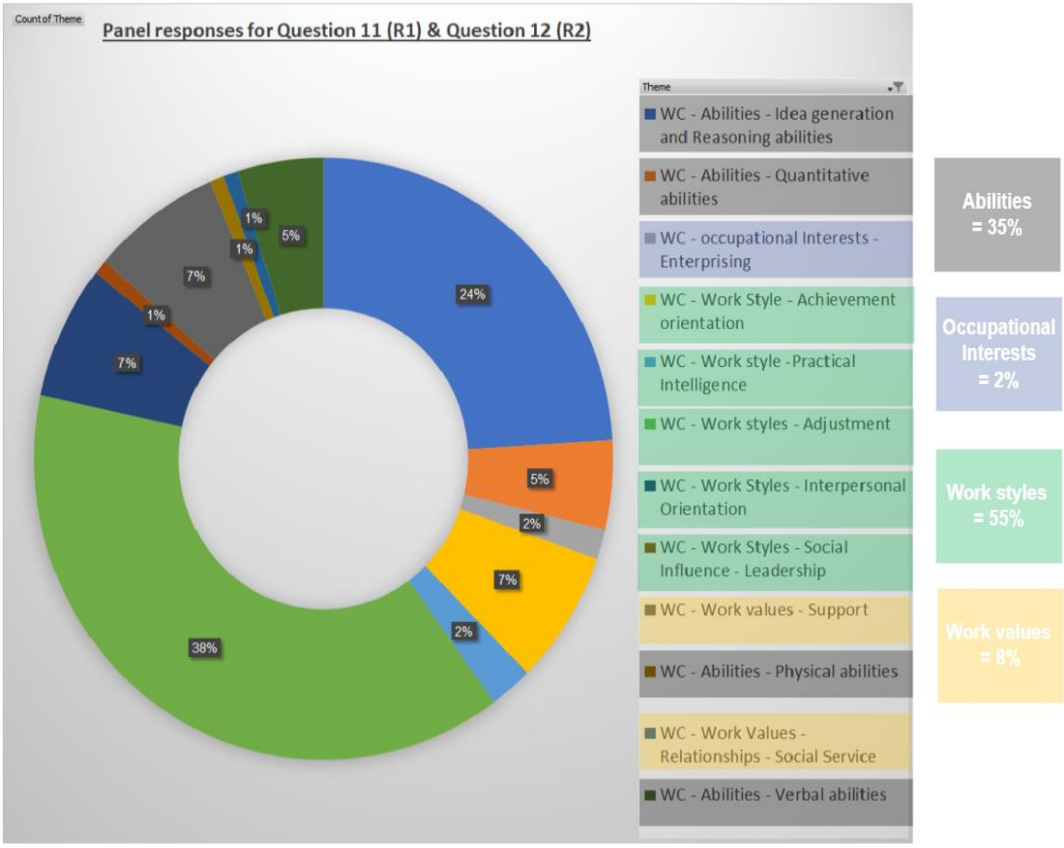

*Figure 4-18 Question 12 (Round 2) Triangulation of O*NET Framework and participant responses worker characteristics.*

Along with worker characteristics, 40% of responses were mapped to '*worker requirements*,' these were predominately skill related, 88% with the remaining 12% being knowledge based and specifically split equally (6% each) across '*Mathematics and science'* and '*Business and management'* knowledge. Figure 4-19 provides a graphical view of the worker requirement themed responses. The highest consolidation of responses from the participants related to '*social skills*,' 36% felt that these skills that are classified as *'Cross Functional skills'* in the O*NET Framework were required for future work by people. This was followed by the need for '*technical skills'* and '*complex problem-solving skills*.'

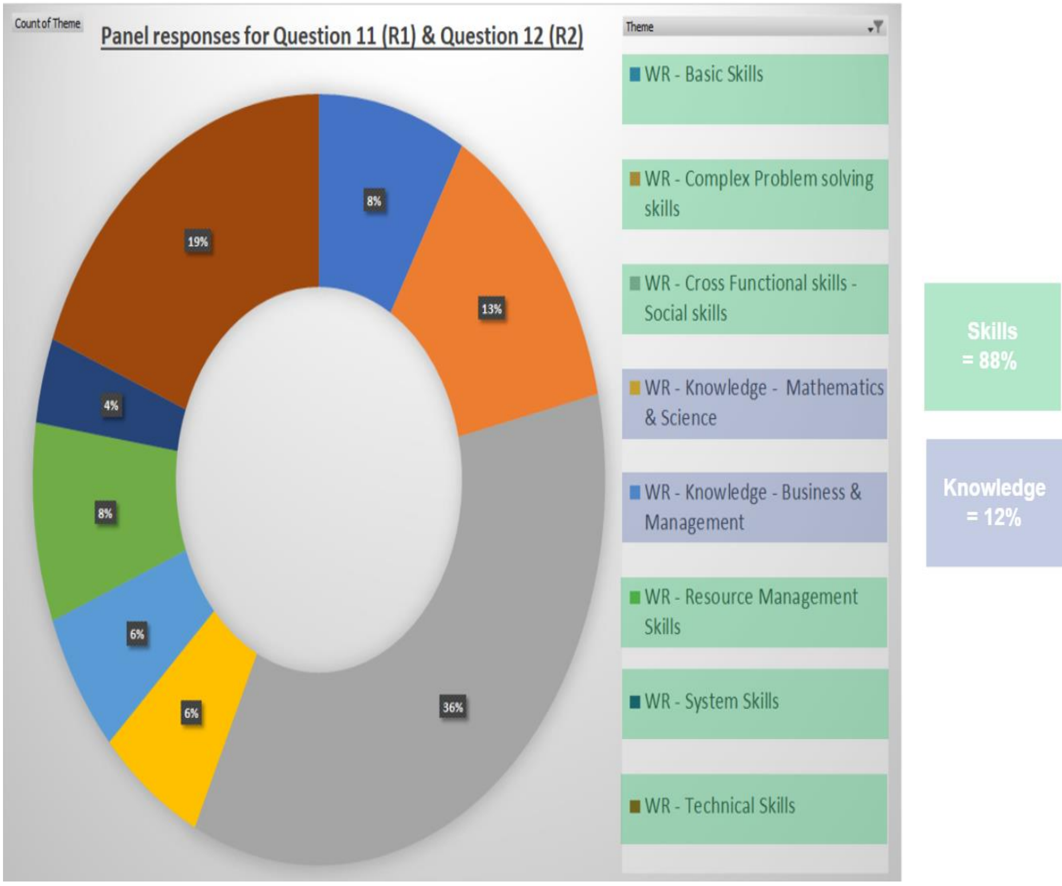

*Figure 4-19 Question 12 (Round 2) Triangulation of O*NET Framework and participant responses Worker requirements view*

To summarise responses from question twelve (round two) 60% of the responses related to worker characteristics, how they approach work, their abilities, values, interests and work styles, with the key two areas being recorded as, 'adjustment' and an ability to generate ideas and reasoning, which are set out in the O*NET as;

- Adjustment, "*Job requires maturity, poise, flexibility, and restraint to cope with pressure, stress, criticism, setbacks, personal and work-related problems*" and
- Idea Generation and Reasoning Abilities, *Abilities that influence the application and manipulation of information in problem solving*" (US Bureau of Labor, 2019).

The remaining 40% related to worker requirements and most responses that fell under this theme related to '*social skills*' and '*technical skills*.'

The skillsets from question eleven in round two correspond with the thematic analysis carried out on the triangulation with the O*NET in this question. Question eleven (round two) captured the following top four human skill competence areas:

1. Ability to change and learn was top of the skills followed by,
2. Analytical, interpretation, problem solving and critical thinking and,
3. Creativity, Innovation and curiosity,
4. Empathy and Emotional Intelligence (EQ).

In question twelve (round two) the following four areas emerged:

1. The work style of '*Adjustment,*' a worker characteristic,
2. The ability of '*Idea* generation and reasoning' again a worker characteristic,
3. Cross functional skills, specifically '*Social skills,'* a worker requirement and,
4. '*Technical skills*,' also classified as a worker requirement.

4.1.12 Question 13

Participants were asked if there was anything they would like to add in relation to technological change and the human future workforce, is there anything that concerns or excites them about the future workforce? When reviewing and conducting familiarisation of question thirteen responses, through the initial analysis a pattern emerged around concerns of unemployment and technology removing or replacing people's jobs. To explore this further, the last fifteen years of employment data were reviewed by occupational '*Major group (MG)*' (Office for National Statistics, 2019b) see Figure 4-20.

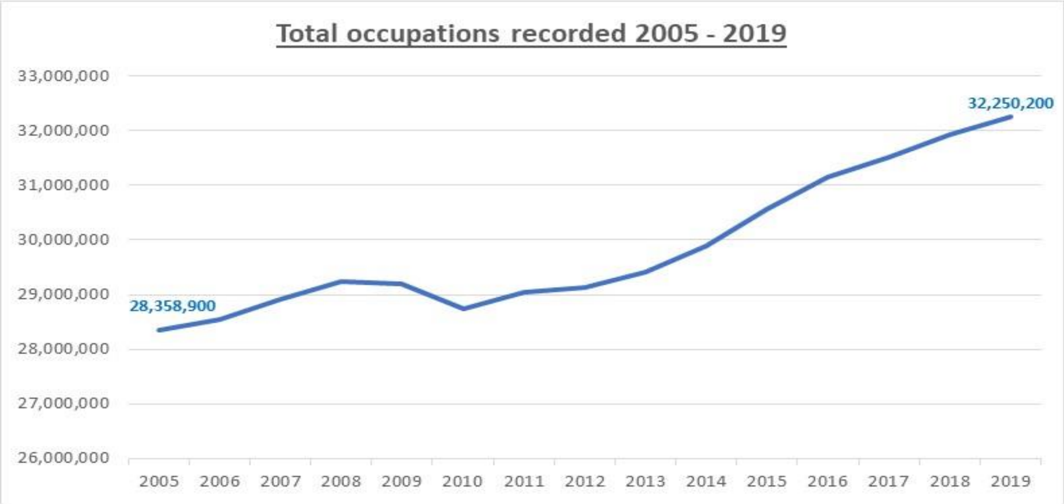

Figure 4-20 UK total employment profile 2005-2019(Office for National Statistics, 2019)

The total number of jobs across all groups had increased since 2011 which did not support the perceptions of participants that technology had reduced human work. Further analysis of the occupational groups, namely reviewing groups 1-3 (Managers, Directors and Senior Officials (MG1); Professional Occupations (MG2); Associate Professional and Technical Occupations (MG3); with groups 4-9 (Administrative and secretarial occupations (MG4); Skilled trades occupations (MG5); Caring, leisure and other service occupations (MG6); Sales and customer service occupations (MG7); Process, plant and machine operatives (MG8); Elementary occupations (MG9) across a window of fifteen years. The data indicated some displacement across job groups, as the overall employment numbers increased the occupational mix appeared to have changed. See Figure 4-21.

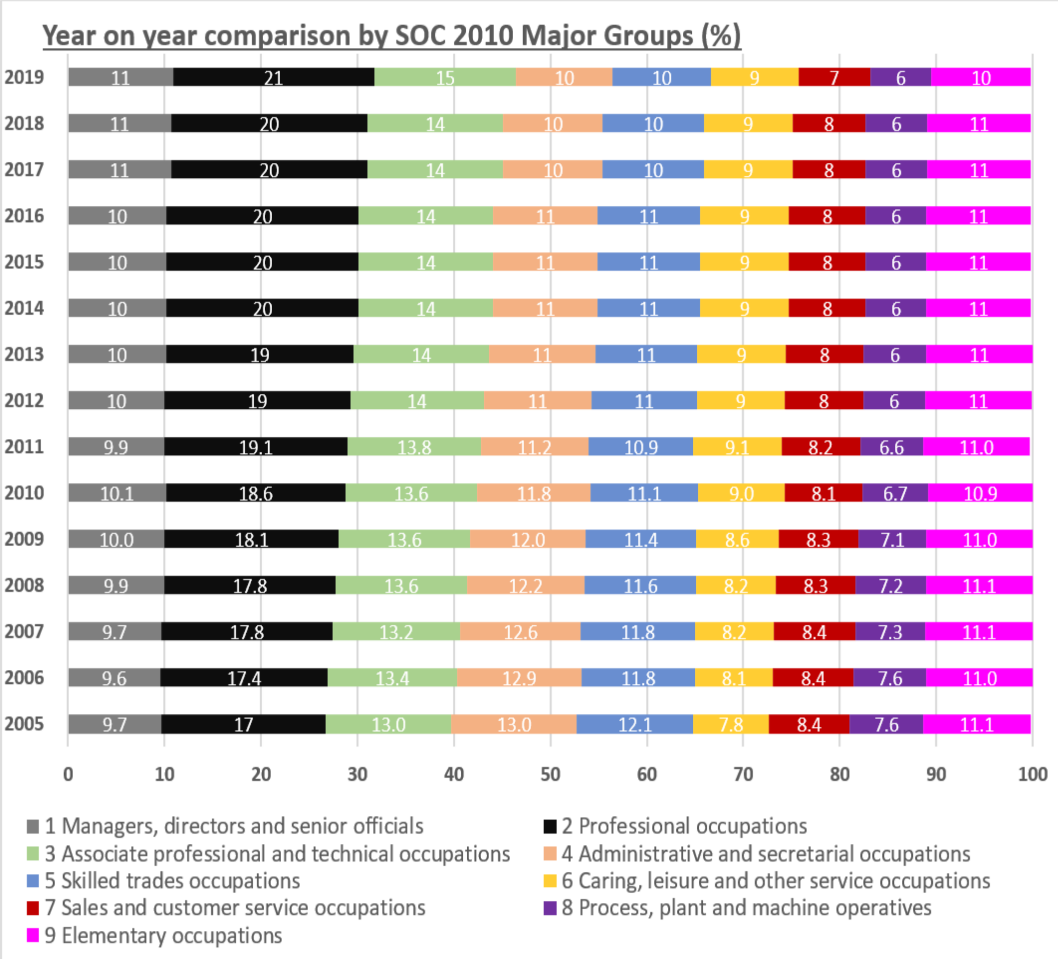

Figure 4-21 UK total employment profile by Major Occupation Group 2005-2019(Office for National Statistics, 2019)

Figure 4-21 shows how role distribution has changed over the fifteen-year period. It should be noted that the SOC was updated in 2010, so some fluctuations may be attributed to the update, the main change was that some management roles (MG1) were reclassified and moved to MG2, this would attribute to the small reduction in 2011 in MG1 and increase in MG2. The graph shows that changes have been gradual over the years across all groups.

Figure 4-20 showed that employment numbers have been increasing since a dip in 2010, a possible explanation for the 2009, 2010 dip is a knock-on effect of the financial crisis of 2008 (Rojko, Lesjak and Vehovar, 2011). The extent of the employment increase has varied year on year, Figure 4-22 captures the difference when comparing total occupational numbers on the preceding year. Figure 4-22 captures a significant peak in 2015, where employment increased by 675,100 jobs, the following year, 2016 also indicated employment growth of 582,200 jobs. The last three years, 2017, 2018 and 2019 also showed employment growth. (377,400 for 2017, 418,800 for 2018 and more recently 311,800 for 2019, the data capture period is March to April). Another theme that emerged from the data was one of displacement, where workers are displaced from one area to another. Whilst the data indicates employment growth, further analysis was carried out to explore whether there was a pattern or specific occupational group that was declining or increasing over time and how any changes mapped to technological change.

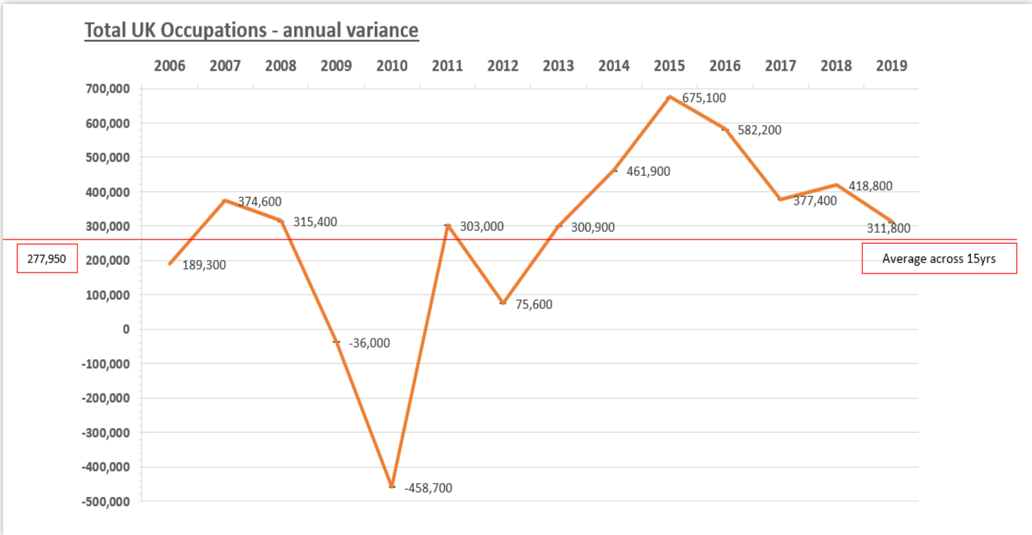

Figure 4-22 UK occupations year on year fluctuations 2005-2019(Statistics, 2019a)

Figures 4-23 and 4-24 capture the coverage by major group as classified by the UK Standard between 2005 and 2019(Office for National Statistics, 2019a). In 2005, 17% of the occupations in the UK were classified as '*Professional Occupations*' and this major group was the largest single group, followed jointly by '*Associate professional and technical occupations*' and '*Administrative and secretarial occupations*' both represented 13%. '*Skilled trade occupations*' denoted 12%, '*Managers, directors and senior officials*' had a 10% representation and '*Elementary*' roles 11%.

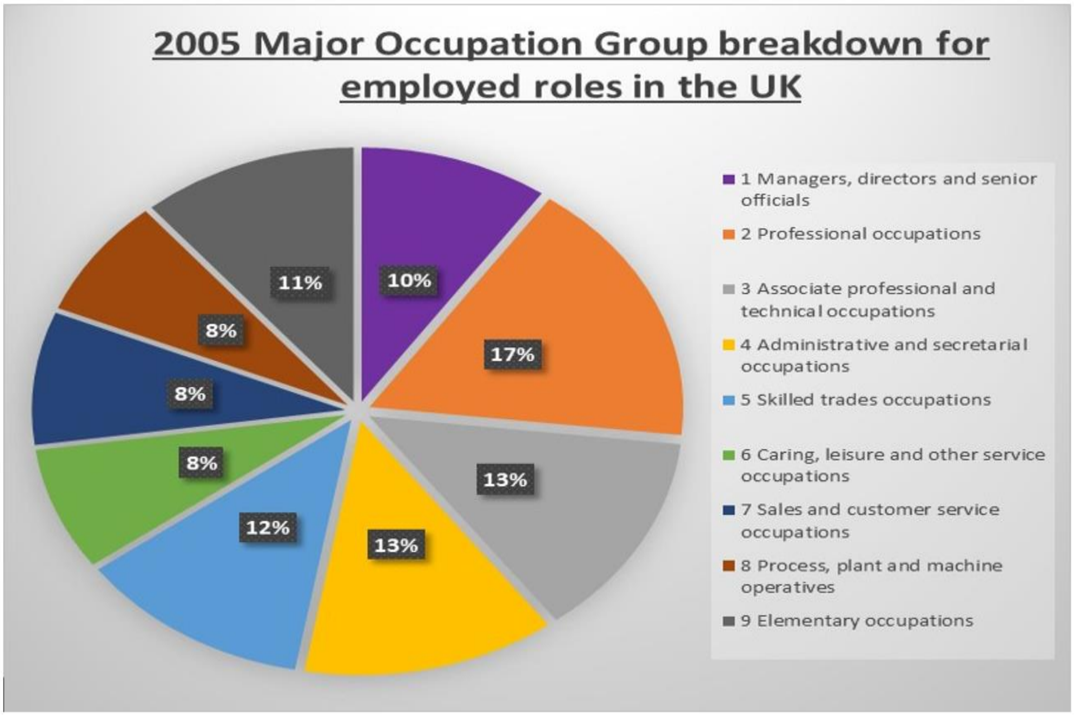

Figure 4-23 2005 Major Occupation Group (MG) breakdown for employed roles in the UK(National Office for Statistics, 2020c, 2019, 2010b)

The smaller major groups were 8% each; '*caring, leisure and other service occupations, Sales and customer service occupations and Process, plant and machine operatives*.' In 2019, see Figure 4-20 there were 3,891,300 more roles recorded than those in 2005. The profile of those occupational roles are (figure 4-24); 21% '*Professional Occupations,*' 15% '*Associate professional and technical occupations,'* 11% '*Managers, directors and senior officials,*' followed by '*Administrative and secretarial occupations, Skilled trade occupations and Elementary roles,*' all with 10% representation, '*Caring, leisure and other service occupations*' had 9% share and '*Process, plant and machine operatives*.' '*Sales and customer service occupations'* at 8% and lastly '*Process, plant and machine operatives'* were at 6%.

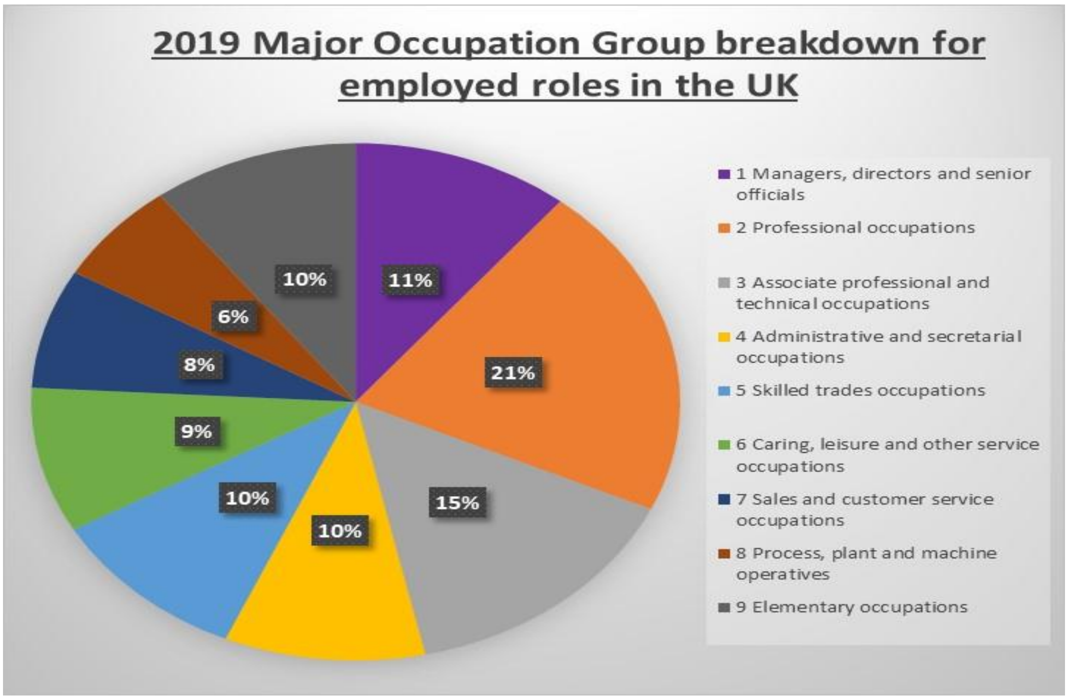

Figure 4-24 2019 Major Occupation Group (MG) breakdown for employed roles in the UK (National Office for Statistics, 2020c, 2019, 2010b)

When comparing the change in occupation major groups at two data points 2005 and 2019, Figures 4-23 and 4-24, the biggest growth area was the '*Professional occupations*' (Major Group 2) which grew a 4% share of the total jobs from 17% to 21%. The roles that declined the most were *'Administrative and secretarial occupations'* (Major Group 4). Table 4-10 compares the 2005, 2015 and 2019 occupational group breakdowns to analyse any changes across the job groupings.

Major Group (MG) #	Major Role Group	In 2005	In 2015	In 2019	Trend
1	Managers, directors and senior officials	10%	10%	11%	↑
2	Professional Occupations	17%	20%	21%	↑
3	Associate professional and technical occupations	13%	14%	15%	↑
4	Administrative and secretarial occupations	13%	11%	10%	↓
5	Skilled trade occupations	12%	11%	10%	↓
6	Caring, leisure and other service occupations	8%	9%	9%	↑
7	Sales and customer service occupations	8%	8%	7%	↓
8	Process, plant and machine operatives	8%	6%	6%	↓
9	Elementary occupations	11%	11%	10%	↓

Table 4-10 UK total employment profile 2005-2019 by Major Occupational Group(National Office for 2010b, 2019)

The stack ranking by role distribution across the Major Groups is the same across the three-year comparison, whilst the allocation of percentage changes slightly the pattern is the same with '*Professional occupations*' being the single highest group in all three years and '*Process, plant and machine operatives*' being the lowest. However, when analysing the data in more detail the '*Elementary role*' share has decreased 1% compared to other role groups, in 2019 there were 159,000 more people employed in these roles in comparison to the numbers employed in 2005. The '*Process, plant and machine operatives*' have experienced a change in role volumes over time. In 2005 there were 2,151,300 roles employed in the UK, in 2015 this had reduced by 212,000 and by 2019 then increased on the 2015 number by 106,000 still behind the 2005 number by 106,000.

The same analysis was carried out on MG1 (*Managers, directors and senior officials*) to evaluate the total numbers across the 2005 to 2019 window, the percentage increase was from 10% to 11%, however the increase in employed roles in this group between 2005 and 2019 was 27.09% with additional 746,300 occupational roles in this group. The analysis on MG2 looked at the '*Professional occupations'* and found that the role increase was 39.48% when comparing the 2005 and 2019 volumes with a role share growth of 4% from 17% to 21%. Three occupational groups had the highest growth in roles: Groups 2,3 and 6 – across these areas totalling an increase of 3,667,900 roles from 2005 to 2019. The three areas that have had the biggest reduction were Groups 4,5 and 8 which equalled 709,200 roles.

Another area that was analysed was the stack ranking of the nine occupational major groups over a fifteen year period to explore whether the perception of displacement, job inequality and unemployment in human jobs was supported by employment data that was available and whether any changes corresponded to technological milestones. Figure 4-25 shows the ranking, one to nine. One being the occupational group with the biggest share of employment volumes and nine being the lowest. Table 4-11 captures the positions in a tabular format.

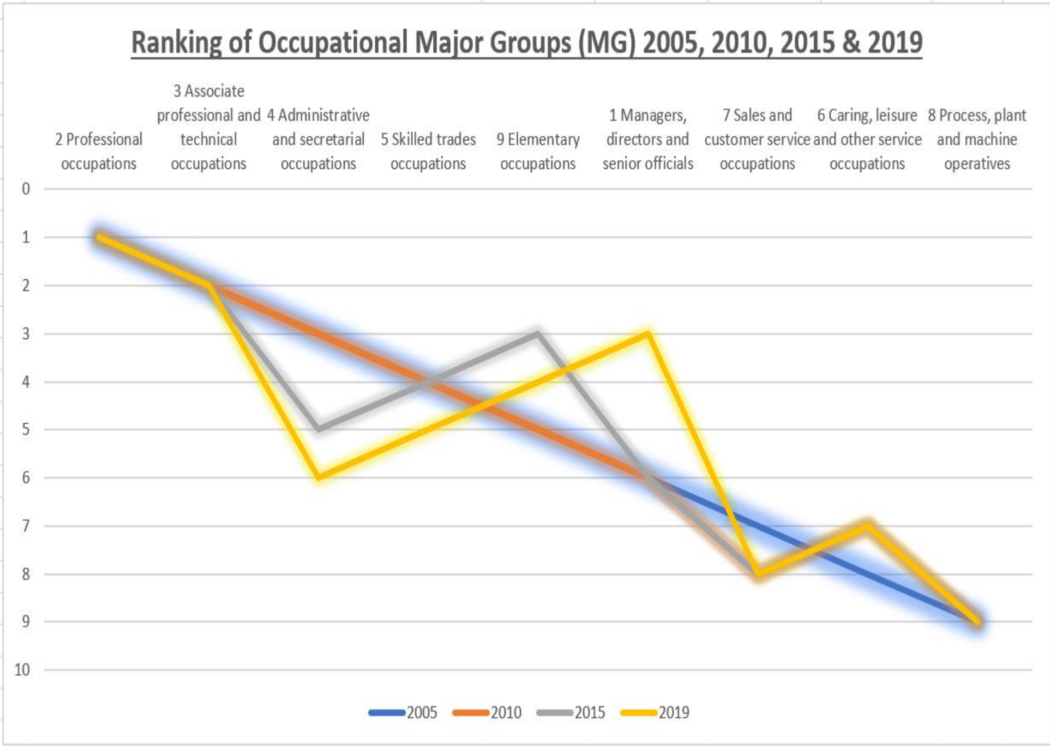

Figure 4-25 UK Ranking of Occupational Major groups 2005, 2010, 2015 & 2019 (National Office for Statistics, 2019)

Total occupations recorded	Ranking 2005	Ranking 2010	Ranking 2015	Ranking 2019
2 Professional occupations	1	1	1	1
3 Associate professional and technical occupations	2	2	2	2
4 Administrative and secretarial occupations	3	3	5	6
5 Skilled trades occupations	4	4	4	5
9 Elementary occupations	5	5	3	4
1 Managers, directors and senior officials	6	6	6	3
7 Sales and customer service occupations	7	8	8	8
6 Caring, leisure and other service occupations	8	7	7	7
8 Process, plant and machine operatives	9	9	9	9

Table 4-11 Major Occupational Group stack ranked by employment numbers for 2005, 2010, 2015 and 2019

2005 was plotted first and used as a control baseline and years 2010, 2015 and 2019 were mapped against 2005 to review whether there were any patterns in the ranking over time. What emerged is that for the last fifteen years Professional Occupations(MG2) and Associate professional and technical occupations (MG3) have employed the majority of people consistently with these two groups being ranked first and second and the occupational group that came ninth, out of nine was Process, plant and machine operatives. Whilst the percentage allocations across the total employment numbers by occupation may have changed slightly over fifteen years the first, second and ninth place occupations have remained consistent. The lowest ranked occupations have also remained the same since 2010 with some fluctuation between 2005 and 2010 across MG 7 and 8. The biggest changes have been in the Administrative and secretarial, MG 4 occupations and the Managers, directors and senior officials, MG1. MG4 since 2005 has been declining in employed numbers, digitalisation and the introduction of computers is a possible explanation for this decline (Levy and Murnane, 2005). In 2005 the MG3 group was ranked high at third place out of the nine occupational groups and employing 3,693,300 people in the UK, by 2019 this had slipped to sixth and the employment volume was down to 3,225,400 with MG1 taking the third place with 3,501,300 people in those roles. What the data does not tell us is whether workers in MG4 retrained or changed career paths and switched to another occupational group, such as MG9, Elementary roles which had similar fluctuations in the opposite direction. This would be difficult to assess given the lack of data.

Given the timeline of technological change, the adoption and implementation of advancements in processor speed (Moore, 2008) and the embracing of social media and advancements in general AI through big data (Greengard, 2011; Bauer *et al.*, 2015; Schwab, 2017; 2018; Vetrò *et al.*, 2019) focus was given to changes in occupational data from 2015 to 2019. Figure 4-20 profiles the year on year fluctuations in employment volumes. Employment growth across the occupation groups peaked in 2015 and has stayed above the fifteen-year average (year on year change 277,950). The data does not support the view that jobs are being removed as a result of technology and the counter argument is that since technology has matured the employment rates have increased above 300,000 annually since 2013. See Appendix 8.26 for a technological timeline that supports this view.

Returning to question 13, thematic analysis (Clarke, Braun and Lane, 2014, Braun and Clarke, 2006) continued with the coding of the verbatim from the expert panel participants. The themes that emerged from the codes were reviewed and Figure 4-26 captures the three themes across the classifications of comments, the first being what '*excites*' the participants about future work, the second, what '*concerns*' them and thirdly any general or '*neutral*' comments that were captured.

'*Existential Position'* was the most significant theme which people raised. The comments had a number of sub-areas; social equality and inequality, economic improvement and potential for increased efficiency and personal growth and diversification along with concerns how technological change would be governed, controlled and regulated. The expert panel raised more excitement than references of concern: -

Participant 18 asserts,

> "*Humans will be better utilised and be able to provide greater utility with the advance of technology.*"

Other quotes included advantages such as,

> "*Precision decision making"* (Participant 18)

Participant 39*,*

> *"The volume of information and ability to make informed timely decisions,"*

Participant 36 shared a recurring area of concern under the theme of existential position along with Participant 65,

> *"ethics, culture, governance, are so important to ensure that the reach of technology and AI is safe, controlled, and appropriate - the risk of that going too far, and of impacts on privacy, does concern me."*

Under the theme of '*Preparation*' concern and general comments were captured on a lack of awareness of the timing and associated communication from government bodies and other large organisations. Participants flagged that the dissemination of information was sometimes inaccurate and or incomplete and people are not being prepared sufficiently to embrace the opportunity that the technology could bring.

Participant 16 raised two concerns:

> *"(1) My first concern is the lack of 'technical training'/awareness within the UK education system. This has the risk of creating a gap in skills & knowledge within the younger generation. Working within the IT industry we understand the impact that technology is having and will continue to have in all industries and therefore it is so vital that this issue is addressed, and the future generation are well-equipped. (2) In addition, I think there is a risk in putting too much emphasis on the technical element and forgetting the importance of the emotive and ethical element."*

Another participant raised preparation concerns in relation to the human skillset required for the future, the,

> *"Lack of human evolution, adaptability, resilience, curiosity and resourcefulness need to be part of the skillset."*

Participant 48 supported the theme of preparation, adding,

> *"We are not training or educating people for the impact of change. The pace of change is not factored into people's training. Many jobs will not be replaced or cannot be replaced so we need to train for them. Governments are not in a position to react fast enough to the impact of modern tech and its requirements."*

The remaining theme that emerged from the data was one of '*Augmentation.*' Participant 15 captured it as,

> *"Roles will become geared around working alongside machines to analyse problems and interpreting results as opposed to humans performing the analysis,"*

Participant 24 added to this advising that,

> *"AI will bring efficiency and augment human capabilities"* and a specific example is provided by participant 52 with the *"integration of technology & biology."*

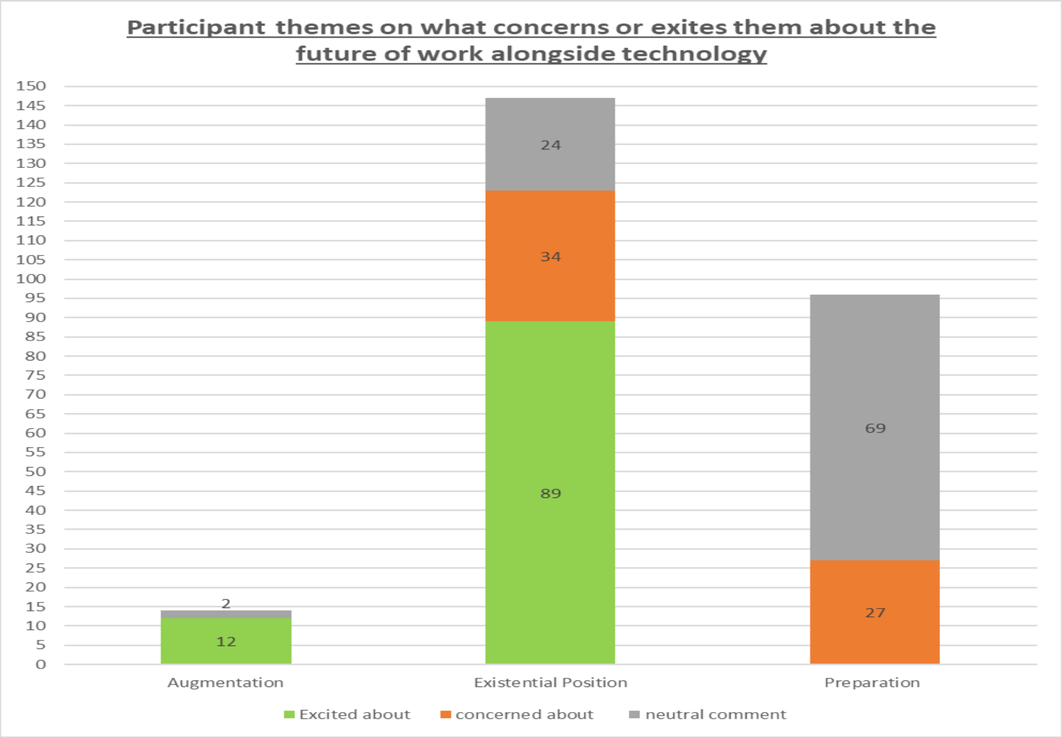

Figure 4-26 Participant themes – question 13

4.1.13 Summary of Delphi findings

The Delphi rounds returned a rich data set, both quantitative and qualitative data sets. Familiarisation of the data was very time consuming and the use of concept maps (see Appendix 8.18) helped explore the insight the expert participants had shared. Across the stack ranked questions agreement which was measured through the application of Kendall's statistical modelling, '*Kendall's Coefficient of concordance*' (see section 3.10.1). Utilising Schmidt's (1997) interpretation table of '*W*' the agreement across the expert panel was classified as 'Low, ' although it was noted that agreement increased in the second round when comparing the statistical scores across the two rounds for questions 6 and 7, which looked at job groupings. Although the agreement level was low, it should be noted that there was a level of concordance or agreement captured across the panel of experts, the specific calculations can be found in Figures 4-8, 4-9, 4-10 and 4-11 in section 4.1.5.

Another observation from the data was that when the job groupings were stack ranked one particular grouping was ranked lowest each time across both rounds and both questions. Specifically, "*Sales specialists and Marketing specialist roles*" (see Figures 4-8, 4-9, 4-10 and 4-11). Roles that were ranked higher by the collective panel when comparing roles now and to 2025 and then looking further than 2025 included "*Legal, Compliance, Regulatory and Ethical Roles.*" When the role grouping rankings were analysed side by side a slightly different pattern emerged. The importance of '*AI Integration and Human augmentation roles,*' '*Creativity'* and '*Healthcare roles*' were elevated in the rankings in round 2 for after 2025 compared with up to 2025, suggesting that the experts believed that there would be a potential change in demand for certain roles as technological change matures, specifically in these areas. Another area that was prioritised across the rounds (see Figures 4-8 and 4-9) were '*Specialist operators'* or '*Industry specialists,*' as they were updated after the round 1 responses. These roles moved from 9th place up to 5th place both for questions 6 and 7.

The Delphi responses when evaluated alongside the O*NET data showed clear linkage, with the role groupings and the skills being presented. The following mapping (figure 4-27) captures the linkage between the importance of the key skills stack ranked (note that skills were as a result of answers provided through Question 11 in round 1, see section 4.1.9). The skills were ranked by the expert panel through Question 11(Round 2) and the results are captured in Table 4-8 and show the top skill presented by the expert participants, is "*An ability to change & learn (including resilience, motivation and tenacity*) ' this links to the Worker characteristics that were as a result of the triangulation activity with the O*NET data, which presented a need for people to have a work style that include '*adjustment'* when looking at future work alongside technological change.

There was further linkage 'social skills' with the job groupings, and skills presented, for example 'social skills' emerged and this links to the demand for Healthcare roles. Similarly, other key '*worker characteristics'* such as idea generation links directly with the demand for creativity roles, and lastly there is linkage between the demand for Worker requirements that were also captured, specifically; '*technical skills'* which links to the '*Industry Specialist roles*' that were also elevated and referred above. Figure 4-27 depicts the high-level analysis, starting with the agreement level in the top right box, followed with the skill breakdown against the O*Net types. The bottom right hand side of the diagram shows the skill areas captured, with the bottom left hand side recording the technical, specialist skills. The top left hand-side captures the new roles area that were presented.

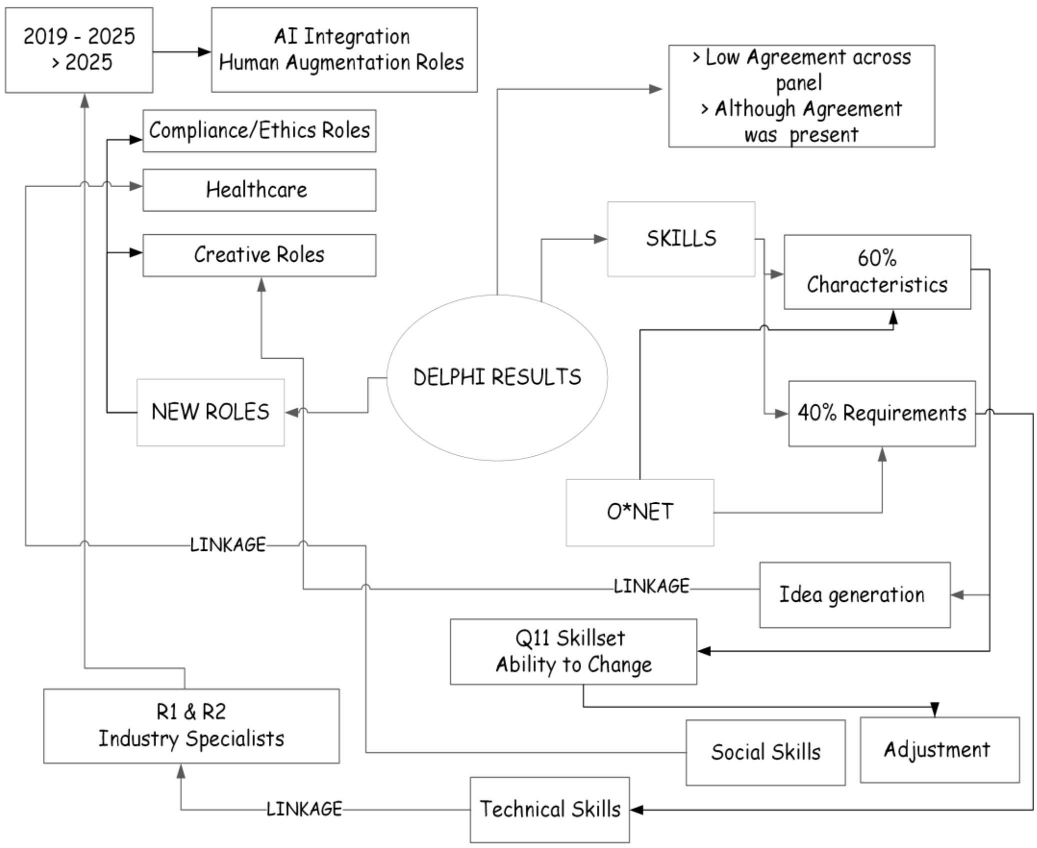

Figure 4-27 Delphi findings mapping

4.2 Triangulation findings and analysis

The preceding section referred to the triangulation with the O*NET data, the skills presented through the Delphi responses were triangulated with the O*NET Content Model, See section 3.6 for further information, the patterns and themes that emerged through the Thematic Analysis (Braun and Clarke, 2013) and the descriptive ordinal data (Saunders,Lewis and Thornhill, 2012), came together addressing the research objectives of exploring future jobs and future skills alongside technological change.

When analysing the Delphi question 13 data set, an initial pattern emerged that there was a concern of technological unemployment (Keynes, 1933) with technology replacing or removing people's jobs. To validate this pattern, historical quantitative numerical data was analysed (see section 4.1.12). The last fifteen years of employment data (see section 3.6) showed that employment rates had increased since 2010, the timeline was then evaluated against a chronology of technical change to date, see Appendix 8.26. The triangulation validated that professional roles, along with associate professional and technical occupations and Managers, Directors and other senior official occupations since 2005 had all increased, one possible reason is the technological change is driving higher demand for professional and skilled work.

Lastly, another area that involved triangulation with other data sources, was in response to question 5 (section 4.1.4) of the Delphi study. Experts were asked, "*What professional or technical occupations do you think could be created over the next decade?*" The responses provided 434 job roles, these were triangulated with the 2010 and then when fully published in Feb 2020 the 2020 Standard Occupation Classification (SOC) which are maintained by the Office for National Statistics in the UK. Roles of augmentation, compliance and ethical management, with a focus on how people and technology complement and augment one another were presented through the delphi responses and not represented specifically in the SOC versions. A theme of role merging was discovered through the data, elements of the roles provided by the expert panel existed in the SOC versions, however the roles articulated by the expert participants required the marrying of two or more existing roles, suggesting a further readiness and training requirement to meet demand for such roles. This was evident through specialist roles that overlapped with one another.

The next section describes the analysis and findings from the follow up interviews.

4.3 Follow up Interviews

This research design incorporated the option to explore further the findings and themes that emerged from the Delphi study. The Delphi analysis triggered a phase of triangulation with quantitative workforce data and worker characteristics, as captured in the previous section. The follow up interviews were required to pursue the two key themes that emerged from the Delphi stage and data triangulation activity. The interview objectives identified and shared with the experts were as follows:

“*The Research aim is to explore future high-skilled professional work alongside Technological Change. The research interview objectives were to explore:*

1. *The area of 'augmentation' where technology and the human worker could or do complement one another*
2. *The potential human capabilities/skills and requirements that would support future technological and human augmentation as part of future professional roles.”*

4.3.1 Interview Participant breakdown

The Interviewee demographic covered multiple sectors to gather expert opinion and further insight and to limit an industry bias. All participants were experienced professionals meeting the '*expert criteria*' set out in the research design, see figure 3-4 in section 3.5.2. Some interview participants had worked across sectors and all sector experience was recorded. Figure 4-28 records the industry reach from the interviews. The majority were from the technology sector, just over a third which was expected, to seek insight into how technology was being deployed and the skills that they were seeing being required as areas of technological change mature. This was followed by experts within academia, interviewees were from disparate higher education organisations, working in different faculties including Business and Strategy, Science, PGCE and post graduate enablement. The Public sector interviewees provided a range of armed forces, national health and public safety exposure. The remaining three areas that were represented were Finance, manufacturing, utilities and Retail or CGP (Consumer Goods and Products).

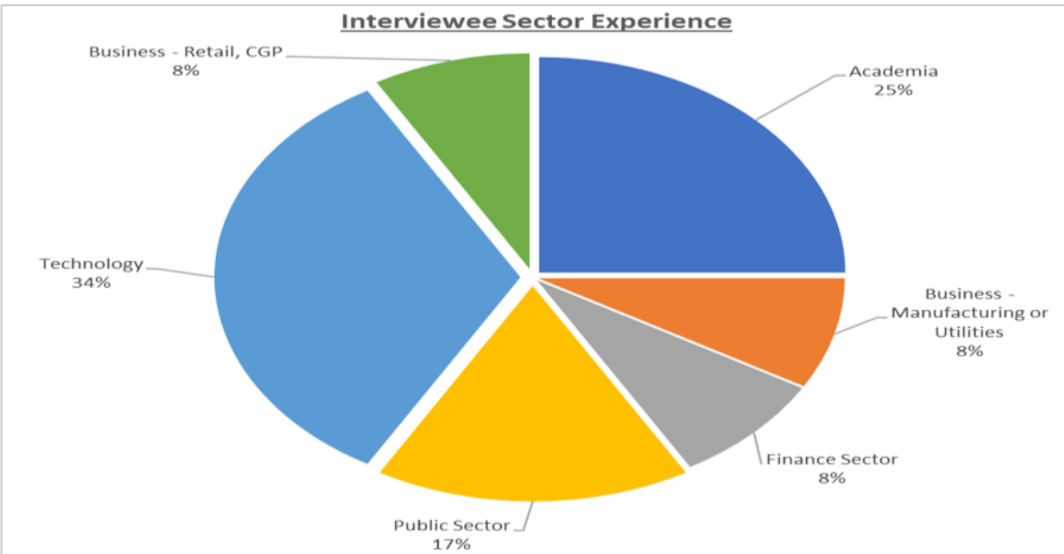

Figure 4-28 Interviewee sector distribution graph

In addition to tracking the industry experience of the interviewees, their professional experience was also captured. All participants had in excess of eleven years experience and 75% had more than sixteen years work experience. There was an equal split of male and female experts interviewed. See Figures 4-29 and 4-30 for a pictoral summary.

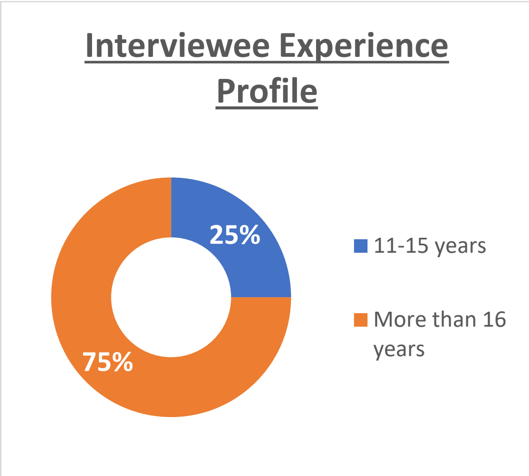

Figure 4-29 Interviewee experience in years

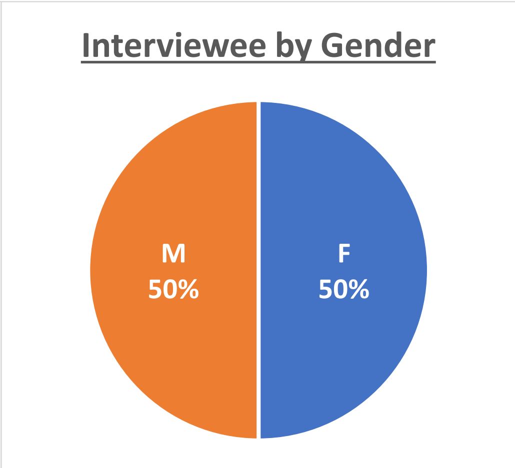

Figure 4-30 Interviewee view by gender

4.3.2 Interview themes

The interviews were scheduled following the analysis of the Delphi study and to explore the:

1. *The area of 'augmentation' where technology and the human worker could or do complement one another and*
2. *the potential human capabilities/skills and requirements that would support future technological and human augmentation as part of future professional roles*

The interviews were transcribed and through participant validation the discussion points confirmed to minimise interviewer misrepresentation. This was to ensure that the researcher had not misinterpreted what the interviewee had said as part of the transcription phase and to further validate the insight from the expert being interviewed. Thematic Analysis(TA) (Clarke,Braun and Lane, 2014) was carried out on the transcribed data and four themes emerged from the data. The dominant two themes being '*Augmentation*' and '*Readiness.*' The other two themes were '*Technological Disadvantage*' and '*Technological Value Add*.' The following sections will outline these in more detail.

4.3.2.1 Augmentation

The thematic analysis process produced themes of automation and augmentation from the Delphi rounds, this was explored further through the semi-structured interviews. Automation related to where activities or tasks that were carried out by people were automated through technology. The automation included tools that enabled workflows to be modelled and replicated that removed the need for manual and therefore human intervention. Examples included automating compliance activities to assist with regulatory requirements, automating regular report generation, automation of scheduling activities when a threshold or defined trigger point had been reached along with documenting of standardised reports and forms. The automation of activities also supported the theme of augmentation, the automation of repetitive activities such as information and data gathering from IOT devices and automation of reports which triggered a phase of augmentation or further automation depending on the next steps in a business workflow. Another area of augmentation captured was where the technology supports the work of the human, such as productivity tools and access to information from big data. A further area of augmentation that was raised related to where humans complement the work carried out by technology to drive more impactful results. Participant 21 stated.

> *"The information that we can now obtain digitally speeds up things and makes us much more efficient and has the capacity to make us far more informed, assuming that the data sources are valid."*

Other Participant quotes included, Participant 9, *"Technology has provided advancement in the ability to work anywhere and to collaborate digitally, however the need for human interaction and rapport still exists. As a society we have never been more disconnected, the skills to collaborate digitally are different and an ability to create trust and rapport digitally is extremely difficult."*

The last quote captured a human comparative advantage, specifically relationship management which was captured as a key skill area that surfaced through the interviews, there was agreement across the interviews that technological change has great potential to enhance the work carried out by people. Understanding the comparative advantage (Simon, 1969; Langlois, 2003) for both the human worker and the technology is important. The role of augmentation and understanding the integration between human and technology was an occupational gap that emerged from the Delphi phase, see section 4.1.3. Where they complement and augment is key and the readiness and preparation for understanding, implementing and developing those skills was another key theme that emerged.

Participant 10 shared an example of where they are seeing benefit from technology augmenting learning,

"I'm starting to see some uses in augmented reality in the classroom that perhaps we didn't see years ago that are going to make learning a little bit more exciting perhaps. If you think, you know, one example I can give is the solar system, rather than looking at images of the planets in a book or on a screen. Now augmented reality enables pupils to be able to have iPads or Chromebooks or whatever it is over images and that then brings that to life. So that has been really useful. There are tools out there for revision as well that are quite useful to be able to enable pupils to perhaps revisit areas that they're struggling with."

Participant 52 raised the importance of having dialogue rather than replying on automated output and flagged that being able to ask questions to understand the logic and rationale behind the decision making is important. This raised questions around the the transparency of technology driven outputs and ethical transparency, with human generated models you can probe and check validity against a specific scenario,

> *"Generally, from having a conversation and asking, asking some questions and having that dialogue with them, you may do a little bit of digging into it like okay, you've said, you've done a cost model. Tell me a little bit more about what you think of it, how have you done it, and then having that dialogue then you can figure out pretty quickly whether or not someone has included those key attributes that you feel you they needed."*

An area of insight that emerged from the interviews when discussing how technology can augment professional roles is one of being '*overwhelmed.*' Participant 52 advised,

> *"We've got all these software programs and information at our fingertips it is knowing what you're looking for, and where to look quite often that can be part of the problem as well, and that's going to be a bigger problem as time goes on."*

This area of mass information was also flagged by participant 14, who called it '*a wealth of Noise,'* this is also captured under the theme of technological disadvantage and highlights that there is a balance to be achieved with what technological change presents to us and how we consume and make use of it. Participant 5 also flagged that there is a risk presented and a level of '*naivety*' when consuming online data. Participant 5 flagged this from an educational concern and participant 52 flagged it as "*misinformation*" that can cause stress and incorrect conjecture by patients when they search their symptoms without any professional context or medical specialist training to augment that information.

When exploring the future potential of work and how technology may impact the work carried out, Participant 14 shared,

> *"If augmented technology is the future, it requires you to be good at what you do now. If you're not good at what you do now*

> *augmenting it won't make it any better. It's a little bit like in the 1970s when computing systems first became affordable, and we computerised organisational processes out there thousands of times faster, thousands of times faster doing the wrong thing it just wasn't very clever, it wasn't a qualitatively different result."*

This raised an important consideration around how technology is adopted and the importance of driving technological value against a defined outcome. Technological value add is one of the four themes that emerged and further findings are captured in sub-section 4.3.2.4.

This view of understanding the existing and also being good at what you do now and how that resonates or gets represented into the adoption of technology was supported by Participant 250, who added:

> *"Technology is going to do what you tell it to? How can technology cater for something that you didn't consider yourself from the onset."*

The conversation with Participant 14 raised further interesting and pertinent insight when discussing their thoughts on 'human skills,' their response included:

> *"the most important thing there, is that word 'human.' The more we look at the things that technology can do, the more work it can do, but not human-like things. What does it mean to be human? I know that it's different, but I don't know what it is."*

4.3.2.2 Readiness

A theme of readiness emerged through multiple channels. One channel was the requirement for people to be able to adopt and adapt to change, this supported the output from the Delphi round 2, specifically question 11(see Table 4-8) which identified a key worker characteristic of being able to adjust to change. The interviews presented that whilst being able to use technological tools people's approach and mindset was an important factor. Participant 10 supported the view that mindset and how people approach technological change is extremely important articulating,

> *"the skills aspect of this is so that we create individuals that that are willing to learn that will embrace change, and then be equipped with the skills to be able to enable them to move into those areas that haven't yet been created with ease rather than see it as a challenge."*

Participant 9 raised that,

> *"how these changes are brought to pass in the workplace is important, ensuring sufficient comms and indeed workshops showing people what the technology is and how to use it."*

This verbatim reaffirms the requirement for readiness activities to be defined and captured including organisation communication plans along with people readiness through skills development.

An area of readiness that emerged which was of great interest and unexpected was linked to skills that were identified as a human comparative advantage but as a result of existing technological advancements such as social media and the ability to work remotely. It was flagged that key human skills are being eroded or not developed through younger generations, which raised a significant concern. Therefore, an area of readiness that was flagged is the need to develop social skills such as human interaction, growing relationships and having empathy. As more and more people work and study remotely the ability to interact and build rapport is waning. Another area identified as needing a level of readiness is to address an emerging theme of data naivety and the ability to develop an analytical and a challenging mentality. Participant 5 asserted,

> *"there can be something really unscrupulous about a digital thread and Technology can be very dangerous, based on the data and algorithms taking you in a certain direction,"*

this was further expanded on,

> *"if people don't have research skills, they can't interrogate the information."*

Participant 21 shared this view identifying,

> *"that people often take data or posted online information at face value without validating or verifying sources or the integrity of the information presented, there is a real sense of data naivety which is of concern."*

Lastly, an area of readiness that complemented the theme of augmentation is that people need to understand the integration points with technology, which drives skills development in the technological areas and also the overlap with the human centric skills captured, such as Empathy, EQ and interpersonal skills to meet key business and citizen requirements and objectives, which supported the findings from question 11 in round 2 of the Delphi study (see Table 4-8). Participant 14 highlighted that whilst technology has transformed academia, an area that cannot be automated or digitalised is student pastoral care,

> *"I think what comes as a great surprise to people is the amount of time you spend stopping students from giving up or several occasions committing suicide and it is only because it has been a person. You know, I've done that a few times myself, that you save people and make a real difference to them. And that emotional connection, away from the prescriptive, this is the job, but just to be a person who's normal, has enormous impact."*

This emotional connection was also flagged by participant 5, 21 and 250. Heightening the comparative advantage for professional roles, across multiple sectors and industry. The interesting themes that emerged from the interviews related to the focus on soft skills and the need to inform people and help them develop life skills to cope with the unknown nature of emerging technological change, which was prioritised by the experts over technical skills.

Participant 10 highlighted a need for readiness in education in relation to students and the access to online learning materials, *“I think it needs to be made clear to those individuals that they're not getting the holistic package if they aren't engaging with humans. So although they could theoretically stay at home and watch a lecture online, they are not then actually in a position where they could engage one to one with the lecturer if they had anything they didn't understand, or they couldn't talk to anyone else in that lecture room. So perhaps we've been too eager just to say that well the video is a replacement for the lecture, but it's not a complete replacement. It's a replacement of the verbal aspects of it. But there's more to the lecture than perhaps up until now we've been willing to actually share”*

This highlights the need for both readiness around the use of technology and also how it should augment the learning process rather than replace it.

The interview output supported the findings from the Delphi rounds relating to skills for the future, a clear theme was the need for pastoral care across sectors. The need for human to human interaction and a concern was raised by experts. It was flagged that whilst technology has enabled remote and digital learning and working, along with creating new channels of communication; they believed that this has and is affecting people’s mental health along with the nurturing of the required interpersonal skills which poses a technological disadvantage.

4.3.2.3 Technological Disadvantage

Along with the concerns raised above on the risk to an individual’s mental health as a result of technology powered isolation another area that emerged was linked to the rise in access to data. A sense of being overwhelmed by the sheer abundance of information that people can access or be directed to through multiply channels. Participant 14 highlighted,

“There's lots of stuff but they're not really things I actually need. It's like, I suppose walking into the British Library without an index of books. When I only need one or two, we are bombarded with this information. I wonder if something like big data is an offshoot

> *of that. Wow look at all this data we've got. Yeah, what could we do then? I don't know. But it's great."*

It was also raised that people need to be able to filter information more than ever before, email provides a reply to all for example, online channels push articles and targeted retail prompts. Criminals target people through digital channels mimicking individuals and organisations. All these additional pushes of data to people creates a wealth of "*noise*" (Participant 14). To be able to deal with the '*noise*' people need to have strong skills such as prioritisation driven by analytical and evaluation abilities to make the right decisions and be able to filter out irrelevant and also risky information or requests that are sent them. Participant 5 supported this view articulating,

> *"Students have a bank of information within the internet, but it's actually then teaching them the research skills and how to distinguish good and bad information, what they do with that information, how relevant is for their life and you know, all the implications of that."*

The contrasting element of this concern is that with the right skills and filters technology can provide great value to individual, business and society.

4.3.2.4 Technological Value Add

Participants shared the risks that they saw as outlined above, an area of interest that emerged was the necessity for being able to understand the technological value add and how this was linked to successful adoption. Participant 10 raised that people approach change differently and it is common for people to experience an element of fear. Participant 21 noted that,

> *"Going back many years, six sigma and lean were regularly applied to optimise processes. I think there's a huge demand coming for this approach. I don't think what we're seeing is particularly new, I just think people are quite a bit overwhelmed, and also a bit frightened or in fear of what technology could do*

> *based on media representation. I think until people understand the outputs and what they're trying to achieve from the technology I don't think we'll move forward. Processes need to be optimised and well understood before they can be automated or the required outcomes clearly understood before technology can be used to achieve them."*

This focus on value add drives a set of roles and skills for future work, an ability to identify, articulate and capture business or social outcomes that technology can help achieve. As stated by Participant 21 this not a new phenomenon. The theme of value add was supported by Participant 5 who strongly shared,

> *"I am an early adopter, if I see something is beneficial, I'll just take it on, but I won't do that without being informed. I won't just go for the glitzy, it's shiny. If it is some new technology in a way, I get a little bit cynical. I think, let's have a look, do I want to adopt this? Do I want to invest in understanding this tool and learning specific skills about it?"*

This approach supports the need for understanding value and also the need to have evaluation skills to be able to assess the value to their professional environment. The adoption of technology requires an investment of users time and understanding, Participant 9 and 10 also supported this view, that the use of technology is not straightforward and without demonstrable value to those consuming it adoption will be difficult.

4.4 Findings and Analysis summary

The findings from the three research phases, the Delphi study, the triangulation with employment and O*Net data along with the follow-up interviews were mapped using mind mapping software to help consolidate the analysis and findings to inform the discussion element of this thesis. See Figure 4-31 overleaf. The findings will be discussed in the next chapter, Chapter 5 Discussion.

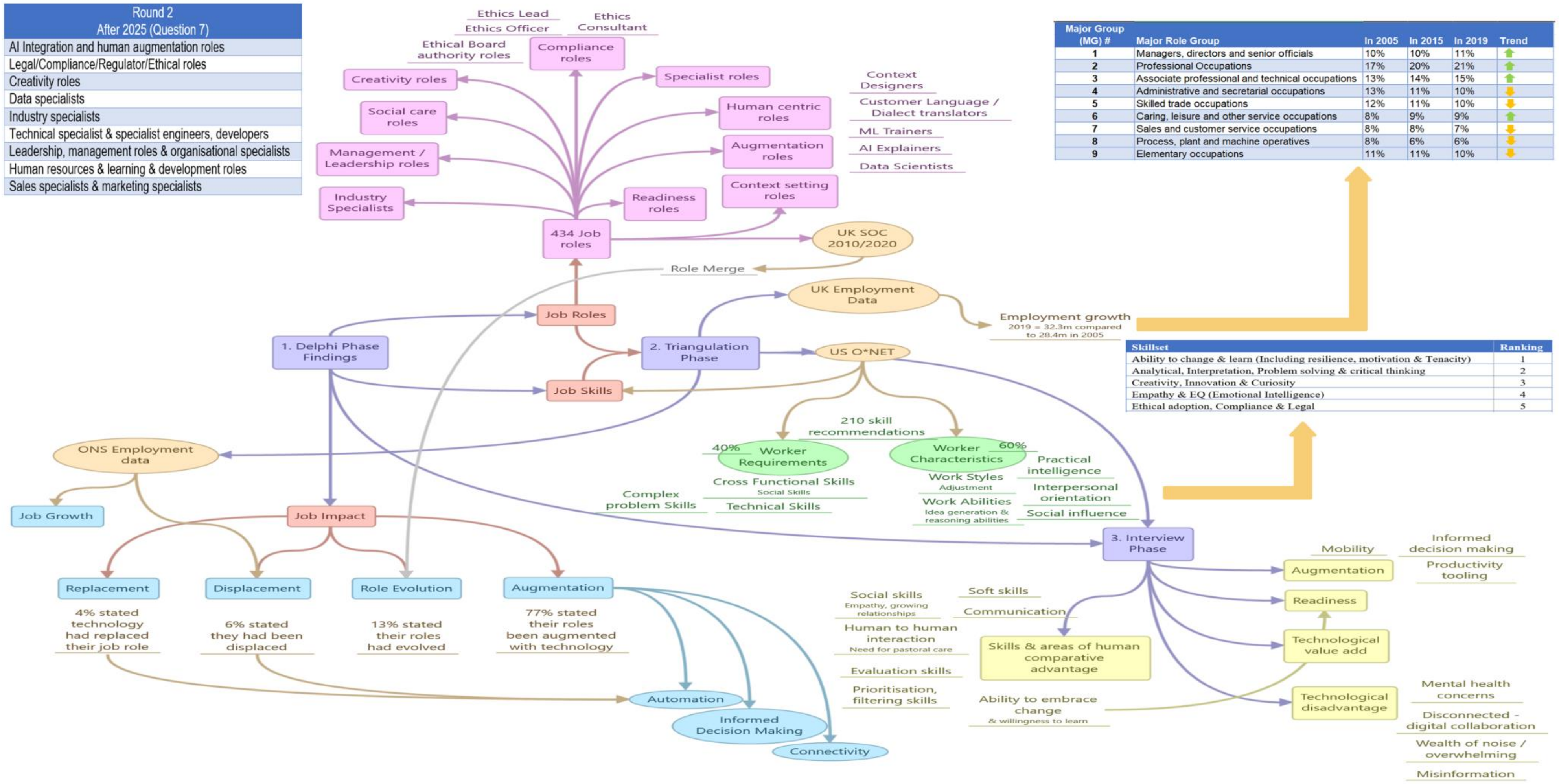

Figure 4-31 Research findings mapping

5 Discussion

5.1 Introduction and chapter structure

This thesis explored an identified gap in the literature, as outlined in Chapter 2. The research aim and objectives that were achieved in this thesis are captured below in Figure 5-1.

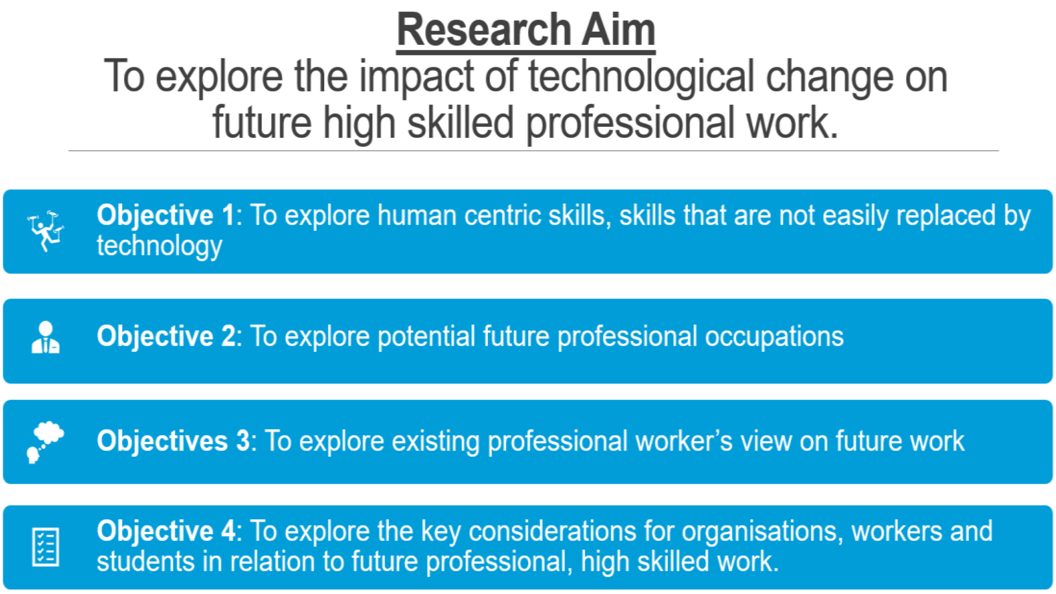

Figure 5-1 Research aim and objectives

Figure 4-31 at the end of Chapter 4 captured a diagrammatic summary of this research analysis and findings chapter. The research aim, to explore the impact of technological change on future high-skilled professional work was achieved by gathering expert insight, through a two round Delphi study, followed by a phase of triangulation with data from the UK Office for National Statistics and the US Bureau of Labor. The initial findings were further validated through follow-up semi-structured interviews and the whole data corpus revisited to further analyse the responses from the expert participants. To structure the discussion in this chapter alongside the research aim and objectives the chapter is structured into seven sub-sections. Starting with a high-level initial discussion on the findings, section 5.2.

The third to sixth sub-sections respond to each of the individual research objectives. With a summarising seventh sub-section that closes the chapter before moving to the conclusion chapter, Chapter 6.

5.2 High-level findings

The Delphi Study presented several key themes relating to:

1. The expert panel experiences of job impact to date of technological change
2. Views on potential future professional job roles
3. The key future skills that the panel believed would be required alongside the emerging technology.

The first point above, impact to date of technological change, four themes emerged, replacement, displacement, role evolution and augmentation. A low number of the panel, 4% highlighted that they had been in a role previously that had been replaced by technological change. This supported the view of Frey and Osborne (2017) and the earlier views of Keynes (1933) who both claimed that technology would substitute peoples work and the theme of technical unemployment. However, despite the 4% of the panel went on to seek and obtain further employment, which could be interpreted as supporting the second theme of displacement (Levy and Murnane, 2004). The 4% were recorded as replacement, to capture the direct reference made by the participants, who specified, head-count reductions and redundancy as a result of technology. The second theme of displacement related to 6% of the expert panel responses. Captured that technology had meant their roles had led to them having to switch roles and even sectors in some cases. Examples included operators who had to retrain to become programmers (Participant 14) and participant 58 shared an experience from within financial services stating that there was,

> *"significant displacement of traditional roles with technical roles - so no net reduction of headcount, but a need for people with different skills to support digital transformation."*

An observation of the comments relating to examples of displacement demonstrated an activity of upskilling and training in technical or digital skills. This upskilling supports the views from the literature review on job polarisation,(Levy and Murnane, 2004; Goos and Manning, 2007; Goos,Manning and Salomons, 2014) with workers upskilling which further supported the theory of skills bias technological change(SBTC) (Autor and Acemoglu, 2010; Caines,Hoffmann and Kambourov, 2017; Benzell *et al.*, 2019).

In addition to the 10% that referenced exposure to both job role replacement and displacement, 13% of responses highlighted a theme of role evolution. Stating that their role had not disappeared, technology had changed the work they carried out, the role had evolved alongside the technological change. This role evolution is not something that was presented in the existing literature.

The remaining 77% of participants shared a theme of augmentation when responding to how they felt technology had impacted their roles to date. In relation to how technology had augmented their roles, three key areas emerged. Automation, Informed decision making and connectivity. The theme of augmentation reinforced the views of Billings (1991; 2018) and Webster and Ivanov (2020), who both highlighted the importance of humans being in control, at the centre with technology supporting the human worker. The detailed findings on the types of augmentation and how technology integrates with the workforce addresses a gap in literature that was flagged by Aicardi (2018), who highlighted the need for further research to explore the relationships between technology and the workforce specifically how they interface. The findings presented that technology augments people. Technology integrates through automated processes and tooling, through informing decision making and connectivity tooling. The second area returning to the three areas set out at the start of this section, related to the views on potential future professional job roles. The Delphi study returned 434 job roles along with the stack ranking of roles that the panel thought would be in demand between up to 2025 and the stack ranking after 2025. The top two stack ranked role groups aligned with the roles that were put forward by the panel. Integration and human augmentation roles along with compliance and roles that focused on ethical adoption. The Delphi phase presented several roles that the panel believed would be required in the future alongside technological change, context designers, customer language/dialect translators, machine learning trainers, artificial intelligence explainers and data scientists. These roles involved human centricity and the focus on protecting human values and establishing applications of artificial intelligence for good. The focus on ethical compliance roles supported the request for further research (Stahl,Timmermans and Flick, 2017; Dwivedi *et al.*, 2019) on understanding how technology will be adopted and the ethical consideration in the workforce.

The third area highlighted at the start of the section related to the key future skills that the panel believed would be required alongside the emerging technology. The highest stack ranked skill for professional jobs in the future alongside technological change was an '*Ability to change and learn*. The interviews presented a further level of detail that enhanced the insight from the Delphi rounds. They emphasised the importance of understanding the reasons behind the technological change being adopted. Stressing the importance of the value proposition being identified and understood, which supported a requirement for evaluation skills, which were stack ranked 2nd in the Delphi study, under '*analytical, interpretation, problem solving and critical thinking'* (See Table 4-8). This need for understanding the 'why' supported the views of Boyd and Huettinger (2019) and Bessen et al. (2020a), who highlighted that because something is technologically possible, it does not mean it will or should be adopted. This is also supported by the earlier views of Billings (1991), who referenced the aviation sector and the importance of human centric automation. Understanding the '*why*' is a key human comparative advantage. It requires '*analytical, interpretation, problem solving and critical thinking*' skills. These skills were highlighted in the findings as the second most important skillset grouping for future work, followed by '*creativity, innovation and curiosity*.' The need for these skills to be applied by professional people in the workplace aligns with '*Polanyi's paradox*' (Polanyi, 1966; Autor, 2014), highlighting the importance of '*tacit knowledge*.' The ability to apply the skills such as problem solving and creativity, driven by curiosity to interpret problems and challenges is '*tacit*.' This research highlighted that technology informs and provides workers with tooling. However, the contextualisation presented within this thesis of the situation is a human comparative advantage. This again supported the view presented by Billings (1991) who articulated the importance of the pilot retaining responsibility for flying the plane. Whilst the technology could automate the process the inconsistencies such as the weather or mechanical failure anomalies required human intervention to evaluate the '*sum of the parts'* (Polanyi, 1966) rather than the '*explicit knowledge*' of the individual parts, the wider context. The ability to evaluate the wider context is a human differentiator which was highlighted in the research findings of this thesis.

A significant finding was captured by Participant 52 as part of the follow up interviews, they highlighted a challenge that technology presents, the '*misinformation*.' This was supported by other participants (Participant 5 and 14) referring to the '*noise*' technology can create and the need for people to validate and verify the information. This need for validation supports the future requirement for professional workers to possess analytical skills. Emphasising technology presents a view, through data. "*A bank of information*" (Participant 5) the challenge that workers and organisations have is the filtering and applicability of that information, this drives a requirement for humans to be able to apply that context and applicability to drive value from the data being presented. They need to complement one another.

An area of interest that emerged from the Interviews was the need for human to human contact in relation to individual pastoral care. The Delphi phase captured the need for '*Empathy and Emotional Intelligence skills*' which was reinforced through the voice of the interviewed experts. That technology cannot and should not replace the requirement for pastoral care was stressed by multiple interviewees. This supported the views presented through the Delphi findings, that captured the required skills of empathy and emotional intelligence. Hess and Ludwig (2018) raised that they saw a comparative advantage for humans over smart machines, capturing the skills already mentioned, critical thinking, creativity. They also cited emotional engagement of others and collaboration, although they did not articulate what that would look like in the workplace. This research has provided further clarity and specificity on the comparative advantage for workers. Whilst Hess and Ludwig and others (Simon, 1969; Aicardi *et al.*, 2018) captured a comparative advantage they did not focus on the why or how that would be applied in the workforce. Participant 14 captured the enormity of the significance that people have on others, the emotional connection, which is not prescriptive, technology cannot and should not replace the '*pastoral care*' activities that humans carry out. This was further reinforced by other participants (5, 21 and 250) who highlighted the augmentation with collaboration tools and the digitalisation of aspects of work as driving an increased need or demand for human to human interaction. When evaluating the literature on the impact of technological change and future work the focus was on what the technology can do and where it replaces rather than where it should not replace or substitute. Simon (1969) captured that there would be 'fraternisation' in the future with technology, highlighting robots. This thesis has highlighted the importance of maintaining the collaboration between people and how technology should not substitute this human necessity. This supports the trend recorded (Aicardi *et al.*, 2018) in an increase in healthcare roles which require the human to human interaction and empathy.

The participants also raised concerns that the increase in technological adoption could be linked to mental health concerns from isolation due to the ability to work and learn remotely. This is an area that would require additional research and could be a future consideration for ethical adoption and compliance which was captured in the Delphi study. What was of interest from the Interviews and observed in the output from the Delphi study was the focus on the softer skills or '*Worker Characteristics'* as defined by the O*NET (US Bureau for Labor, 2019; 2020) rather than the *'specialist*' and '*technical skills*' or as defined by the O*NET, '*Worker Requirements.*' The output from the Delphi phase explored the area of '*augmentation*' with interview participants, all agreed that technology was a fundamental part of their roles in multiple ways. Examples included automation of report generation, repeatable activities some of which could be triggered without human involvement and workplace tooling, ranging from sophisticated devices including robotics to productivity tools augmenting workplace communication and digital interfaces. The interviews supported the views of the Delphi study, capturing that readiness is required in several areas, adoption is linked to people's ability to embrace the change and understand the value that can be realised. Understanding the options for augmentation are also key, where technology starts and ends and leveraging the human comparative advantage through those human centric skills, such as '*empathy, relationship nurturing and management.*' Applying '*analytical and problem-solving skills*' alongside data presented from automated intelligent solutions. '*Communication*' was flagged as a key component of '*readiness,*' helping people understand the value that could be achieved through technological change is key to minimising the fear of the technological unknown and flagged as a conduit of adoption. The experts flagged that the adoption of change is not a new phenomenon, developing the right worker characteristics are key.

The skillsets that emerged support the views of Autor (2015) who highlighted the skills that humans have a comparative advantage in. The ability to communicate and have analytical capability and skills were flagged as key. Hess and Ludwig (2017) reinforced this view of comparative advantage skills for humans, capturing critical thinking, creativity, emotional engagement with other people and being able to collaborate effectively.

Figure 5-2 captures the findings against the four research objectives that were achieved. The next four subsections will discuss each of the research objectives against the findings.

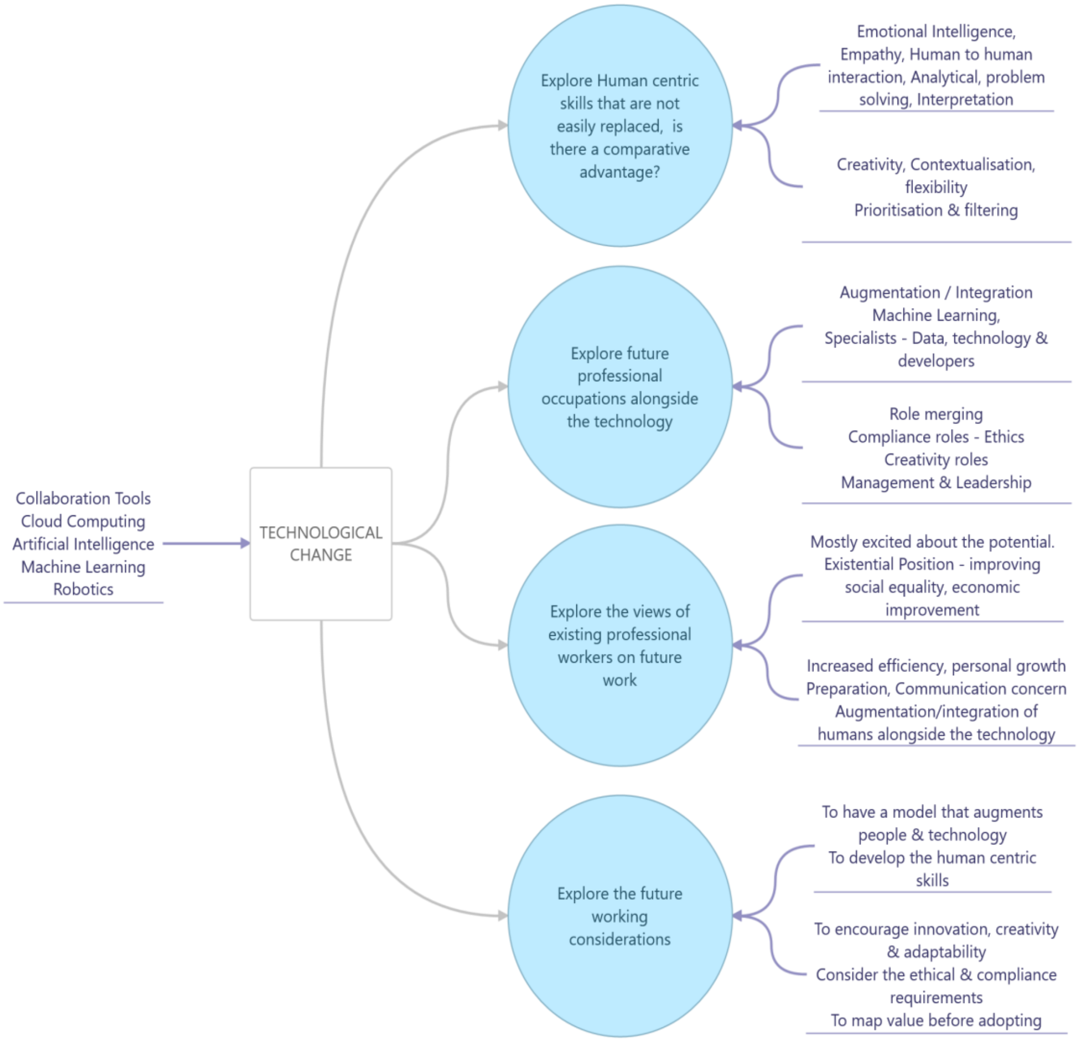

Figure 5-2 Findings consolidation map

The next section will discuss the first research objective against the finding:

Objective 1: To explore human centric skills, skills that are not easily replaced by technology

5.3 To explore human centric skills that are not easily replaced or carried out by technology

The Delphi rounds presented a number of skills that the expert panel believed were key to future work alongside technological change, an '*ability to change and learn and this included resilience, motivation and tenacity.'* The interviews also confirmed the importance of these attributes and highlighted the importance of the '*human to human*' interaction. The emotional support that humans provide to each other through the workplace, the need for context when evaluating multiple feeds of data. The findings highlighted a requirement that professional roles must evaluate what is going on around them to draw informed decisions, the variability that exists in decision making and also identifying high risk emotional situations such as medical diagnosis with patients that have complex medical backgrounds or lecturers who identify mental health warnings across a class to enable intervention. In business the evaluation of multiple objectives and goals against a complex organisational structure and the mapping of technological possibilities to help achieve those goals all underpin the human centricity of tacit skills (Polanyi, 1966; Autor, 2014). Polanyi, captured this as,

> "*It has shown that within a whole its parts have a functional appearance which they lack in isolation and that we can cause the merging of the parts in the whole by shifting our attention from the parts to the whole" (Polanyi, 1966, p.3)*

Technology provides great value in isolation through discrete tasks and activities, through productivity tooling, informing with data collection and analysis, automating repeatable tasks, providing enhanced networking capability and supporting the human in delivering '*the whole.'* Humans and technology complement one another, technology provides tooling and humans apply that tooling with '*analytical, interpretative, problem solving and critical thinking skills.*' In addition to this the '*creativity, innovation and curiosity,'* that humans bring enables growth and efficiency. This research highlighted the requirement for people to understand and evaluate the value that technology would bring to their environment, this supported the view of Smith (1776), Schumpeter (1934) and Weitzman (1998) who believed that people find new ways of doing historical things which then generates new concepts and ideas, therefore driving innovation through new inventions. Schumpeter referred to this as, "*development consists primarily in employing existing resources in a different way, in doing new things with them*" (p.68).

Weitzman called this *'recombinant innovation,'* the significance is that innovation is driven by humans, automation is driven by people looking for more efficient ways to do things, this view is supported by others (White, 1931; Metcalfe,Leontief and Duchin, 1988; Vivarelli, 2012; Dachs and Peters, 2014b). This is achieved by humans augmenting their social skills, empathy and relationship building and ability to interpret and evaluate a situation or scenario. The research highlighted that whilst specialist technical skills are important, how people approach work is key. The '*Worker Characteristics'* are a fundamental part of work, and an ability to adjust and change and to embrace learning is required for future work alongside the emerging technological change. This supported the view set out by Autor (2015) who referred to a comparative advantage which workers have over technology, citing, "*interpersonal interaction, flexibility, adaptability and problem solving*" (p.27). Autor also highlighted '*abstract*' tasks which are key to the human comparative advantage tasks, carried out by professional occupations, including managerial roles. This reinforces the earlier point of view that there are tasks that are difficult to automate within the service industry (Autor and Dorn, 2013). Highlighting that these jobs require, "*dexterity, flexible interpersonal communication and direct physical proximity*" (p. 36).

The findings from chapter 4 in relation to human centric skills come together to form a model of human competency and contextualisation. Figure 5-3 captures the model. The model depicts four competency areas that humans have a comparative advantage over technology. Firstly, humans 'assess,' applying analytical, interpretation, problem solving and critical thinking skills to a situation or specific problem, in addition to assessing situations humans 'create.' They create through curiosity and applying creative thinking. People innovate and present solutions or options to address the situation or problem they have assessed. A third area is how humans can 'relate,' through empathy and emotional intelligence competencies. The 'relate' competency supports the views of Nedelkoska (2013) who highlighted the human advantage of empathy and compassion. Along with Webster and Ivanov (2020), who also captured emotional intelligence and interpersonal communication, along with problem solving as human centric skill areas, which supports the assess competency in the model. The fourth segment of the model is 'adapt.' The ability to change and learn from situations which then feed into future assessment activities.

The model of competency, supports and builds on Polanyi's (1966) theory of tacit knowledge, the sum of the parts present a further human comparative advantage of contextualisation, the ability to 'assess, relate, create and adapt' differentiates humans from technology which creates a significant consideration for the future workforce planners and policy makers. An observation from the findings is that technology complements these competencies, it provides tooling for helping humans assess through informed decision making driven by data, it underpins the human ability to create and enables adaptation through learning tools and programmes and the relate competency is augmented by collaborative tooling and connectivity. A further area of human comparative advantage that was captured in the findings was the ability for human workers to filter and prioritise work and information, this is also captured in the model as a reoccurring activity that human professional workers apply as part of contextualisation.

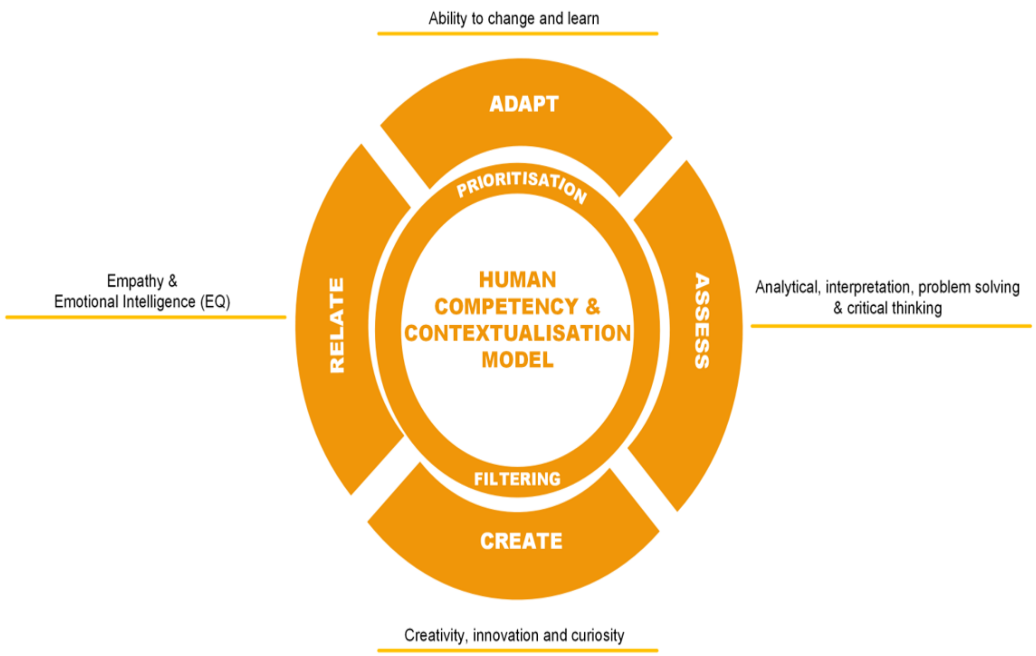

Figure 5-3 Model of human competency and contextualisation

The next section will discuss the second research objective,

Objective 2: To explore potential future professional occupations

5.4 To explore the potential professional occupations in the future alongside technology

This research presented 434 job roles, the majority of which already existed within the Occupation Classification, SOC (Office for National Statistics, 2020c) in some form. There were several role areas highlighted that could not be matched to the existing roles in the SOC. A number of these focused on how humans augment technology to maximise the potential of integrating existing areas of specialism. This augmentation cut across multiple role areas highlighting a requirement for roles to merge to drive context. A significant finding was that technology is no longer a separate role it is embedded as part of all roles and industries. The embedded nature of technology drives a need for digital and technological enablement across all sectors. This supported the view expressed by Coplin (2013; 2014) that technology needs to be optimised by a balance of human involvement. The integration between professional workers and technology also supported the views of Deming (2017) who described the "*increasing returns to skill as a product of the complementarity between technology and high-skilled labor"* *(p.1594)*. Also reiterating the importance of the comparative advantage skills that was discussed in the previous subsection 5.3. Two areas were flagged from the findings in relation to future job role considerations, they were roles that focused on integration and augmentation with technology and the second was the need for compliance, regulation and roles that considered the ethical adoption of technology. When asked if technology had impacted their work previously, 77% of the responses provided by the expert panel of professional workers shared that their roles had been augmented by technology. Capturing aspects of work that had been automated, technology had enabled more informed decision making (it was noted in this research that it was flagged that automated reports still require human validation). Other augmentation examples included improvements in connectivity and digital collaboration tools.

A further pattern that emerged from the data when triangulating the 434 roles with the UK SOC was role merging. Where roles presented by the panel such as Data scientists crossed over the SOC occupational groups. Data scientists use technical and data specialist skills within specialist areas or industries, this could be financial services, health care, public safety. A key component of the data scientist role is the context knowledge is required to drive the value from the data. The roles are business led, but require mathematical competencies along with technical, programming skills. '*Machine learning roles*' are another example of where the skillset for that area already exists today across three or four roles. A Machine Learning specialist is not a defined or captured role in the 2020 SOC, the skillset for such a role crosses multiple roles, software developer, mathematician and statistician. A further example that emerged from the findings was a role of machine mentor, which merges roles that understand the technology such as a developer or technical architect with behavioural scientists, merging the human and social science with the technology. An additional occupational area that demonstrated the merging of roles is within healthcare, professionals require additional operational technical skills to integrate the emerging technology with their specialist medical skills and knowledge.

The World Economic Forum (WEF) (2018) captured a set of stable (indicating roles that would remain) and new roles that they believed would be required in the future, the findings align to the roles in the WEF 2018 report supporting the gap in the SOC listings on machine learning as a discrete occupational group.

This research highlights that future work is predicated on a model of coalescence, being one of integration and augmentation of technology with human skills and optimised by human characteristics and competencies such as assess, create, relate and adapt, that were set out in the previous section 5.3. This supported previous literature from two parallel areas. One which reports on the technological progress (Stone *et al.*, 2016) the AI progress and the eleven areas discussed in section 2.5 which included Machine learning. The second being the contribution from Autor (2015) and Polanyi (1966) who highlighted the importance of the human tacit skills. The findings have brought together the two documented areas and acknowledged the requirement for technical and mathematical based roles to consider more contextual skills as captured by Autor.

The findings build on the claims of Makridakis (2017) who captured the '*pragmatists*' view, which presented two elements. The first was the duplication of '*human intelligence*' followed by '*augmentation*.' Where humans manipulate the technology to maximise the human capability, referring to "*intelligence* *augmentation*" (p.52). This thesis confirms the importance of the '*intelligence augmentation'* and future professional work should consider the readiness and skills development of workers to meet this demand. The findings from chapter 4 highlighted the requirement for specialist workers in the future alongside technological change. Table 4-3 in section 4.1.4 captured the emphasis on specialist roles in the future. This supports the theory of skills bias technical change (Autor and Acemoglu, 2010; Caines,Hoffmann and Kambourov, 2017; Benzell *et al.*, 2019).

This thesis has presented potential future roles that focus on the management of technology to maximise human capability. Data scientists, machine mentors, machine learning specialist and augmentation roles.

A further area of significant focus that emerged from this research when exploring the potential professional occupations of the future was the need for governance roles. Specifically, ethical governance was an emergent theme. The WEF report (2018) as referenced above highlighted several roles that would remain and be created, compliance officers were captured as a role expected to be required, however the report did not specifically call out roles that focused on the ethical considerations of technological adoption. The findings captured the following roles as being a future requirement for professional job roles alongside technological change:

"*Ethics Officer"* (Participants, 4, 12, 35, 46, 51,59 and 233).
"*Ethics Lead"* (Participant 222)
"Ethical authority roles" (Participants, 26, 215, 20)
"*Ethics Board roles"* (Participants, 33,50 and 60)
"*Ethics Roles"* (Participants, 8, 27, 31, 48, 64, 220 and 238) and lastly
"*Ethics Consultant"* or "*Specialist"* (Participants, 37, 40 and 42).

This thesis supported the limited view presented in existing literature (Stahl,Timmermans and Flick, 2017; Dwivedi *et al.*, 2019) for further understanding and research to consider an ethical standpoint. Stahl, Timmermans and Flick invited further analysis to be carried out to explore answers and potential scenarios relating to future workforce considerations and the relationship people will have with intelligent technology. Supporting the view that there is a significant gap in existing literature on how intelligent technology could integrate and complement the workforce. This thesis has presented a number of roles that should be considered when evaluating future professional occupations. The roles fall into two key areas, the first an area of augmentation that maximises the human comparative advantage (which supports the findings of the first research objective, see section 5.3) alongside the intelligent technology. The second being a need for governance and compliance over the application of the intelligent technology. Other roles were presented in the findings, for example technical and non-technical specialist roles, with management and leadership roles and roles that focused on social care. The two areas that have been highlighted represent the areas that are not represented in existing job role classifications, such as the SOC.

The next section discusses the third research objective, which explored the views of professional workers on the topic of future work.

Objectives 3: To explore existing professional worker's view on future work

5.5 To explore professional workers views on future work

Overall, the views of the expert panel were positive, when asked to provide a quantitative rating on how they felt about future impact on professional occupations. However, a theme that presented itself through the participant verbatim was that there was a perception of historical unemployment as a result of technology and this was evaluated through triangulation with employment data, (Office for National Statistics, 2019). The triangulation confirmed that overall, from

2005 to 2019 employment had increased, supporting a view of job creation rather than unemployment. The data showed some evidence of job role movement across the major occupation classification groups, which supported the claims on displacement (Autor,Katz and Kearney, 2006; Goos and Manning, 2007; Goos,Manning and Salomons, 2009; Autor, 2010; Heyman, 2016; Fonseca,Lima and Pereira, 2018) there was no evidence of unemployment in the overall job numbers. This highlighted a requirement for awareness and clarity in relation to how technological change is communicated to help address the negative perception. Significant literature exists (Bostrom, 1998; Kurzweil, 1999; 2005; Frey, 2012; Frey and Osborne, 2013; Bostrom, 2017; Frey and Osborne, 2017) that portrays a *pessimistic* view. Makridakis (2017) referred to four views, the pessimist being one of them. This thesis supports the pragmatist views set out by Makridakis with technology augmenting human work. The respondents when asked to score, on a scale of one to ten (ten being positive) how they felt about future professional work alongside technological change, an average of eight out of ten was presented. Additional insight was gathered through the interviews to help explore the views on future professional work, and the premise of value-add was presented, highlighting the importance of understanding the value technology can provide and the significance of this being understood. This supports the views of Boyd and Hettinger (2019) and Bessen (2020a) who stressed that because something is technically feasible it does not mean that it will be adopted, there needs to be clarity on why the technology is required to aid its adoption.

This supports the views shared in the Delphi stage in relation to readiness, highlighting that there is a requirement for clarity to be shared by organisations on the benefits of technology and how it supports work rather than destroy it. The expert panel also identified the need for ethical compliance and governance around the augmentation of how technology is embedded and applied, and this is an area that requires further research and definition. This supported the views of Stahl, Timmermans and Flick (2017) that were referenced in the previous subsection 5.4, who highlighted the importance of ethical considerations.

Policy making along with audit and compliance are not new role considerations, the research analysis categorised this as an area that required updating and readiness as the technological change areas mature. A key theme that emerged from the views was that people need to be more informed and readied for the future, acknowledging that the '*how*' work is conducted is changing, rather than '*what*' the work is. Data and communication were the two main considerations, acknowledging that how people accept and use data needs to be through a much more analytical, evaluative and sceptical way, challenging and proving its integrity and validity in the context that it's being applied.

For communication this raised the need for more awareness and readiness on how to communicate in a digital world, empathy, human interaction and building rapport were captured as key human skills. Further consideration is required as to how people can develop and grow these attributes within a digital world, the concern that was raised in relation to this was that technology has made us increasingly more digitally connected. However, there was a perception that interpersonal skills and people's resilience were being impacted by the lack of human to human interaction and this raised further concern around people's mental health through isolation, an area that requires further research and consideration. This does raise the question whether our communication skills have not advanced in line with the technology and resonated with the views of Huxley back in 1937 who believed that "*Technological progress has merely provided us with more efficient means for going backwards*" (p.8).

The next section looks at the last research objective,

Objective 4: To explore the key considerations for organisations, workers and students in relation to future professional, high skilled work.

5.6 What the future working considerations alongside technology should be

Technological change is driven by the needs that arise from people and organisations, examples include; labour saving through automation, informed decision making from enhanced data analytics, robotics for dangerous or labour intensive activities, improved efficiency on specific tasks and activities and the ability to communicate with anyone virtually anywhere all have led to the requirement for additional training and readiness. The US O*NET Content Model (see appendix 8.10) (Bureau of Labor, 2020) captured skills, knowledge and education as Worker requirements. This thesis supports the O*NET and captured that future professional work will require specialist skills, both technical and non-technical. In addition to the specialist skills this research captured the need for social skills when exploring future professional work. This supported the views presented by Winterbotham at al et. (2018) who captured that there were shortages of required skills, highlighting 'technical' and 'practical' skill areas.

This research has generated fresh insight into the competency considerations for future professional workers. Capturing a link between how people approach work and the importance of worker characteristics in addition to the workers requirements mentioned above (see Figure 5-4 below for a copy of the model presented in section 5.3).

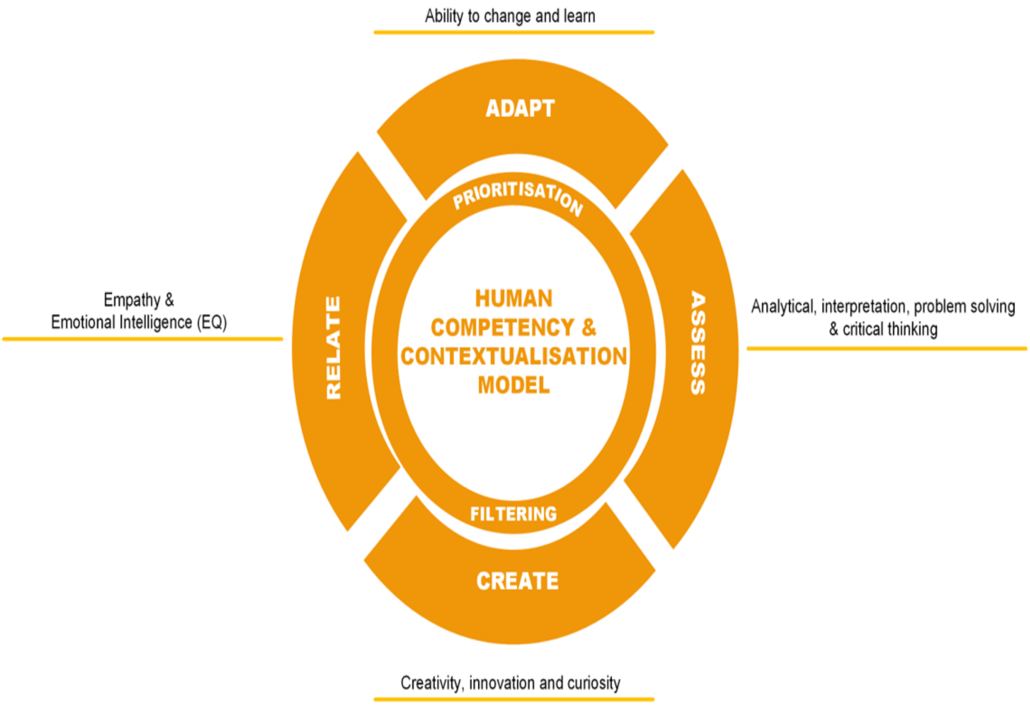

Figure 5-4 Human competency and contextualisation model

Existing literature (World Economic Forum, 2018; Winterbotham *et al.*, 2018) has focused on worker requirement skills with limited attention given to workers characteristics. This research offers an enhanced understanding of future worker considerations when exploring technological change and future high-skilled professional work. It has highlighted the importance of supporting workers in understanding and preparing for *'how'* they approach work in the future, building and developing key characteristics, such as analytical mindsets, a thirst for learning and growth, driving problem solving approaches to look for solutions that augment the technology. This research has presented a competency model for Human Resources (HR) teams to consider and integrate into employee training plans. In addition to HR departments the competency model can also help inform education strategy and policy, to develop courses and programmes that encourage individual workers and students to develop their worker characteristics. Existing

National Curriculum policy and approaches have focused on the future worker requirements, teaching of knowledge and subject matter skills, limited consideration is presented to future worker characteristics and abilities. The significance of this research is that it raises further considerations for HR policy setters and education policy owners to develop approaches that incorporate the worker characteristics that make up the competency model in Figure 5-4. The comparative advantage of understanding the context supports the earlier views of Autor (2015). Autor referred to '*purposiveness*' and how this was a limitation of machine learning (ML) where ML regularly will get things correct but will miss key exceptions.

A further consideration is required to establish a consistent ethical model for digital interfaces and technological augmentation. This research highlighted several role considerations that organisations need to evaluate alongside technological change. The expert panel believed that there would be a demand for roles that focused on the ethical aspects of technological change adoption along with human centric roles that augmented technology with human behaviours. Machine learning trainers, AI explainers, language translators, data scientists that focused on business outcomes and context designers. The highlighted future ethical job role considerations are consistent with Stahl, Timmermans and Flick (2017) and Dwivedi et al. (2019) who identified the need for further research and consideration to the ethical considerations associated with technology, specifically acknowledging AI.

Understanding the whole versus the segment (Polanyi, 1966) is another human centricity that needs to be encouraged and developed in future workforces. Furthermore, a set of worker characteristics was identified that need to be enhanced and developed across industries to protect and grow the human comparative advantage. This research has highlighted the need for focus on how people approach work alongside the more measurable or taught skills. This research builds on the theory of tacit skills set out by Nelson and Nelson (2002) and Autor (2015) along with the views of Makridakis (2017) who captured the importance of augmented intelligence.

This thesis summarises the findings into two models, the first was captured in figure 5-4, the human competency and contextualisation model, which represents the key human centric skills that organisations and policy owners should consider when evaluating future training and development requirements for students and workers. In addition to the competency model a workforce coalescence model, see Figure 5-5 captures the technological change areas along with the identified human skills and abilities required to augment the technology, with a need for ethical compliance and governance oversight. The coalescence model depicts how human contextualisation augmented with the emerging technology enables economic and organisational growth. The key considerations for academic, corporate organisations along with Government departments specifically Education and Business, Energy and Industrial Strategy departments is how they prepare for the future labour force demands and address the skills shortage that has been highlighted within high skilled professional work (Winterbotham *et al.*, 2018; Edge Foundation, 2020). This thesis advises on key competency areas that policy education and learning owners should include in future training and readiness plans, policies and strategies.

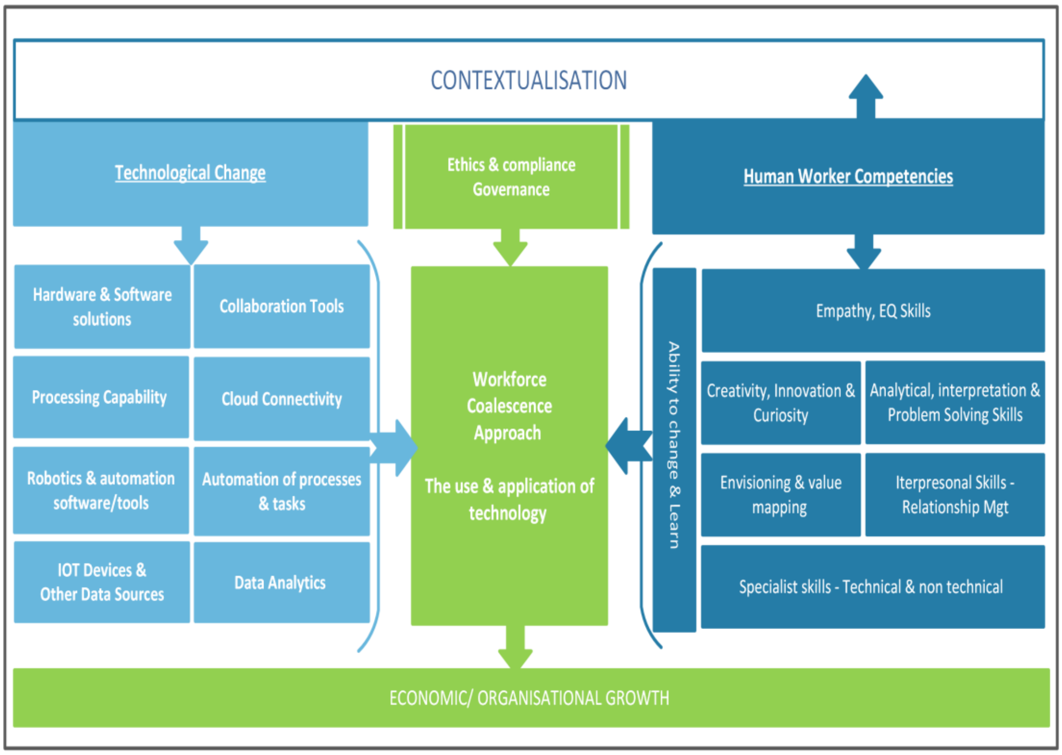

Figure 5-5 Workforce Coalescence model

5.7 Discussion Summary

To summarise, the key considerations for future professional work alongside technological change, there is a need for readiness and a review of how existing and future workforces are enabled to augment and drive innovation which is key to future economic growth (Weitzman, 1998). Worker characteristics such as how people approach work is key, developing an ability to be able to adapt to change and learn and relearn. This requires attributes such as resilience, motivation and tenacity, an ability to develop and enhance analytical, problem solving and critical evaluation skills to be able to interpret data and apply it to real life scenarios. High skilled, professional workers need to have an analytical approach, driven by curiosity through creativity seeking out innovative ways of reaching goals and outcomes. Another attribute that future workers need to establish is one of filtering and prioritisation, in a world of '*digital deluge*' *(Coplin, 2013)* it will be essential that people can filter and address the ‘noise’ to stay focused and productive. Lastly other pertinent considerations are around ethics and governance and the pastoral care of workers as the working environment continues to change. This drives focus on empathy and emotional intelligence and abilities to establish rapport and relationships with others. The human attributes and competencies alongside the technological change, such as artificial intelligence, digitalisation and automation of mundane routine labour activities present an opportunity for economic growth and further industrial innovation through coalescent working, which is only possible if workers have the right skills to meet the skills gaps that technology cannot fulfil.

A further consideration and interpretation of this research relates to how technological change to date has created an inequality across the workforce through job polarization (Autor and Dorn, 2013; Goos,Manning and Salomons, 2014; Katz and Margo, 2014; Fonseca,Lima and Pereira, 2018; Oesch and Piccitto, 2019). Where the middle layer of skilled workers have been removed, a consideration is by upskilling the existing lower skilled workers and students, this would create a new middle layer of work. As people mature through the competencies this would balance out the inequality and meet the goals of the UK Industrial Strategy (2017) one of which is to provide good jobs for people with ‘greater earning power for all’ (UK Department for Business, Energy and Industrial Strategy, 2017, p.10).

This concludes chapter 5, Discussion, the next chapter, 6 will set out the conclusions and original contribution to knowledge that this thesis provides.

6 Conclusion

6.1 Key findings

The key findings of this research are:

- Future work has an important focus on how people approach work, worker characteristics are fundamental alongside the skills and knowledge professional workers require to carry out their work.
- Human professional workers have a comparative advantage over technology, the ability to assess, create, relate, adapt, filter and prioritise enables high-skilled professional workers to apply context.
- Ethical adoption of technology is an important consideration to future work alongside technological change.
- The value recognition of technological adoption was recognised, identifying the rationale and reasons behind adoption is key.
- The future of work is one of coalescence rather than substitution, technology should augment and integrate with the professional high skilled work force to drive economic and societal growth.

6.2 Introduction

Exploring the impact of technological change on future high skilled professional work starts with a reflection on the past. Sardar (2010) highlighted the importance of future studies being ‘*futureless*,’ advising that studies need to be conducted in the here and now. Sardar captured “*the impact of all futures explorations can only be meaningfully assessed in the present”* (p.183). Sardar further captured the importance of future studies on influencing decisions and perceptions in the present for the future. This thesis addresses the gap in literature on the impact of technological change and future high skilled professional work. It contributes to original knowledge supporting the views of Sardar, that future studies are meaningful in the present to inform future policy and planning. This thesis makes an original contribution to knowledge by meeting the research aim and objectives informing future policy and planning in relation to shaping and preparing the future workforce, which underlies future economic innovation and growth. This closing chapter in the thesis is set out over nine sub-sections; this introduction, an outline of the research background, a reminder of the research aim and objectives that were achieved, a description of the conclusions reached, followed by an articulation of the contribution to knowledge that this thesis provides, acknowledgement of the research limitations along with future research recommendations and reflections on this research and a final quotation to close this thesis.

6.3 Research background

Three industrial revolutions have disrupted the workforce (Schwab, 2016a; 2017; 2018), the Fourth is claimed (Hermann,Pentek and Otto, 2016; Schwab, 2018; Marnewick and Marnewick, 2019) to have arrived with the connection of the virtual world with the physical world (Alin, 2017). Technology has evolved over the last five decades through a series of changes (see appendix 8.26). The jobs carried out by people have and are changing and comparisons have been drawn against the disruption caused by machinery as a result of the first and second Industrial revolutions. Fears of technological unemployment (Keynes, 1933; Rumberger and Levin, 1985; Frey and Osborne, 2017) have been counterclaimed by job displacement (White, 1931; Levy and Murnane, 2005) and declarations that technology creates jobs and economic growth (Drucker, 1954; Makridakis, 2017).

A dual effect of 'Creative destruction' (Schumpeter, 1942; Dachs and Peters, 2014b; Acemoglu and Restrepo, 2019a) and inequality (Autor,Goldin and Katz, 2020) driven by a polarisation (Murphy and Oesch, 2017) of job skills and wages, are all theories of workforce impact resulting from technological change. A further claim that emerged from the existing literature was *'skill biased technological change*' SBTC (Piva,Santarelli and Vivarelli, 2005; Lin, 2011; Benzell *et al.*, 2019) where technology has driven an increase in demand for higher skilled workers. Existing literature has focused on the inequality debate and also the displacement or unemployment of the middle tier jobs, which has highlighted a gap in the literature to explore the higher skilled or professional work of the future alongside technological change. This thesis addresses that gap through the research objectives and questions captured in the next subsection, 6.3.

6.4 Research aim and objectives revisited

Figure 6-1 Research aim, objective and questions revisited

The research aim and objectives of this thesis guided this research throughout the empirical approach and design (see section 3.4 and 3.8). This research set out to explore the potential impact of technological change, which was defined in the literature review section 2.5 on future high skilled professional work. This research aim was achieved and Chapter 5 discussed the findings against each of the four research objectives that were also achieved, the next section, 6.4 consolidates the findings and discussion from the previous chapters and articulates the conclusions that have been drawn from the research.

6.5 Conclusions drawn

Technology will disrupt future work, there is consensus across economists, futurists and technologists (White, 1931; Levy and Murnane, 2004; Autor, 2010; Autor and Acemoglu, 2010; Acemoglu *et al.*, 2014; Bessen, 2016b; Huang and Rust, 2018; Bessen *et al.*, 2020a). There is also agreement that there is a demand for high skilled, professional workers alongside technology. What has not been clear prior to this research being conducted is what the demand for high skilled work could look like and the skills that high skilled workers may need in the future alongside technological change. The gap in existing literature relates to the future high skills that may be required alongside the emerging technological change. A further gap in the literature relates to what future jobs and training considerations organisations and education planners should be preparing for through their policies and approaches. This thesis addresses that gap and presents two models of practical contribution. The first a model of '*coalescence'* highlighting an approach where technology and professional workers augment whilst adhering to ethical compliance requirements. The second a '*human competency and contextualisation model'* presents the key competencies that future professional workers need to possess to complement technology. These competencies are human differentiators and areas that technology struggles to fulfil, which further supports the claim that there are human comparative advantage areas that need to be protected and developed further by educators and organisations.

Figure 6-3 captures the coalescence model, depicting the multiple components that drive technological change on the left-hand side and how the human competencies on the right come together to create an approach of coalescence.

This thesis further identified the complexity associated with the technological change terminology, capturing the multi-faceted nature of the term, and the lack of consensus on terminology such as the Fourth Industrial revolution and artificial intelligence as two key technological areas. A theoretical implication of this obfuscated terminology is that workers, students and policy makers may be confused or ill-informed on the meanings and implications of technological change, this thesis through the structured approach taken in the literature review presents a practical consolidation of terminology. The implication is that this thesis illustrates the requirement for awareness and readiness on understanding key terminology when evaluating future policies and approaches that affect the future workforce.

This research concludes that the future human workforce requirements are not isolated to worker skills, knowledge and education, as depicted in the US O*Net content model (See appendix 8.10). This research acknowledges that 'Worker requirements' are important aspects to preparing future workers, however this research extended our knowledge in relation to exploring the future professional workforce and concluded that worker characteristics are equally if not more important than the technical skills and knowledge accreditations that are the key focus of existing national curriculum policies. Figure 6-2 presents a model of human competency and contextualisation that encapsulates the worker characteristics presented through this research as key human competencies required by professional workers alongside technology. This research has shown that these competencies present a significant human comparative advantage over technology, that these are areas professional high-skilled workers can excel at and technology struggles to replicate or achieve to a level that would be required. This research contributes to understanding of human centric areas of competency that need to be developed in students and workers who may not possess a maturity in these competency areas to date.

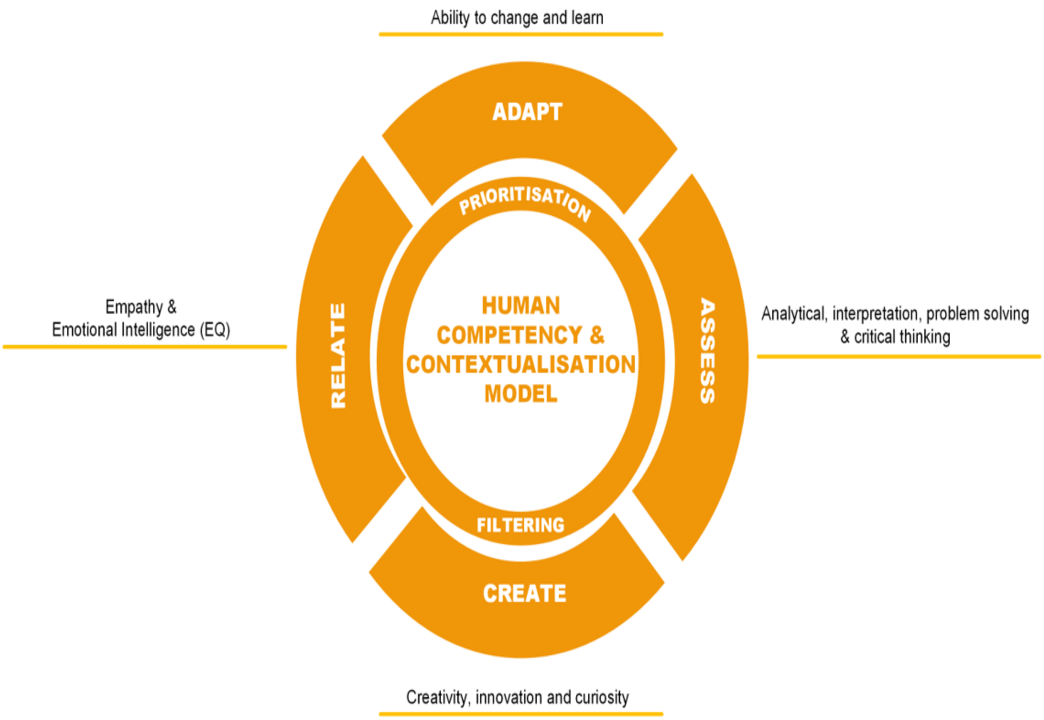

Figure 6-2 Human competency and contextualisation model

The right-hand side of Figure 6-3, the coalescence model articulates the people/worker characteristics along with the worker skill requirements identified (technical skills, cross functional skills) with an ability to change and learn being an important competency which enables technological integration and augmentation. The model builds on the human competency model (Figure 6-2) and presents it within the context of how technology (on the left-hand side of the model) augments the human competencies to drive innovation and economic growth, which is shown as an output in green at the bottom of the model. The findings provide additional evidence, building on the recommendations set out in the existing literature (Stahl,Timmermans and Flick, 2017; Aicardi *et al.*, 2018; Dwivedi *et al.*, 2019) that additional consideration is required for ethical compliance and governance on the adoption of emerging technologies with artificial intelligence being a key area that requires balanced and ethical controls. This research presented several high skilled professional job roles that should be developed and could be required in the future, these included ethics consultants, officers, specialists along with ethics board and authority roles. The coalescence model (figure 6-3) captures this demand in the top middle green box overseeing and feeding into the workforce coalescence approach where the technology and human workers augment and use and adopt the technology. The coalescence model captures a further finding that firmly establishes the human comparative advantage alongside technological change, building on the claim (Autor, 2015; Makridakis, 2017) that humans have a comparative advantage over machines through tacit knowledge and skills. The human ability to contextualise, be creative and innovative in approach, adapt and apply empathy and emotional intelligence are key human comparative advantage areas over technology. Makridakis (2017) spoke of '*intelligent augmentation*' where humans maximise the technology to drive benefit. This thesis supports that Makridakis's '*pragmatist*' approach and presents further insight into how that maybe presented in future professional work. It highlights the requirement for future focus on ethical compliance roles and people development to grow and harness human capability in the identified human comparative advantage areas. The ethical considerations are captured in the workforce coalescence model (figure 6-3) in the overarching box that sits at the top of the model. The coalescence model also captures the important role that human professional workers have in contextualising situations whether that be to react to a specific event or to map out future benefits that technology could help accomplish within a specific customer or industry situation. This contextualisation is driven through several human competencies and characteristics that need to be nurtured and developed in future students and workers in addition to the job role worker requirements that are currently catered for in National curriculum policies such as STEM and specialist education programmes.

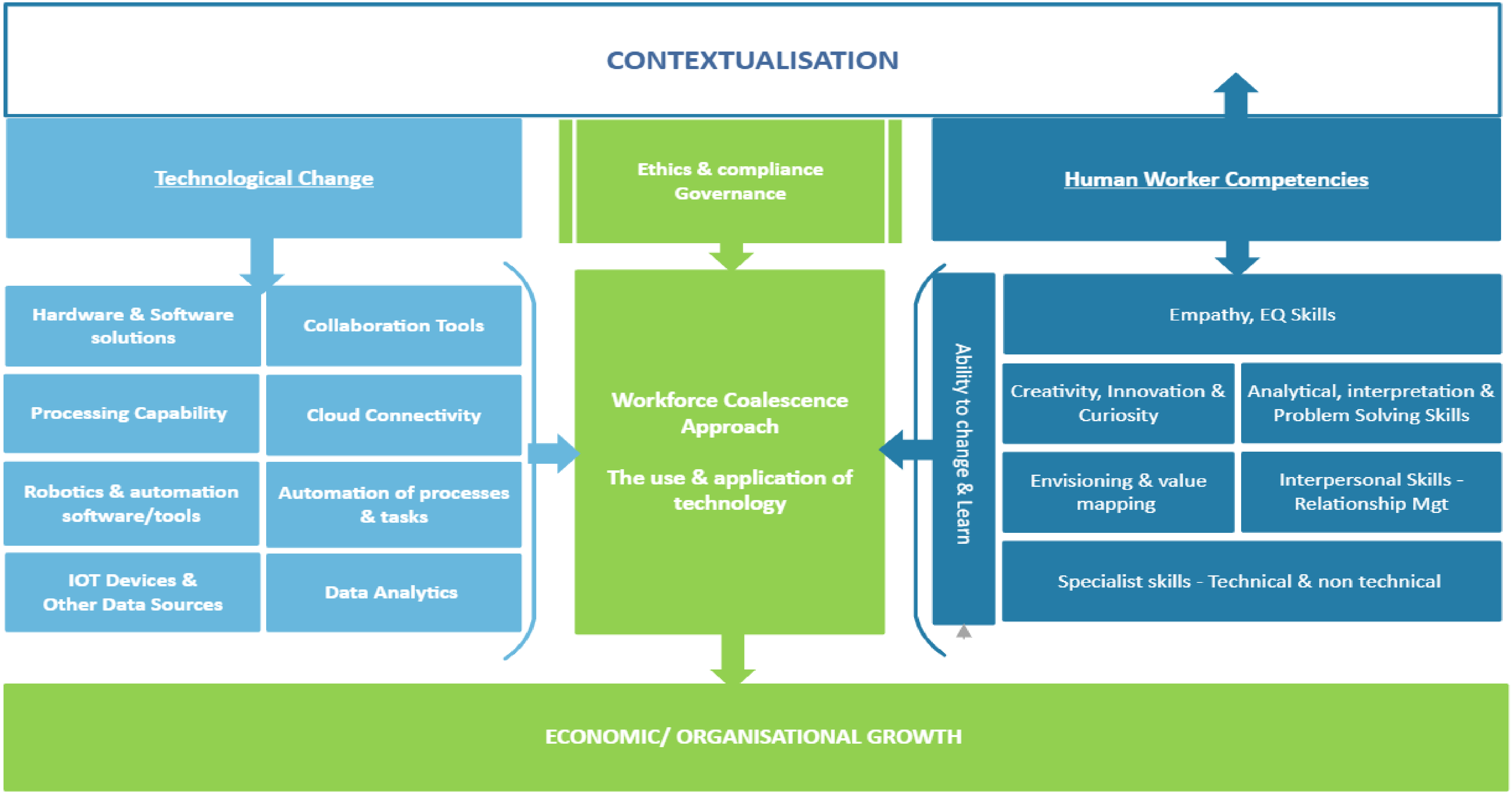

Figure 6-3 Workforce Coalescence model

This research has gone some way towards enhancing understanding of future considerations for policy owners, at a government departmental and organisational level, establishing practical models of human skill competency and workforce coalescence with the emerging and maturing technological change areas. This research presents a further consideration when evaluating future professional job roles. It is the first study to identify a pattern of role evolution and merging as a result of technological change. This is a significant discovery and challenges future policy and training considerations, highlighting that existing job roles are merging; technological skills are a component of all professional roles and technology is no longer a stand-alone profession. Examples from the research findings of this thesis include behavioural scientists and computer programming being merged, along with machine learning roles that merge mathematics and statistician competencies with software development and programming skills. Healthcare professional roles require specialist technology operational skills to augment and use specialist robotic technology. The role merging across existing occupational groups creates a further consideration for education policy owners to update courses and programmes to accommodate the cross functional requirement that has emerged from the research.

To summarise the conclusions drawn from this research which achieved the aim of; exploring the impact of technological change on future high skilled professional work, the first conclusion is the need for an approach of 'workforce *coalescence*' (see figure 6-3) highlighting the need for integration and augmentation between technology and people. The approach captured the need for a focus on ethical roles that drive transparency and ethical adoption of technology, specifically highlighting the area of artificial intelligence and machine learning. The approach

depicts the fundamental role the human professional worker plays in the workforce, the ability to contextualise complex situations and scenarios, an area that technology struggles to replicate. This research has highlighted the importance of accentuating the human comparative advantage presented as a 'human centric competency and contextualisation model,' see figure 6-2. The human competencies represent a model of six key human centric areas: '**assess, create, relate** and **adapt**' along with an ability to **filter** and **prioritise**. These competencies need to be encouraged and developed through education and organisational policies. An area of original contribution is that this research puts forward an approach of existing occupational role merging, where there are two or more discrete occupations that are married up to drive technological value. The adoption of technology is creating new hybrid roles, where two or more skillsets are coming together to form a new specialism which creates the demand and necessity for specialist training and development. Technology is no longer an occupational island, it is a component and tooling for work and the people development and readiness programmes and policies need to accommodate such requirements.
The professional workforce is evolving, technology is ubiquitous and together, professional workers and technological change augment to deliver innovation that supports economic and organisational growth. A fundamental consideration is that technological adoption requires contextualisation, purpose and value mapping to minimise efficiency regression, workers need to be enabled and prepared with the skills and characteristics to adapt and change as technology supports the professional worker in their role.

The next section sets out the original contribution to knowledge founded by this thesis.

6.6 Contribution

This thesis makes an original contribution to theoretical knowledge by highlighting the importance of worker characteristics, the values and approaches taken by workers in addition to the worker requirements, such as knowledge and skills alongside technological change. The thesis defines human competency areas that present a comparative advantage for future professional workers over the emerging technological change. The identified human competency areas are empathy, emotional intelligence, creativity, curiosity, analytical, interpretation, problem solving, envisioning and contextualisation, interpersonal and relationship skills.

This research also offers an original contribution to practice by presenting two models for inclusion in policy setting and planning. The first model encapsulates the 'Human centric competency and contextualisation,' approach that human workers should be encouraged to follow and adopt, developing and maturing the competency areas in the model to help accentuate the human comparative advantage alongside technological change. The second model builds on the competency areas and helps policy setters and organisations understand how the human worker and technology augments, highlighting the contextualisation that human professional workers can provide and the requirement for ethical compliance and governance over the use and adoption of technology.

A supplementary contribution to practice of this thesis is that it highlights the relevance of the seminal historical definition that exists for AI. AI has been described as an ambiguous term, with individual studies proffering their own interpretation on the term. This thesis provides a reminder of the definition provided by McCarthy, who in 1959 coined the term Artificial Intelligence (AI) and later defined it as, "*the science and engineering of making intelligent machines, especially intelligent computer programs*" *(McCarthy, 2007).* This was further supported by Stone et al. (2016) who utilised McCarthy's description when referring to AI, describing it as a '*science*.' This thesis presents that this definition is still valid today and recommends that it is used to drive consensus across education and industrial policies to help educate and inform people on this maturing area of technological change and minimise confusion on terminology.

Further practical contribution is established by the identification of a gap in the existing UK occupational standard. Machine learning roles, along with ethical compliance roles, technology integration or augmentation roles are not specifically included in the current UK Standard Occupation Classification (Office for National Statistics, 2020c). These are key professional roles that need to be evaluated and development programmes established.

A further contribution to knowledge is the identification of the need to augment existing roles to create new specialisms, highlighting the requirement for workforce development plans to include information technology readiness in all roles. The emerging technology is ubiquitous in nature and embeds to all roles, driving a higher level of technical generalisation for all professional workers. The thesis provides ground-breaking consideration for cross-functional training and development to encourage the upskilling of roles to create new specialisms. Data scientists for example need to have industry specific knowledge and experience alongside the technical computer and data skills, the requirement for industry contextualisation is key to driving value from data. Health professionals need to upskill and adopt technological operational skills to use state of the art tooling to augment their medical knowledge and experience.

This research also challenges the negative aspects of existing literature relating to technological change, the inequalities of polarisation driven by displacement. This thesis has built on the findings of others (Autor,Katz and Kearney, 2006; Goos,Manning and Salomons, 2009; Autor, 2010; Bogliacino,Lucchese and Pianta, 2012; Autor and Dorn, 2013; Autor, 2015; Murphy and Oesch, 2017; Fonseca,Lima and Pereira, 2018) where they have stated technological change has benefited the more skilled workers, such as professional work and the focus of their literature was on the inequalities of the lower skilled work. This research has explored the attributes of those higher skilled workers to contribute to future policy and readiness programs which could offset some of the polarisation explained in existing literature. Encouraging students and workers to '*upskill*' and meet the demand for future professional work. This research has presented original theoretical and practical contributions to knowledge by highlighting the significant comparative advantage that human high skilled professional workers have over technology, the ability to contextualise through assessing, creating, relating to situations and adapting whilst also being able to prioritise and filtering out key information is a major differentiator alongside technological change which challenges previous claims (Kurzweil, 2005; Bostrom, 2017; Huang and Rust, 2018; Susskind, 2020) of existential risk and singularity from technology. This thesis presents a more pragmatic set of findings grounded in the data provided by an expert panel on an emerging area that can help inform and set educational and organisational policies and approaches.

The thesis further establishes contribution to methodological knowledge, by applying a novel and original approach when exploring the impact of technological change on future professional work. This thesis is the first comprehensive mixed method exploration into future professional work alongside emerging technological change. Utilising a mixed method approach to gather insight from experts in the field of professional work and with exposure to the areas of emerging technological change. It utilised an online survey mechanism to simplify the capturing of data from experts and increased the response rates by making it as agile and accessible as possible for the expert respondents. The method triangulated responses with governmental data and standards to help validate answers and utilised thematic analysis to help identify patterns and themes from qualitative data that was collected, the identified themes were then further validated through a series of follow up semi-structured interviews. The mixed method approach contributes to methodological knowledge demonstrating practical and theoretical results when conducting future exploratory studies. Table 6-1 in section 6.5.1 summarises the original contribution to knowledge made by this thesis.

6.6.1 Contribution to knowledge summary table

#	Area of Contribution	Description
1	Theoretical	The thesis has captured the theoretical importance of worker characteristics, the values and approaches taken by professional workers in addition to the worker requirements (knowledge and skills). Capturing the need for future workers to focus on being flexible in their approach and to be able to adapt to change, along with presenting the theoretical importance of specific human centric competencies that differentiate professional workers from technological change, empathy, emotional intelligence, creativity, curiosity, analytical, interpretation, problem solving, envisioning and contextualisation, interpersonal and relationship skills.
2	Practice	The thesis has provided a practical model of human centric competencies and contextualisation for adoption for professional workers, proposing a model of six competency areas, assess, create, relate, adapt along with prioritisation and filtering, together these competencies establish a further competency of contextualisation. The model can be adopted by policy planners and makers.
3	Practice	The thesis has presented a model of workplace coalescence, building on the human centric competencies, augmenting and integrating with the technological change areas and presented a requirement for ethical compliance and governance for technological use and adoption.
4	Practice	The thesis has further presented the requirement for practical role merging. Readiness programmes need to apply training across multiple occupations to address the growing need to apply business knowledge alongside the technological skills.
5	Methodological	The thesis has contributed to methodology by implementation of a novel and original mixed method approach. It has utilised digital methods to elicit expert opinion, built on the Delphi model, utilised digital tooling (Microsoft Forms, Digital recording application, Otter AI Software) applied triangulation with quantitative government-controlled data and adopted a mixed method analysis approach. See Table 3.7.

Table 6-1 Contribution summary

6.7 Research Limitations

The key limitations noted in this research are captured below along with details on how this thesis research design mitigated or contained them where possible.

6.7.1 Geography

This thesis is limited to developed markets with expert participants working in established industries in the UK, EMEA (Europe, Middle East and Asia) and the US.

6.7.2 Target audience

The responses were limited to the views of the expert panel and their industries and exposure to the emerging technology.

6.7.3 Delphi approach

This research was limited to two Delphi rounds, saturation was reached after the second round with data representing itself through the verbatim provided by the expert respondents. Further validation was conducted through follow up semi-structured interviews.

6.7.4 Timeframe

This research was limited to a view of the expert respondents at a point in time for the Delphi rounds (May 2019 for Round one and June 2019 for Round two) and the views on the day of the follow-on interviews (November and December 2019).

6.7.5 COVID-19 and technological change adoption

This research is limited to expert views that were shared prior to the 2020 COVID-19 pandemic and the findings exclude any technological change considerations that may have resulted from the pandemic.

6.8 Further research considerations

This thesis has provided an original empirical model of coalescence for strategic planners and policy makers, both at an organisation level and also within education to adopt. Further research is recommended in the following areas:

6.8.1 Professional Role merging

To understand the 'role merging' requirements captured in this thesis of existing professional job roles and to further evaluate whether there are additional role merging opportunities for future high skilled professional workers.

6.8.2 Ethical controls and balance in the adoption of technological change

Further research considerations include evaluating how to achieve an acceptable and flexible balance of ethical controls and governance that protect societal interests whilst also optimising the value from technological adoption.

6.8.3 Readiness programmes and courses for contextualisation

This research presents a practical contribution through a model of human centric competencies and contextualisation, further research is required to explore the next level of how organisations can measure and adopt these competencies within students and workers to help establish a programme of maturing and developing these key competencies in workers that do not naturally exhibit them.

6.8.4 Impact of COVID19

This research was conducted prior to the COVD-19 pandemic further research is required to explore the impact COVID may have had on technological adoption and whether this has accelerated some areas and or delayed others.

6.8.5 Impact of digitalisation on worker mental health

A fourth area that was flagged that warrants additional research is the risk that technological change could have detrimental effect on societal well-being. The increase in digitalised communication and ability to reduce human to human interactions was flagged as a mental health risk during this research. This is an area that is already being explored (Wiederhold, 2017; Wilcockson,Osborne and Ellis, 2019; Goldenberg and Gross, 2020; Odgers and Jensen, 2020; Shirley Archer, 2020), this thesis reinforces the need for research to continue in this area as technological change is adopted and workers transition and adopt new ways of working.

6.9 Research Reflections and recommendations

6.9.1 Use of EndNote from the start of this research

When embarking on this journey the decision was taken to purchase an EndNote licence to help capture identified literature from the beginning. In addition to exporting the citations from Google Scholar and the FindIt search engines, copies of the documentation (where possible, due to some items being book references) were also loaded against the individual items, along with the details on the literature type. The ABS journal rating was also captured in the rating field in the tool. Utilising EndNote as a database tool structured the analysis of literature and simplified the ability to search for key articles later in the research process, for example, drafting the discussion chapter and synthesising the findings into the Conclusion Chapter. A recommendation as a result of adopting this approach to this research is that future Doctoral Students should consider utilising EndNote as a Database tool, storing the literature where possible and also capturing as much information relating to the literature to support analysis across the literature to help identify key themes and also gaps

6.9.2 Use of Mind map software

In addition to utilising EndNote software, Mind mapping software was also leveraged. The software enabled the mapping of authors against themes that emerged from the Literature review. Along with the mapping of topics that were presented through the analysis and findings stage. The ability to map topics, authors against timelines or research themes and theories was extremely insightful and helped to add clarity amidst a vast amount of information and is highly recommended as a technique for future Doctoral Students.

6.10 Closing quotation

"Computers are magnificent tools for the realization of our dreams, but no machine can replace the human spark of spirit, compassion, love, and understanding."

Louis V. Gerstner, Jr.

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8 Appendices

8.1 ABS Rated Journals

The following table captures the ABS journals that were accessed along with the article count for each. The numbers at the top (1-4*) relate to the ABS ranking of the Journal.

Journal	1	2	3	4	4*	Total
Kybernetes	160					160
Technological Forecasting and Social Change			46			46
Industrial Management & Data Systems		35				35
Strategy & Leadership	27					27
Foresight	24					24
Journal of Knowledge Management		24				24
Research Policy					21	21
Futures		18				18
Journal of Service Management		17				17
Business Process Management Journal		16				16
Management Decision		15				15
Communications of the ACM		15				15
Benchmarking: An International Journal	14					14
Worldwide Hospitality and Tourism Themes	14					14
The Quarterly Journal of Economics					12	12
New Technology, Work & Employment			12			12
Journal of Quality in Maintenance Engineering	11					11
American economic review					10	10
Journal of Manufacturing Technology Management	9					9
Journal of Business Strategy	9					9
Journal of Science and Technology Policy Management	8					8
Journal of Systems and Information Technology	8					8
International Journal of Web Information Systems	8					8
Engineering, Construction and Architectural Management	7					7
Online Information Review	7					7
Tourism Review	7					7
Computers in Human Behavior			7			7
International Journal of Operations & Production Management				7		7
Organizational Research Methods				6		6
International Journal of Contemporary Hospitality Management			6			6
Academy of management journal					6	6
Work, Employment and Society				6		6

Journal	1	2	3	4	4*	Total
International Journal of Productivity and Performance Management	5					5
Academy of Management Review					5	5
Journal of Strategic Information Systems			5			5
Supply Chain Management: An International Journal			4			4
The TQM Journal	4					4
European Journal of Innovation Management	4					4
International Journal of Lean Six Sigma	4					4
International Journal of Information Management		4				4
Administrative science quarterly					4	4
Journal of Management Development	4					4
Transfer: European Review of Labour and Research		4				4
Journal of Organizational Effectiveness: People and Performance	4					4
Management science					3	3
Digital Policy, Regulation and Governance	3					3
Journal of Hospitality and Tourism Technology	3					3
Journal of Political Economy					3	3
Journal of Organizational Change Management		3				3
Journal of Research in Interactive Marketing	3					3
Managerial Auditing Journal		3				3
Computers & Industrial		3				3
Review of Economics and Statistics				3		3
Journal of Economic Perspectives				3		3
International Journal of Educational Management	3					3
Journal of Strategy and Management	3					3
Economic Journal				3		3
British Food Journal	3					3
Higher Education, Skills and Work-Based Learning	3					3
Economies	3					3
European Journal of Information Systems			2			2
Harvard business review: HBR		2				2
Business Horizons		2				2
Work and Occupations			2			2
Managerial Finance	2					2
Journal of Business Ethics			2			2
Journal of Financial Regulation and Compliance	2					2
Technovation			2			2
International Journal of Health Care Quality Assurance	2					2
International Labour Review		2				2
Journal of Industrial Relations		2				2

Journal	1	2	3	4	4*	Total
MIS quarterly					2	2
Journal of Labor Economics				2		2
European Journal of Training	2					2
Journal of management					2	2
Society and Business Review		2				2
International Journal of Human-Computer Studies			2			2
Journal of Business Research			2			2
Journal of Management Information Systems	2					2
Journal of economic literature				2		2
Industrial and Corporate Change			2			2
Human Resource Management Review			2			2
Journal of marketing					2	2
International Marketing Review			2			2
International Journal of Islamic and Middle Eastern Finance and Management	2					2
Marketing Intelligence & Planning	2					2
Industrial Marketing Management			2			2
MIT Sloan Management Review			2			2
International Journal of Managing Projects in Business	2					2
Internet Research		2				2
Journal of product innovation management				2		2
Philosophy and organization theory			2			2
Engineering and Technology	2					2
Social studies of science		2				2
International Journal of Manpower		2				2
Strategic Management Journal					2	2
Information & Management			2			2
Structural Change and Economic Dynamics		2				2
Journal of Services Marketing		2				2
Economics Letters			2			2
Decision Sciences			2			2
Journal of Communication Management	2					2
International Journal of Quality and Service Sciences	2					2
Tourism management				2		2
Equality, Diversity and Inclusion: An International Journal	2					2
International Journal of Forecasting			2			2
Labour Economics			2			2
Employee Relations		2				2
Australasian Journal of Information Systems	2					2
European Business Review	2					2
Journal of Service Theory and Practice	2					2
IZA Journal of Labor Policy	2					2

Journal	1	2	3	4	4*	Total
The Learning Organisation	2					2
Organization Management Journal	2					2
Applied Economics		1				1
ResearchGate		1				1
European Review of Labour and Research		1				1
International Journal of Production Economics			1			1
Explorations in Economic History			1			1
Journal of Organizational Ethnography	1					1
Total Quality Management & Business Excellence		1				1
Journal of Policy Modeling		1				1
Psychology & Marketing			1			1
International Journal of Production Research			1			1
Review of Environmental Economics and Policy		1				1
ILR Review			1			1
Cambridge Journal of Economics			1			1
Ethics and Information Technology		1				1
The Leadership Quarterly				1		1
Applied psychology			1			1
China Agricultural Economic Review			1			1
Production Planning & Control			1			1
Academy of Management Learning & Education				1		1
Public Management Review			1			1
Journal of Service Research				1		1
Review of Economic Dynamics			1			1
Social Enterprise Journal	1					1
Economica			1			1
Journal of Human Resources			1			1
Information Economics and Policy		1				1
Sustainability Accounting, Management and Policy Journal		1				1
The Indian Journal of Labour Economics	1					1
Journal of Applied Statistics		1				1
Journal of Management & Organization		1				1
Journal of Vocational behavior				1		1
Journal of Management studies				1		1
Journal of Work-Applied Management	1					1
Personnel Psychology				1		1
Knowledge and Process Management	1					1
Policing: An International Journal of Police Strategies & Management	1				1	
British Educational Research Journal			1			1
Psychological bulletin				1		1
Information Processing & Management		1				1
Psychology of Women Quarterly			1			1

Journal	1	2	3	4	4*	Total
Intelligent Systems in Accounting, Finance and Management	1					1
Business & Information Systems Engineering		1				1
International Economic Review				1		1
Research-Technology Management		1				1
Journal of Business Venturing				1		1
Journal of evolutionary economics		1				1
International Journal of Accounting & Information Management		1				1
Science and Public Policy		1				1
Marketing Education Review	1					1
Social Forces			1			1
Journal of Development Economics			1			1
International Journal of Human - Computer Studies			1			1
Journal of Economic Issues		1				1
Communications of the Association for Information Systems		1				1
Cambridge Journal of Regions, Economy and Society			1			1
International Journal of Industrial Ergonomics	1					1
New Perspectives Quarterly	1					1
Journal of Macroeconomics		1				1
Creativity and Innovation Management		1				1
The British journal of sociology		1				1
Omega			1			1
The International Journal of Human Resource Management			1			1
Journal of Economic Psychology		1				1
Online Information Review	1					1
Computational Statistics & Data Analysis			1			1
Economic and Industrial Democracy			1			1
Organization science					1	1
History of political economy		1				1
International Journal of Emerging Markets	1					1
IEEE Transactions on Engineering Management			1			1
Oxford Review of Economic Policy		1				1
Journal of Engineering and Technology Management		1				1
Journal of European Social Policy			1			1
Grand Total	405	210	139	45	73	872

8.2 NIST – Cloud Computing Characteristics

The NIST Definition of Cloud Computing, (Mell and Grance, 2011, p.3; Sokol and Hogan, 2013, p.8)

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

Essential Characteristics:

On-demand self-service. A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

Broad network access. Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

Resource pooling. The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, and network bandwidth.

Rapid elasticity. Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.

Measured service. Cloud systems automatically control and optimize resource use by leveraging a metering capability1 at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

Service Models:

Software as a Service (SaaS). The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure2. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email) or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user specific application configuration settings.

Platform as a Service (PaaS). The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider.3 The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

Infrastructure as a Service (IaaS). The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

Deployment Models:

Private cloud. The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

Community cloud. The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.

Public cloud. The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.

Hybrid cloud. The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

8.3 Aviation guidelines for "Human centered automation"

The following snippet captures the Principles set out for Human centred automation in aviation

- ***To command effectively, the human operator must be involved.***

  To remain in command of a vehicle, operation, or situation, the commander must be involved in the operation. He or she must have an active role, whether that role is to control the aircraft directly or to manage the human or machine resources to which control has been delegated.

- ***To be involved, the human operator must be informed.***

  Without information about the conduct of the operation, involvement becomes random. The commander must have a continuing flow of information concerning the state and progress of the operation or system to maintain involvement with it. The information must be consistent with the command responsibilities of the pilot; it must include all data necessary to support the pilot's involvement in the operation.

- ***The human operator must be able to monitor the automated systems.***

  The ability to monitor the automated systems is necessary both to permit the pilot to remain "on top of" the situation, and also because automated systems are fallible. Flight-critical digital computers, in particular, are likely to fail in unpredicted ways at unpredictable times.

- ***Automated systems must be predictable.***

  The human commander must be able to evaluate the performance of automated systems against an internal model formed through knowledge of the normal behavior of the systems, if monitoring of them is to be effective. Only if the systems normally behave in a predictable fashion can the human operator rapidly detect departures from normal behavior and thus recognize failures in the automated systems.

- ***The automated systems must also be able to monitor the human operator.***

  Humans, of course, are not infallible either, and their failures may likewise be unpredictable, although a good deal has been learned about human failure modes. For that reason, it is necessary that human as well as machine performance be monitored. Many automated monitoring devices are in use in aviation today, but the availability of highly capable computers with access to much of the needed information makes it possible to consider doing more, in a more systematic fashion, to monitor pilot performance than has been done to date.

- ***Each element of the system must have knowledge of the others' intent.***

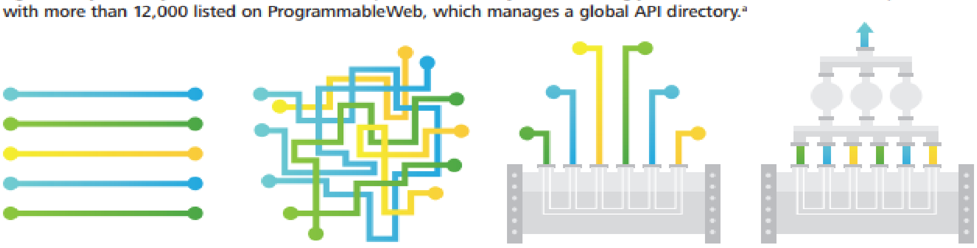
  Cross-monitoring can only be effective if the monitor understands what the operator of the monitored system is trying to accomplish. To obtain the benefits of effective monitoring, the intentions of the human or automated systems must be known; this applies equally to the monitoring of aircraft by humans on the ground, and the monitoring of air traffic control by pilots in flight.

(Billings, 1991, p.13)

8.4 Evolution of APIs

The evolution of APIs

The idea behind APIs has existed since the beginning of computing; however in the last 10 years, they have grown significantly not only in number, but also in sophistication. They are increasingly scalable, monetized, and ubiquitous, with more than 12,000 listed on ProgrammableWeb, which manages a global API directory.[a]



1960–1980

Basic interoperability enables the first programmatic exchanges of information. Simple interconnect between network protocols. Sessions established to exchange information.

TECHNIQUES

ARPANET, ATTP, and TCP sessions.

1980–1990

Creation of interfaces with function and logic. Information is shared in meaningful ways. Object brokers, procedure calls, and program calls allow remote interaction across a network.

TECHNIQUES

Point-to-point interfaces, screenscraping, RFCs, and EDI.

1990–2000

New platforms enhance exchanges through middleware. Interfaces begin to be defined as services. Tools manage the sophistication and reliability of messaging.

TECHNIQUES

Message-oriented middleware, enterprise service bus, and service-oriented architecture.

2000–today

Businesses build APIs to enable and accelerate new service development and offerings. API layers manage the OSS/BSS of integration.

TECHNIQUES

Integration as a service, RESTful services, API management, and cloud orchestration.

Source: [a] ProgrammableWeb, http://www.programmableweb.com, accessed January 7, 2015.

(Collins and Sisk, 2015)

8.5 Eleven AI Research Topic

As set out by Stone et al. 2016

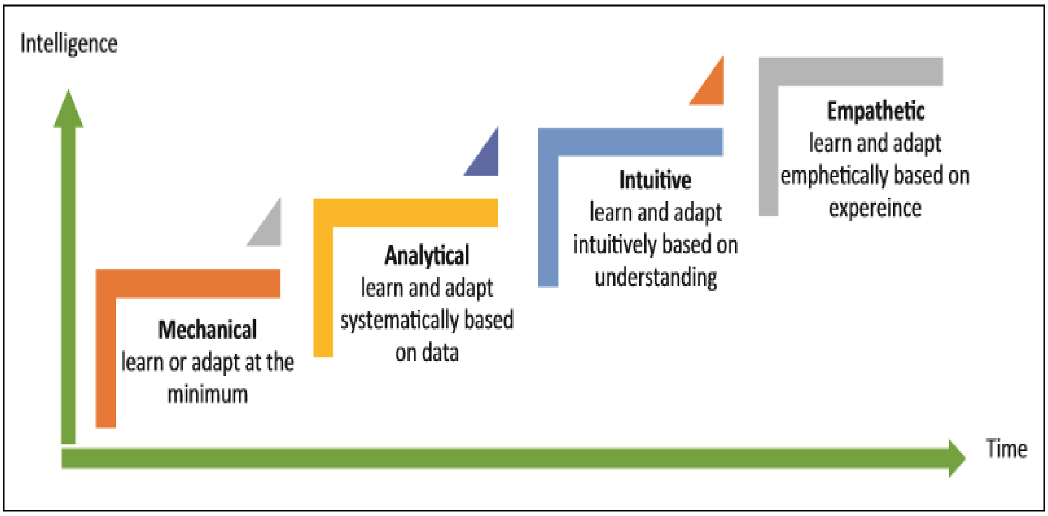
1. *"**Large-scale machine learning** concerns the design of learning algorithms, as well as scaling existing algorithms, to work with extremely large data sets.*
2. ***Deep learning**, a class of learning procedures, has facilitated object recognition in images, video labeling, and activity recognition, and is making significant inroads into other areas of perception, such as audio, speech, and natural language processing.*
3. ***Reinforcement learning** is a framework that shifts the focus of machine learning from pattern recognition to experience-driven sequential decision-making. It promises to carry AI applications forward toward taking actions in the real world. While largely confined to academia over the past several decades, it is now seeing some practical, real-world successes,*
4. ***Robotics** is currently concerned with how to train a robot to interact with the world around it in generalizable and predictable ways, how to facilitate manipulation of objects in interactive environments, and how to interact with people. Advances in robotics will rely on commensurate advances to improve the reliability and generality of computer vision and other forms of machine perception.*
5. ***Computer vision** is currently the most prominent form of machine perception. It has been the sub-area of AI most transformed by the rise of deep learning. For the first time, computers are able to perform some vision tasks better than people. Much current research is focused on automatic image and video captioning.*
6. ***Natural Language Processing**, often coupled with automatic speech recognition, is quickly becoming a commodity for widely spoken languages with large data sets. Research is now shifting to develop refined and capable systems that are able to interact with people through dialog, not just react to stylized requests. Great strides have also been made in machine translation among different languages, with more real-time person-to-person exchanges on the near horizon.*

7. ***Collaborative systems*** *research investigates models and algorithms to help develop autonomous systems that can work collaboratively with other systems and with humans.*
8. ***Crowdsourcing and human computation*** *research investigates methods to augment computer systems by making automated calls to human expertise to solve problems that computers alone cannot solve well.*
9. ***Algorithmic game theory and computational social*** *choice draw attention to the economic and social computing dimensions of AI, such as how systems can handle potentially misaligned incentives, including self-interested human participants or firms and the automated AI-based agents representing them.*
10. ***Internet of Things (IoT)*** *research is devoted to the idea that a wide array of devices, including appliances, vehicles, buildings, and cameras, can be interconnected to collect and share their abundant sensory information to use for intelligent purposes.*

Neuromorphic computing *is a set of technologies that seek to mimic biological neural networks to improve the hardware efficiency and robustness of computing systems, often replacing an older emphasis on separate modules for input/ output, instruction-processing, and memory*"

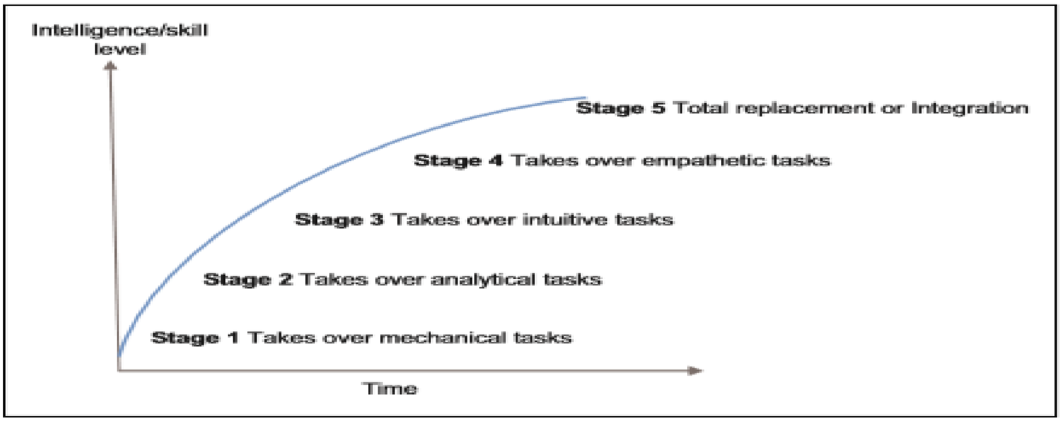
(Stone *et al.*, 2016, p.9)

8.6 Four Stages of intelligence



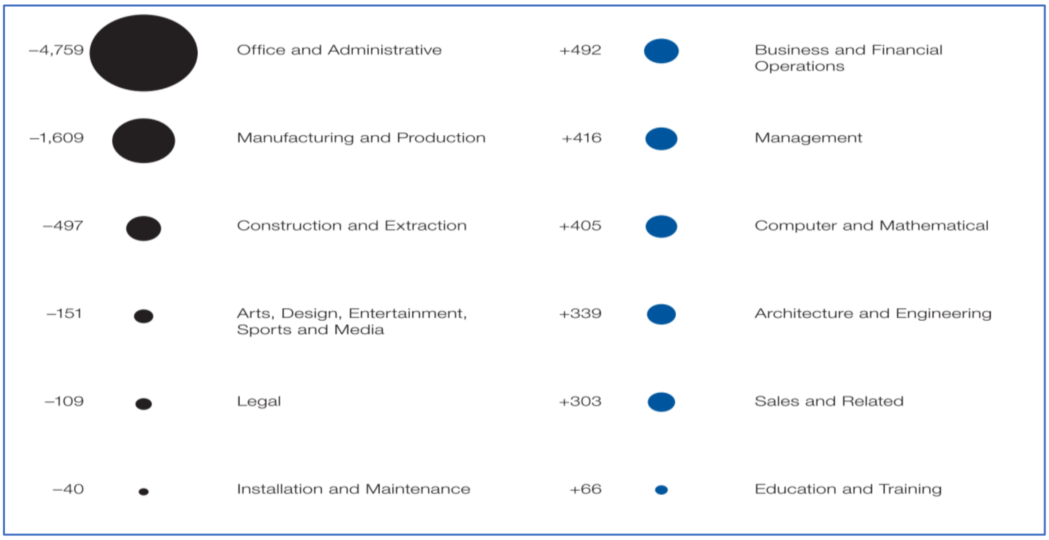
Huang and Rust (2018)

Five Stages of Skill



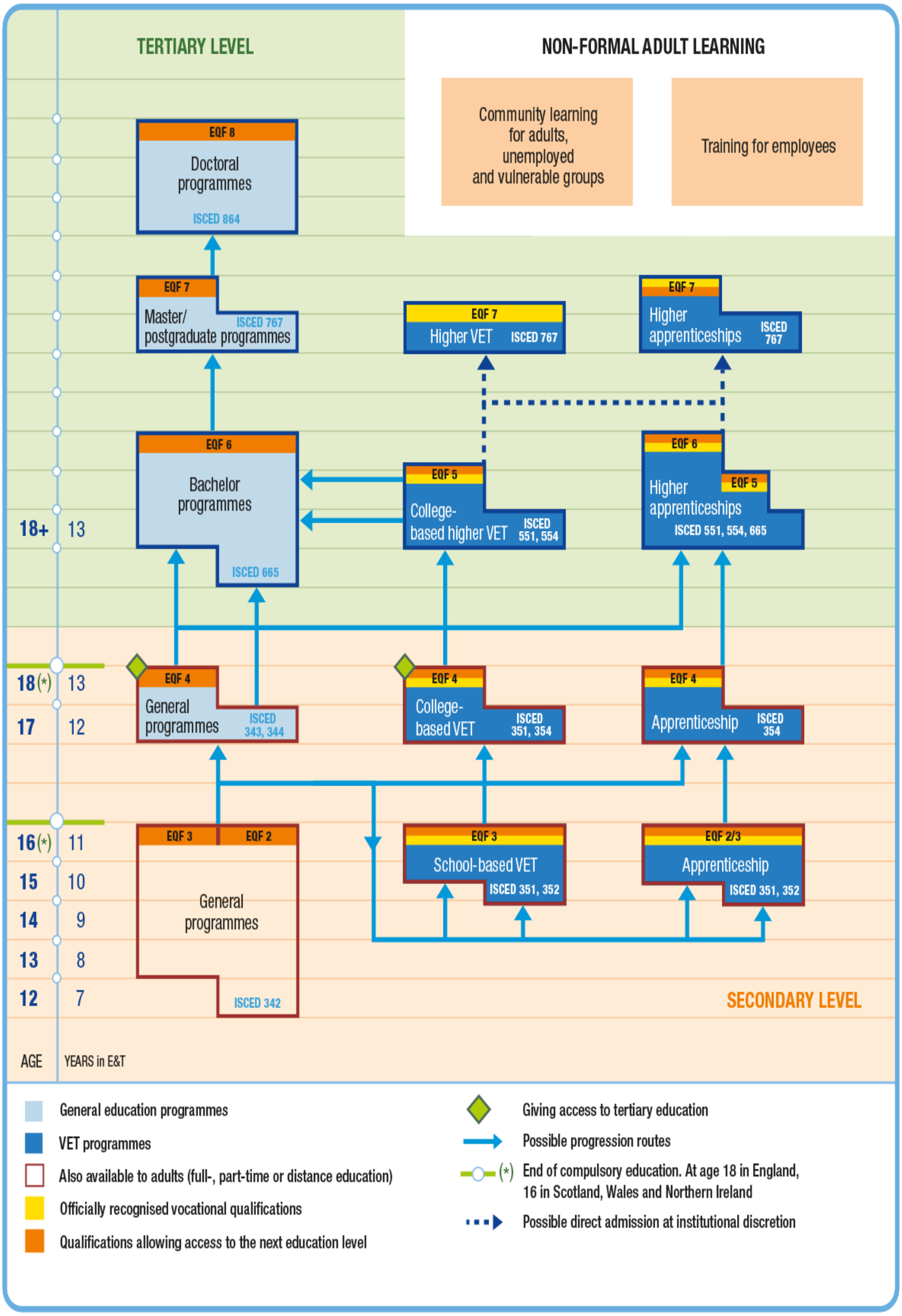
Huang and Rust (2018)

8.7 WEF – Predicted Employment profiling by job family (2015-2020)



(Forum, 2016) (p.15)

8.8 Vocational education and training in UK Structure



NB: ISCED-P 2011. ISCED classification based on the 2018 mapping of UK classifications by the Department for Education.
Source: Cedefop and ReferNet UK, 2019.

(Condon and Burke, 2020)

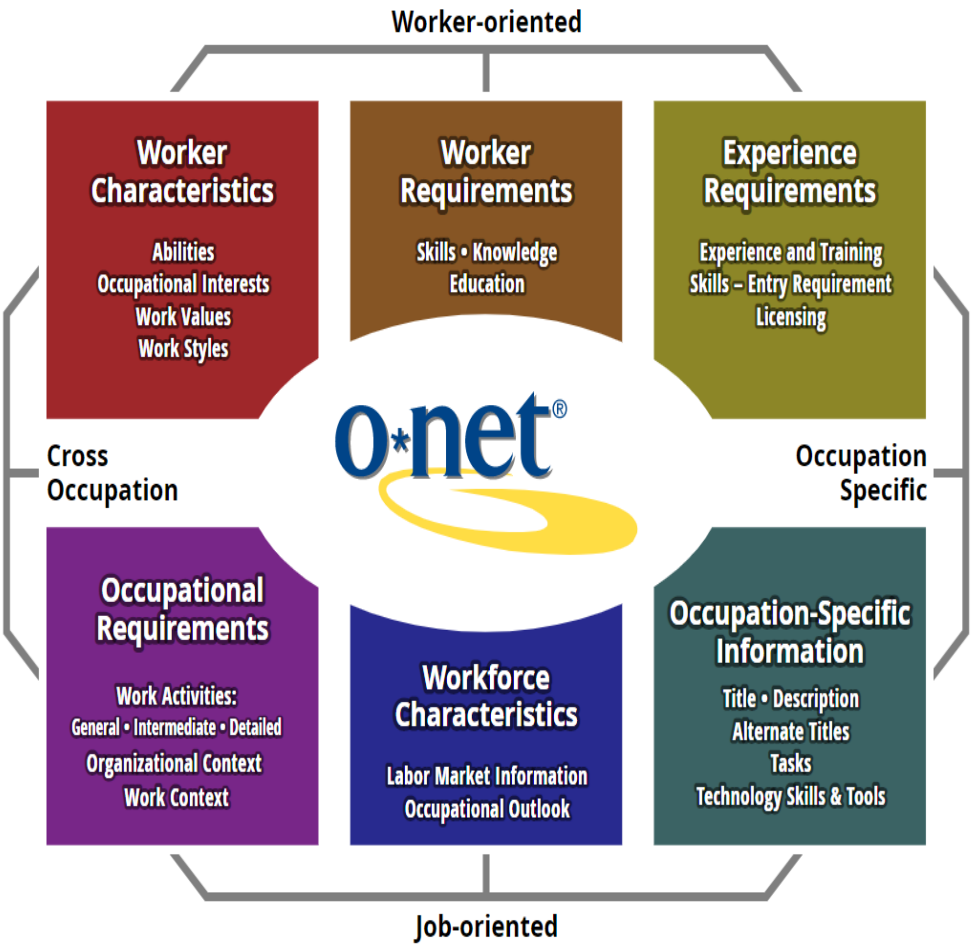
8.9 Standard Occupation Classification

Volume 3: Socio-economic classification - Analytical classes.

Analytic Classes	Operational categories and sub-categories classes	
1.1	L1	Employers in large establishments
	L2	Higher managerial and administrative occupations
1.2	L3	Higher professional occupations L3.1 'Traditional' employees L3.2 'New' employees L3.3 'Traditional' self-employed L3.4 'New' self-employed
2	L4	Lower professional and higher technical occupations L4.1 'Traditional' employees L4.2 'New' employees L4.3 'Traditional' self-employed L4.4 'New' self-employed
	L5	Lower managerial and administrative occupations
	L6	Higher supervisory occupations
3	L7	Intermediate occupations L7.1 Intermediate clerical and administrative occupations L7.2 Intermediate sales and service occupations L7.3 Intermediate technical and auxiliary occupations L7.4 Intermediate engineering occupations
4	L8	Employers in small organisations L8.1 Employers in small establishments in industry, commerce, services etc. L8.2 Employers in small establishments in agriculture
	L9	Own account workers L9.1 Own account workers (non-professional) L9.2 Own account workers (agriculture)
5	L10	Lower supervisory occupations
	L11	Lower technical occupations L11.1 Lower technical craft occupations L11.2 Lower technical process operative occupations
6	L12	Semi-routine occupations L12.1 Semi-routine sales occupations L12.2 Semi-routine service occupations L12.3 Semi-routine technical occupations L12.4 Semi-routine operative occupations L12.5 Semi-routine agricultural occupations L12.6 Semi-routine clerical occupations L12.7 Semi routine childcare occupations
7	L13	Routine occupations L13.1 Routine sales and service occupations L13.2 Routine production occupations L13.3 Routine technical occupations L13.4 Routine operative occupations L13.5 Routine agricultural occupations
8	L14	Never worked and long-term unemployed L14.1 Never worked L14.2 Long-term unemployed
*	L15	Full-time students
*	L16	Occupations not stated or inadequately described
*	L17	Not classifiable for other reasons

(Ofice of National Statistics, 2020b)

8.10 O*NET Content Model



https://www.onetcenter.org/content.html

8.11 HARP

HARP Reflective Tool

		Strongly Agree (3)	Agree (2)	Slightly Agree (1)	Slightly Disagree (-1)	Disagree (-2)	Strongly Disagree (-3)
Your views on the nature of reality (ontology)							
1	Organisations are real, just like physical objects						✓
2	Events in organisations are caused by deeper, underlying mechanisms				✓		
3	The social world we inhabit is a world of multiple meanings, interpretations and realities	✓					
4	'Organisation' is not a solid and static thing but a flux of collective processes and practices	✓					
5	'Real' aspects of organisations are those that impact on organisational practices			✓			
Your views on knowledge and what constitutes acceptable knowledge (epistemology)							
6	Organisational research should provide scientific, objective, accurate and valid explanations of how the organisational world really works						✓
7	Theories and concepts never offer completely certain knowledge, but researchers can use rational thought to decide which theories and concepts are better than others	✓					
8	Concepts and theories are too simplistic to capture the full richness of the world			✓			
9	What generally counts as 'real', 'true' and 'valid' is determined by politically dominant points of view						✓
10	Acceptable knowledge is that which enables things to be done successfully			✓			
Your views on the role of values in research (axiology)							
11	Researchers' values and beliefs must be excluded from the research				✓		
12	Researchers must try to be as objective and realistic as they can	✓					
13	Researchers' values and beliefs are key to their interpretations of the social world	✓					
14	Researchers should openly and critically discuss their own values and beliefs		✓				
15	Research shapes and is shaped by what the researcher believes and doubts			✓			
Your views on the purpose of research							
16	The purpose of research is to discover facts and regularities, and predict future events					✓	
17	The purpose of organisational research is to offer an explanation of how and why organisations and societies are structured					✓	
18	The purpose of research is to create new understandings that allow people to see the world in new ways		✓				
19	The purpose of research is to examine and question the power relations that sustain conventional thinking and practices				✓		
20	The purpose of research is to solve problems and improve future practice			✓			
Your views on what constitutes meaningful data							
21	Things that cannot be measured have no meaning for the purposes of research						✓
22	Organisational theories and findings should be evaluated in terms of their explanatory power of the causes of organisational behaviour			✓			
23	To be meaningful, research must include participants' own interpretations of their experiences, as well as researchers' interpretations		✓				
24	Absences and silences in the world around us are at least as important as what is prominent and obvious						✓
25	Meaning emerges out of our practical, experimental and critical engagement with the world			✓			
Your views on the nature of structure and agency							
26	Human behaviour is determined by natural forces					✓	
27	People's choices and actions are always limited by the social norms, rules and traditions in which they are located						✓
28	Individuals' meaning–making is always specific to their experiences, culture and history			✓			
29	Structure, order and form are human constructs		✓				
30	People can use routines and customs creativity to instigate innovation and change				✓		

Test Score

Positivism

Question	1	6	11	16	21	26	Total
Answer Score	-3	-3	-1	-2	-3	-2	-14

Critical Realism

Question	2	7	12	17	22	27	Total
Answer Score	-1	3	3	-2	1	-3	1

Interpretivism

Question	3	8	13	18	23	28	Total
Answer Score	3	1	3	2	2	1	12

Post structuralism / Postmodernism

Question	4	9	14	19	24	29	Total
Answer Score	3	-3	2	-1	-3	2	0

Pragmatism

Question	5	10	15	20	25	30	Total
Answer Score	1	1	1	1	1	-1	4

(Saunders et al., 2019) – template – p.161

8.12 Displacement of work graph

Research findings which utilised data from the Adult Occupational Distribution.

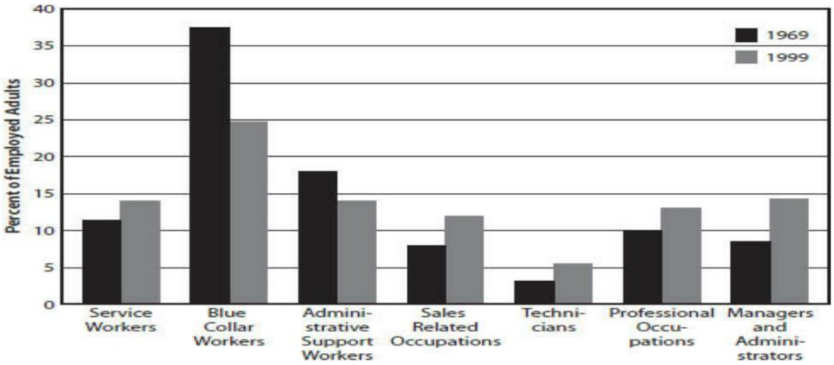


Figure 1. ((Levy and Murnane, 2005)(p.42))

8.13 Ethical principles

Ethical principle	Ethical rationale for and development of this principle
Integrity and objectivity of the researcher	The quality of research depends in part on the integrity and objectivity of the researcher. This means acting openly, being truthful and promoting accuracy. Conversely it also means avoiding deception, dishonesty, misrepresentation (of data and findings etc), partiality, reckless commitments or disingenuous promises. Where appropriate, any conflict of interest or commercial association should be declared
Respect for others	A researcher's position is based on the development of trust and respect. The conduct of research entails social responsibility and obligations to those who participate in or at affected by it. The rights of all persons should be recognised and their dignity respected
Avoidance of harm (non-maleficence)	Any harm to participants must be avoided. Harm may occur through risks to emotional wellbeing, mental or physical health, or social or group cohesion. It may take a number of forms including embarrassment, stress, discomfort, pain or conflict. It may be caused by using a research method in an intrusive or zealous way that involves mental or social pressure causing anxiety or stress. It may also be caused by violating assurances about confidentiality and anonymity, or through harassment or discrimination
Privacy of those taking part	Privacy is a key principle that links to or underpins several other principles considered here. Respect for others, the avoidance of harm, the voluntary nature of participation, informed consent, ensuring confidentiality and maintaining anonymity, responsibility in the analysis of data and reporting of findings, and compliance in the management of data are all linked to or motivated by the principle of ensuring the privacy of those taking part
Voluntary nature of participation and right to withdraw	The right not to participate in a research project is unchallengeable. This is accompanied by the right not to be harassed to participate. It is also unacceptable to attempt to extend the scope of participation beyond that freely given. Those taking part continue to exercise the right to determine how they will participate in the data collection process, including rights: not to answer any question, or set of questions; not to provide any data requested; to modify the nature of their consent; to withdraw from participation; and possibly to withdraw data they have provided
Informed consent of those taking part	The principle of informed consent involves researchers providing sufficient information and assurances about taking part to allow individuals to understand the implications of participation and to reach a fully informed, considered and freely given decision about whether or not to do so, without the exercise of any pressure or coercion. This leads to the right of those taking part to expect the researcher to abide by the extent of the consent given and not to find that the researcher wishes to prolong the duration of an interview or observation, or to widen the scope of the research without first seeking and obtaining permission, or to commit any subsequent breach of the consent given
Ensuring confidentiality of data and maintenance of anonymity of those taking part	Research is designed to answer 'who', 'what', 'when', 'where', 'how' and 'why' questions, not to focus on those who provide the data to answer these. Individuals and organisations should therefore remain anonymous and the data they provide should be processed to make it non-attributable, unless there is an explicit agreement to attribute comments. Harm may result from unauthorised attribution or identification. Reliability of data is also likely to be enhanced where confidentiality and anonymity are assured. This principle leads to the right to expect assurances about anonymity and confidentiality to be observed strictly
Responsibility in the analysis of data and reporting of findings	Assurances about privacy, anonymity and confidentiality must be upheld when analysing and reporting data. Primary data should not be made up or altered and results should not be falsified. Findings should be reported fully and accurately, irrespective of whether they contradict expected outcomes. The same conditions apply to secondary data, the source or sources of which should also be clearly acknowledged. Analyses and the interpretations that follow from these should be checked carefully and corrections made to ensure the accuracy of the research repo and any other outcome
Compliance in the management of data	Research is likely to involve the collection of personal data. Many governments have passed legislation to regulate the processing of personal data. There is therefore a statutory requirement to comply with such legislation. In the European Union, European Directive 95/46/CE has led member states to pass data protection legislation. Other laws may exist in particular countries relating to the processing, security and possible sharing of data. It will therefore be essential for researchers to understand and comply with the legal restrictions and regulations that relate to the management of research data within the country or countries within which they conduct research
Ensuring the safety of the researcher	The safety of researchers is a very important consideration when planning and conducting a research project. The Social Research Association's Code of Practice for the Safety of Social Researchers identifies possible risks from social interactions including 'risk of physical threat or abuse; risk of psychological trauma ...; risk of being in a compromising situation . . .; increased exposure to risks of everyday life' (Social Research Association 2001: 1). Research design therefore needs to consider risks to researchers as well as to participants

(Saunders,Lewis and Thornhill, 2012) p.231.

8.14 Participant Briefing Paper Round 1

ROUND 1

JUNE 2019

AI AND FUTURE WORK

RESEARCH BRIEFING PAPER

RESEARCHER: CLAIRE CLEMENT
UNIVERSITY OF SOUTH WALES

University of South Wales
Prifysgol
De Cymru

AI AND FUTURE WORK

RESEARCH BACKGROUND

Over the last two hundred and thirty plus years the world has experienced three industrial revolutions. The first dating back to 1784 when mechanical equipment disrupted the way in which people lived and worked. About 90 years later, in the 1870s, the second introduced electricity and disrupted the workforce significantly with mass production factories. 90 years later, in the 1960s, the third introduced further automation as a result of advancements in electronics and information technology which disrupted the workforce again and displaced jobs. If advancements were to follow the same historical pattern, we would expect the next industrial revolution to occur around the 2050s. However technological advancements appear to be disrupting how people work and live much earlier than previous timelines, with Artificial Intelligent (AI) solutions maturing and being adopted across business.

A potential explanation is that the third industrial revolution introduced technology which has enabled people to be much more connected. Computers along with advancements in processing power as predicted through Moore's Law and also Cloud computing have created a connected digital world and whilst Artificial Intelligence is not a new term, the ability to collate massive amounts of data and search autonomously through it at rapid speed has meant that jobs that used to be manual, repetitive and time consuming can now be automated with minimal or no human interaction at all. Tasks and activities that have historically been carried out by people are being displaced, driven by AI solutions. The potential AI brings through technological change could significantly change how we live, learn and work. Disrupting all sectors and industries.

This connected age has also created new areas of industry, looking back over the industrial revolutions, society was one of production which made and produced things. Today we are much more a consumer society where we produce much less and consume much more, consuming services and experiences. The growth of data has led to the emergence of a knowledge sector, embracing a data rich world where personalised service can be provided and processes and interactions automated. Society expects much more and at a much faster pace. Businesses need to stay competitive in a world where data is now a commodity and an asset. The customer demands a more personalised and real time experience.

Online connectivity, data and the personal insights this brings is driving a new model of existence, at home, school and work. The boundaries between all of these are blurring as technological change disrupts how we live. One area of disruption is in the workplace and where technology has the potential to displace or change the jobs that people do. This also drives changes to the types of skills required by workers alongside technology.

This displacement has already changed the workforce with tasks and activities changing, some say for the better enabling the workforce to focus on more interesting activities that add value and are more rewarding. Others claim that technology will lead to mass unemployment and that computers and machines will take over and are a threat to mankind. Some jobs are believed to be less likely to be displaced, those that involve creativity and empathy for example. It is claimed that jobs that involve repetitive modelling, forecasting or processing that can be replicated are more likely to be replaced by technology. However, these types of activities are claimed to make up part of people's jobs and the partial replacement of some activities by technology could drive displacement rather than eradication.

This research is exploring the future professional workforce as a result of technological change driven by AI. Whilst literature highlights a potential impact and also the historical displacement of where technological change has disrupted the workforce, currently there is limited literature exploring what a potential workforce could look like. This research seeks to gather insight through expert perceptions and knowledge of the key professional and technical jobs of the future. This would help inform training and development plans and strategies, along with course profiling and educational requirements for future organisations and students.

DEFINITIONS

TECHNOLOGICAL CHANGE

For the purposes of this research Technological Change will be defined as any change that is realized or adopted as a result of solutions that are not fully human and therefore constitute an element of artificial intelligence or an automated solution, (that solution could be partially automated or fully automated). High level examples include but are not limited to solutions or delivered change through: Big Data, Machine Learning (Supervised, unsupervised learning, deep learning and reinforced learning), Internet of Things (IoT), Autonomous solutions, Robotics, Virtual or Augmented Reality.

WORK & ROLES

*For the purposes of this research work is defined as jobs (full or part time) that are carried out by people and classed **as professional or associate professional and technical roles**. For further clarity professional or associate professional and technical roles include roles that require academic study and/or workplace qualifications or certification/s to capture a level of competence and/or accreditation within that role.*

*The Standard Occupation Classification (2010) defines the "general nature of qualification, training and experience for" **professional or associate professional and technical roles as:***

Professional occupations	A degree or equivalent qualification, with some occupations requiring postgraduate qualifications and/or a formal period of experience-related training.
Associate professional and technical occupations	An associated high-level vocational qualification, often involving a substantial period of full-time training or further study. Some additional task-related training is usually provided through a formal period of induction.

Source:https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010/soc2010volume1structureanddescriptionsofunitgroups#major-group-structure-of-the-classification-and-qualifications-skills-training-and-experience

PARTICIPANT ROLE AND REQUIREMENTS

The Research is looking to capture expert perceptions in relation to technological change and the future of work, specifically professional and technical roles.

*As a participant and therefore '**Expert panel member**' the following is required:*

1. *Timely responses **to 2 online questionnaires** within the response window (which will be 2 weeks from issuing for each questionnaire).*

   *Please note that for consistency and validity purposes panel members are required to respond to **both** questionnaires. If both questionnaires are not returned this will be classified as incomplete participation and therefore data provided will be invalid and excluded from the research analysis.*

2. *Provide Responses based on your individual experience and knowledge*

RESEARCH APPROACH

Activity	Objectives	Estimated participant time required
Round 1	*To gain expert opinion and knowledge on the prioritisation of occupation displacement alongside AI*	*10 - 15 mins*
Round 2	*After reviewing Round 1 responses and updating the job groupings inline with expert input - To gain expert opinion and knowledge on the prioritisation of occupation displacement alongside AI*	*10 - 15 mins*

DATA AND CONSENT

All responses will be anonymous, any data collected will be attributed to a randomly selected participant number and no personal identifiable information will be published or shared as part of the research.

By responding to the questionnaire, you are providing consent to the researcher for your responses to be analysed and interpreted in line with the research aim and objectives.

If you have any questions about the storing or use of your responses, please contact the researcher for clarification.

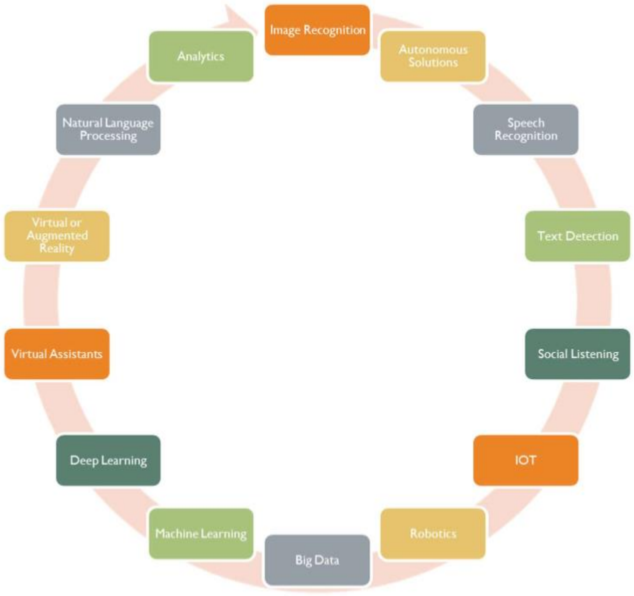
PANEL MEMBER INSTRUCTIONS

1. Read this Briefing document and consider the supporting information. Please pay particular attention to job groupings on page 5 as these relate to the job roles that you will be asked to stack rank in the Questionnaire.
2. Open the questionnaire through this link:
   https://forms.office.com/Pages/ResponsePage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAAa__dOWj-xUODM3VTc5RUtVRVNKMVA0WUZYWlBUVjZLQy4u
   or scan the following QR Code on your mobile device:
3. All questions require answers so if you are not sure please type 'not sure' in the field
4. Please submit the form back to the researcher within the request time to ensure your expert opinion is included in the research
5. Please respond to both questionnaires

Confidential

SUPPORTING INFORMATION

Technological Change - High-level areas of technological change powered by Artificial Intelligence:



***Source**: Created by the Researcher: Claire Clement (2019)*

High-level Technological Change scenarios driven by AI as captured in A1

POTENTIAL HIGH-LEVEL SCENARIOS (NOT EXHAUSTIVE)

Optimisation

Process Automation

Supply chain optimisation – reducing waste & increased efficiency
Automation of repetitive activities – call, claim handling, appointment scheduling
Personal authentication and identification

Manual Automation

Robotics – automating repetitive / Dangerous tasks
Domestic Robots

Predicting Outcomes

Buying Habits: Customer insights
Maintenance demands and scheduling
Supply & Demand requirements
Market trends and demands
Drug trials
Recovery Rates (Health or Financial)
Financial risk profiling
Motorway Congestion
Agricultural yield
Crime rates and hotspots

Anomaly Detection

Health & Safety: potential risk detection
Medical diagnosis: Disease identification
Fraud detection
Sentiment analysis: customer dis-sat
Security threats or illegal activity detection
Environmental anomalies
Protected Species identification,
Extreme weather alerts
Machine/Service malfunctions

Confidential

Job Role Grouping

The following table captures Job roles captured by the World Economic Forum Report (2018)[1], additional data taken from a LinkedIn Report (2018)[2] and occupations from the UK (2010) & US (2018) Standard Occupation Classification (SOC)[3]. This is not an exhaustive list and represented key professional and technical roles highlighted primarily in the WEF Report as being "stable" and "new" as part of a Future Jobs Report.

#	Grouping	Job Role	Source	Potential variants or roles included in this grouping
1	Business Specialists /Advisors/Analysts	Financial and Investment Advisers	WEF 2018	Business Analyst
		Senior Tax Advisor	LinkedIn 2018	Supply Director
		Supply Chain and Logistics Specialists	WEF 2018	
2	Compliance/Regulator roles	Compliance Officers	WEF 2018	Financial Analyst
		Information Security Analysts	WEF 2018	
		Risk Management Specialists	WEF 2018	
3	Creativity roles	Innovation Professionals	WEF 2018	
		Interaction Designers	WEF 2018	
		Service and Solutions Designers	WEF 2018	
		User Experience and Human-Machine Interaction Designers	WEF 2018	
		Culture Specialists	WEF 2018	
4	Data Specialists	Big Data Specialists Digital	WEF 2018	Data Scientist
		Chief Data Officer	US SOC 2018	
		Data Analysts and Scientists	WEF 2018	
5	Healthcare Professionals	Medical Doctors/Surgeons & Professionals	UK SOC 2010	
		Nurses, Dentists, Radiographers, Physiotherapists	UK SOC 2010	
6	Human Resources and Learning & Development roles	Human Resources Specialists	WEF 2018	Recruiting Coordinator
		Technical Recruiter	LinkedIn 2018	
		Training and Development Specialists	WEF 2018	
		Transformation Specialists	WEF 2018	
		University and Higher Education Teachers	WEF 2018	
7	Management Roles and Organisational Specialists	Management Roles	WEF 2018	General and Operations Managers
		Delivery Manager	LinkedIn 2018	Managing Directors
		Management and Organization Analysts	WEF 2018	
		Organizational Development Specialists	WEF 2018	
8	Sales Specialists and Marketing Specialists	Sales Professionals	WEF 2018	Account Managers/ Directors
		Account Executives	LinkedIn 2018	Sales Development Representative
		Digital Marketing and Strategy Specialists	WEF 2018	Sales Engineer
		Product Marketing Manager	LinkedIn 2018	Brand Manager
		Ecommerce and Social Media Specialists	WEF 2018	
9	Specialist Operators	Chemical Processing Plant Operators	WEF 2018	
		Petroleum and Natural Gas Refining Plant Operators	WEF 2018	
		System Administrators	LinkedIn 2018	
10	Technical Specialist and Specialist Engineers/Developers	Electrotechnology Engineers	WEF 2018	Front-End Engineers
		Energy and Petroleum Engineers	WEF 2018	Dev Ops Engineers
		Robotics Specialists and Engineers	WEF 2018	Solution Architects
		Software Engineer	WEF 2018	Solution Consultants
		Software and Applications Developers and Analysts	WEF 2018	
		Database and Network Professionals	WEF 2018	
		AI and Machine Learning Specialists	WEF 2018	
		Technology Specialists	WEF 2018	
		Information Technology Services Process Automation Specialists	WEF 2018	
		Cloud Architect	LinkedIn 2018	

[1] WEF Report 2018: https://www.weforum.org/reports/the-future-of-jobs-report-2018
[2] LinkedIn Report 2018: https://business.linkedin.com/content/dam/me/business/en-us/talent-solutions/cx/2018/pdf/33-most-recruited-jobs.pdf
[3] UK SOC: https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010
US SOC: https://www.bls.gov/soc/2018/home.htm

8.15 Delphi Questionnaire Round 1

Question #	Question
1	Please provide your name so that responses can be tracked across each round. Please note that you name will not be shared or published as part of the research a participant number will be allocated to anonymise responses
2	What Industry or Sector do you or have you worked in? Select all that apply.
3	How many years work experience do you have? (This is the cumulative experience in the sectors captured in Question 2).
4	What is your existing or last Occupation/Job Title
5	What professional or technical occupations do you think could be created over the next decade as a result of AI related technological change? (List all or state not sure if applicable)
6	Looking at the next few years - Please rank the following job role groupings - in order of importance alongside technological change between now and 2025; (1 - the top being most important and 1... Business Specialists /Advisors/Analysts Compliance/Regulator roles Creativity roles Data Specialists Healthcare Professionals Human Resources and Learning & Development roles Management Roles and Organisational Specialists Sales Specialists and Marketing Specialists Specialist Operators Technical Specialist and Specialist Engineers/Developers
7	Looking further ahead - Please rank the following job role groupings - in order of importance alongside technological change post 2025; (1 - the top being most important and 10 - the bottom being... Business Specialists /Advisors/Analysts Compliance/Regulator roles Creativity roles Data Specialists Healthcare Professionals Human Resources and Learning & Development roles Management Roles and Organisational Specialists Sales Specialists and Marketing Specialists Specialist Operators Technical Specialist and Specialist Engineers/Developers
8	Do you think there is a key professional job role missing in the list? If yes please state the job role/s or state Not Sure
9	Have any of your job roles been affected by technological change? If yes please describe the impact and when that was. If No please state No in the box
10	On a scale of 1-10 (1 being negative and 10 being positive) rate how you feel about the impact technological change will have on professional occupations in the future?
11	What do you think are the key skills required by people in the future alongside technological change? Please list
12	Which sector/s do you think will be affected the most technological change?
13	Is there anything you would like to add in relation to technological change and the human future workforce? Is there anything that concerns or excites you about the future workforce?
14	Would you be happy to be contacted by the researcher to take part in a follow up interview?
15	If you are happy to be contacted by the researcher for a follow up 30-60 min interview please provide your email address:

8.16 Round 2 Briefing Paper

ROUND 2

JULY/ AUGUST 2019

AI AND FUTURE WORK

RESEARCH BRIEFING PAPER

RESEARCHER: CLAIRE CLEMENT
UNIVERSITY OF SOUTH WALES

University of South Wales
Prifysgol De Cymru

AI AND FUTURE WORK

RESEARCH BACKGROUND

Over the last two hundred and thirty plus years the world has experienced three industrial revolutions. The first dating back to 1784 when mechanical equipment disrupted the way in which people lived and worked. About 90 years later, in the 1870s, the second introduced electricity and disrupted the workforce significantly with mass production factories. 90 years later, in the 1960s, the third introduced further automation as a result of advancements in electronics and information technology which disrupted the workforce again and displaced jobs. If advancements were to follow the same historical pattern, we would expect the next industrial revolution to occur around the 2050s. However technological advancements appear to be disrupting how people work and live much earlier than previous timelines, with Artificial Intelligent (AI) solutions maturing and being adopted across business.

A potential explanation is that the third industrial revolution introduced technology which has enabled people to be much more connected. Computers along with advancements in processing power as predicted through Moore's Law and also Cloud computing have created a connected digital world and whilst Artificial Intelligence is not a new term, the ability to collate massive amounts of data and search autonomously through it at rapid speed has meant that jobs that used to be manual, repetitive and time consuming can now be automated with minimal or no human interaction at all. Tasks and activities that have historically been carried out by people are being displaced, driven by AI solutions. The potential AI brings through technological change could significantly change how we live, learn and work. Disrupting all sectors and industries.

This connected age has also created new areas of industry, looking back over the industrial revolutions, society was one of production which made and produced things. Today we are much more a consumer society where we produce much less and consume much more, consuming services and experiences. The growth of data has led to the emergence of a knowledge sector, embracing a data rich world where personalised service can be provided and processes and interactions automated. Society expects much more and at a much faster pace. Businesses need to stay competitive in a world where data is now a commodity and an asset. The customer demands a more personalised and real time experience.

Online connectivity, data and the personal insights this brings is driving a new model of existence, at home, school and work. The boundaries between all of these are blurring as technological change disrupts how we live. One area of disruption is in the workplace and where technology has the potential to displace or change the jobs that people do. This also drives changes to the types of skills required by workers alongside technology.

This displacement has already changed the workforce with tasks and activities changing, some say for the better enabling the workforce to focus on more interesting activities that add value and are more rewarding. Others claim that technology will lead to mass unemployment and that computers and machines will take over and are a threat to mankind. Some jobs are believed to be less likely to be displaced, those that involve creativity and empathy for example. It is claimed that jobs that involve repetitive modelling, forecasting or processing that can be replicated are more likely to be replaced by technology. However, these types of activities are claimed to make up part of people's jobs and the partial replacement of some activities by technology could drive displacement rather than eradication.

This research is exploring the future professional workforce as a result of technological change driven by AI. Whilst literature highlights a potential impact and also the historical displacement of where technological change has disrupted the workforce, currently there is limited literature exploring what a potential workforce could look like. This research seeks to gather insight through expert perceptions and knowledge of the key professional and technical jobs of the future. This would help inform training and development plans and strategies, along with course profiling and educational requirements for future organisations and students.

DEFINITIONS

TECHNOLOGICAL CHANGE

For the purposes of this research Technological Change will be defined as any change that is realized or adopted as a result of solutions that are not fully human and therefore constitute an element of artificial intelligence or an automated solution, (that solution could be partially automated or fully automated). High level examples include but are not limited to solutions or delivered change through: Big Data, Machine Learning (Supervised, unsupervised learning, deep learning and reinforced learning), Internet of Things (IoT), Autonomous solutions, Robotics, Virtual or Augmented Reality.

WORK & ROLES

*For the purposes of this research work is defined as jobs (full or part time) that are carried out by people and classed **as professional or associate professional and technical roles**. For further clarity professional or associate professional and technical roles include roles that require academic study and/or workplace qualifications or certification/s to capture a level of competence and/or accreditation within that role.*

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Source:https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010/soc2010volume1structureanddescriptionsofunitgroups#major-group-structure-of-the-classification-and-qualifications-skills-training-and-experience

PARTICIPANT ROLE AND REQUIREMENTS

The Research is looking to capture expert perceptions in relation to technological change and the future of work, specifically professional and technical roles.

*As a participant and therefore '**Expert panel member**' the following is required:*

1. *Timely responses **to 2 online questionnaires** within the response window (which will be 2 weeks from issuing for each questionnaire).*

   *Please note that for consistency and validity purposes panel members are required to respond to **both** questionnaires. If both questionnaires are not returned this will be classified as incomplete participation and therefore data provided will be invalid and excluded from the research analysis.*

2. *Provide Responses based on your individual experience and knowledge*

RESEARCH APPROACH

Activity	Objectives	Estimated participant time required
Round 1	*To gain expert opinion and knowledge on the prioritisation of occupation displacement alongside AI*	*10 - 15 mins*
Round 2	*After reviewing Round 1 responses and updating the job groupings in line with expert input - To gain expert opinion and knowledge on the prioritisation of occupation displacement alongside AI*	*10 - 15 mins*

DATA AND CONSENT

All responses will be anonymous, any data collected will be attributed to a randomly selected participant number and no personal identifiable information will be published or shared as part of the research.

By responding to the questionnaire, you are providing consent to the researcher for your responses to be analysed and interpreted in line with the research aim and objectives.

If you have any questions about the storing or use of your responses, please contact the researcher for clarification.

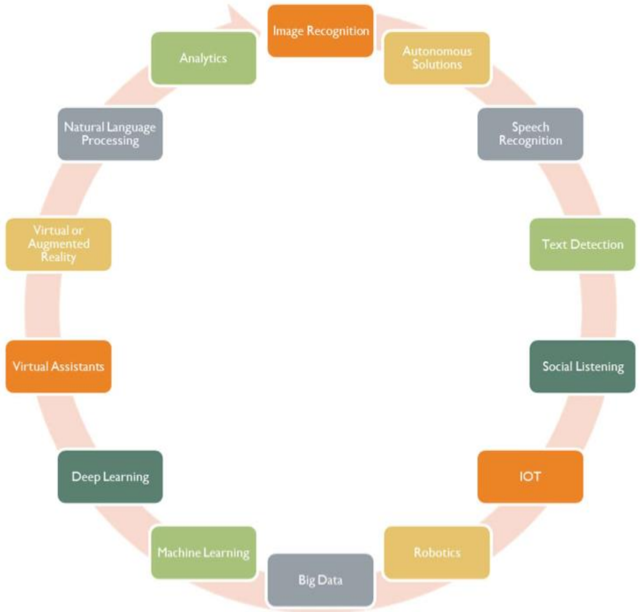
PANEL MEMBER INSTRUCTIONS

1. Read this Briefing document and consider the supporting information. Please pay particular attention to job groupings on page 5 as these relate to the job roles that you will be asked to stack rank in the Questionnaire.
2. Open the questionnaire through this link:
   https://forms.office.com/Pages/ResponsePage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAAa__dOWj-xUN0pPWklHTE1XU1pINEVGQ0s2UjVVQUJPVS4u
   or scan the following QR Code on your mobile device:
3. All questions require answers so if you are not sure please type 'not sure' in the field
4. Please submit the form back to the researcher within the request time to ensure your expert opinion is included in the research
5. Please respond to both questionnaires

Confidential

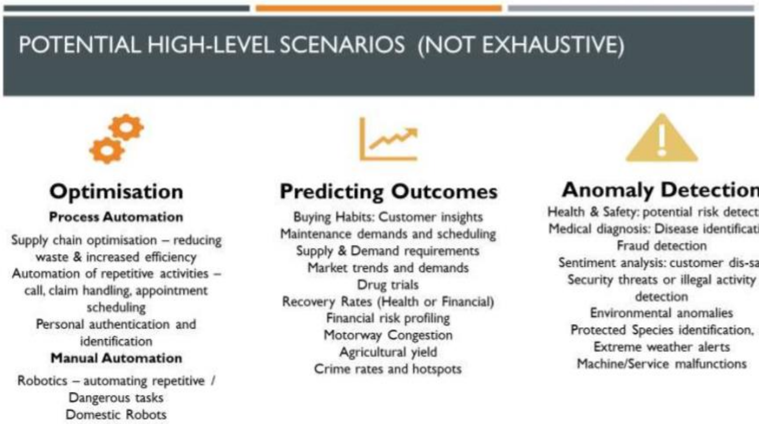
SUPPORTING INFORMATION

Technological Change - High-level areas of technological change powered by Artificial Intelligence:



***Source**: Created by the Researcher: Claire Clement (2019)*

High-level Technological Change scenarios driven by AI as captured in A1



Job Role Grouping The following table captures Job roles captured by the World Economic Forum Report (2018)[1], additional data taken from a LinkedIn Report (2018)[2] and occupations from the UK (2010) & US (2018) Standard Occupation Classification (SOC)[3] and the responses received form Round 1.

#	Grouping	Job Role	Source	Potential variants or roles included in this grouping
1	Industry Specialists	Financial and Investment Advisers	WEF 2018	Business Specialists /Advisors/Analysts
		Senior Tax Advisor	LinkedIn 2018	Supply Director
		Supply Chain and Logistics Specialists	WEF 2018	
		Agricultural Specialists	Round 1 responses	Farmers
		Specialist - Scientist	Round 1 responses	
		Environmental Specialists	Round 1 responses	
		Chemical Processing Plant Operators	WEF 2018	Specialist Operations
		Petroleum and Natural Gas Refining Plant Operators	WEF 2018	Specialist Operations
		System Administrators	LinkedIn 2018	Specialist Operations
2	Legal/Compliance/Regulator/Ethical roles	Compliance Officers	WEF 2018	Financial Analyst
		Information Security Analysts	WEF 2018	
		Risk Management Specialists	WEF 2018	
		Ethical Specialists and evaluators	Round 1 responses	
		Enforcement Officers	Round 1 responses	Police Officers
		Legal Specialists	Round 1 responses	Solicitors, Lawyers, Barristers, Judges etc
3	Creativity roles	Innovation Professionals	WEF 2018	
		Interaction Designers	WEF 2018	
		Service and Solutions Designers	WEF 2018	
		User Experience and Human-Machine Interaction Designers	WEF 2018	
		Culture Specialists	WEF 2018	
4	Data Specialists	Big Data Specialists Digital	WEF 2018	Data Scientist
		Chief Data Officer	US SOC 2018	
		Data Analysts and Scientists	WEF 2018	
		Algorithm/ Mathematical Specialists	Round 1 responses	
5	Healthcare Professionals	Medical Doctors/Surgeons & Professionals	UK SOC 2010	
		Nurses, Dentists, Radiographers, Physiotherapists	UK SOC 2010	
		Health care professionals	Round 1 responses	
		Health care professional - Psychologists	Round 1 responses	
6	Human Resources and Learning & Development roles	Human Resources Specialists	WEF 2018	Recruiting Coordinator
		Technical Recruiter	LinkedIn 2018	
		Training and Development Specialists	WEF 2018	
		Transformation Specialists	WEF 2018	
		University and Higher Education Teachers	WEF 2018	
		Career/ Personal Coaches	Round 1 responses	
		Teachers	Round 1 responses	
		Educational/ Learning Specialists	Round 1 responses	
7	Leadership, Management Roles & Organisational Specialists	Management Roles	WEF 2018	General and Operations Managers
		Delivery Manager	LinkedIn 2018	Managing Directors
		Management and Organization Analysts	WEF 2018	
		Organizational Development Specialists	WEF 2018	
		Government & Political Official	Round 1 responses	Civil Servants/ Politians
8	Sales Specialists and Marketing Specialists	Sales Professionals	WEF 2018	Account Managers/ Directors
		Account Executives	LinkedIn 2018	Sales Development Representative
		Digital Marketing and Strategy Specialists	WEF 2018	Sales Engineer
		Product Marketing Manager	LinkedIn 2018	Brand Manager
		Ecommerce and Social Media Specialists	WEF 2018	
9	Technical Specialist & Specialist Engineers, Developers	Electrotechnology Engineers	WEF 2018	Front-End Engineers
		Energy and Petroleum Engineers	WEF 2018	Dev Ops Engineers
		Robotics Specialists and Engineers	WEF 2018	Solution Architects
		Software Engineer	WEF 2018	Solution Consultants
		Software and Applications Developers and Analysts	WEF 2018	
		Database and Network Professionals	WEF 2018	
		AI and Machine Learning Specialists	WEF 2018	
		Technology Specialists	WEF 2018	
		Information Technology Services Process Automation Specialists	WEF 2018	
		Cloud Architect	LinkedIn 2018	
10	AI Integration and human augmentation roles	AI Integration/ Mediation	Round 1 responses	
		Human Integration - Speech Specialist	Round 1 responses	
		Human Integration Specialists - Biological	Round 1 responses	
		Human Integration Specialists - Gaming	Round 1 responses	
		User Experience and human integration specialists	Round 1 responses	

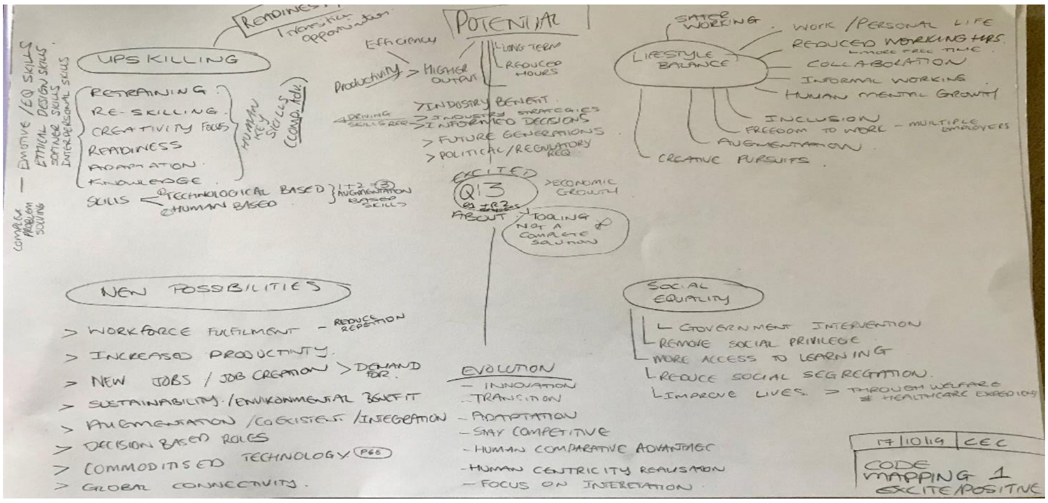
For an electronic copy that maybe easier to review click **here**

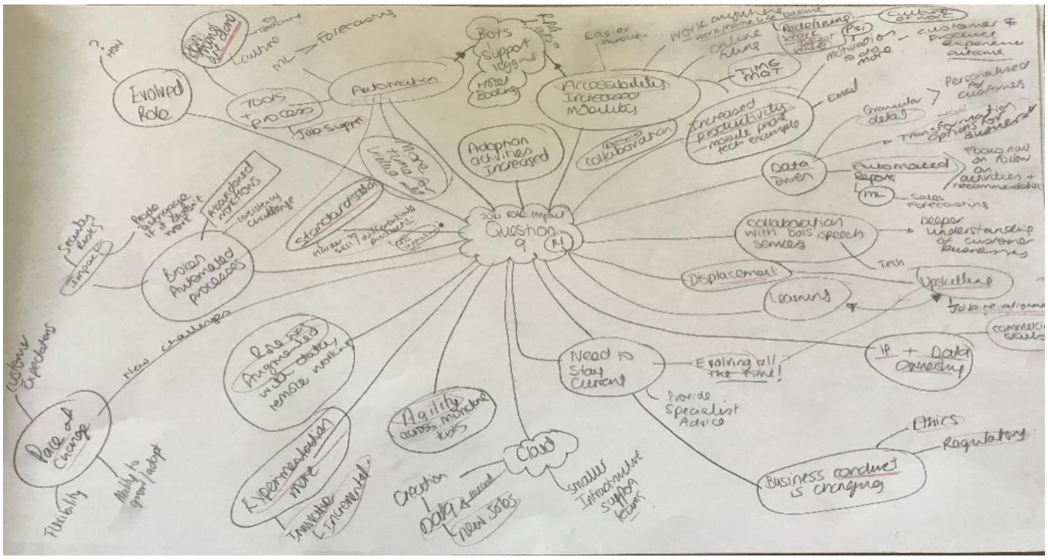
[1] WEF Report 2018: https://www.weforum.org/reports/the-future-of-jobs-report-2018
[2] LinkedIn Report 2018: https://business.linkedin.com/content/dam/me/business/en-us/talent-solutions/cx/2018/pdf/33-most-recruited-jobs.pdf
[3] UK SOC: https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010
US SOC: https://www.bls.gov/soc/2018/home.htm

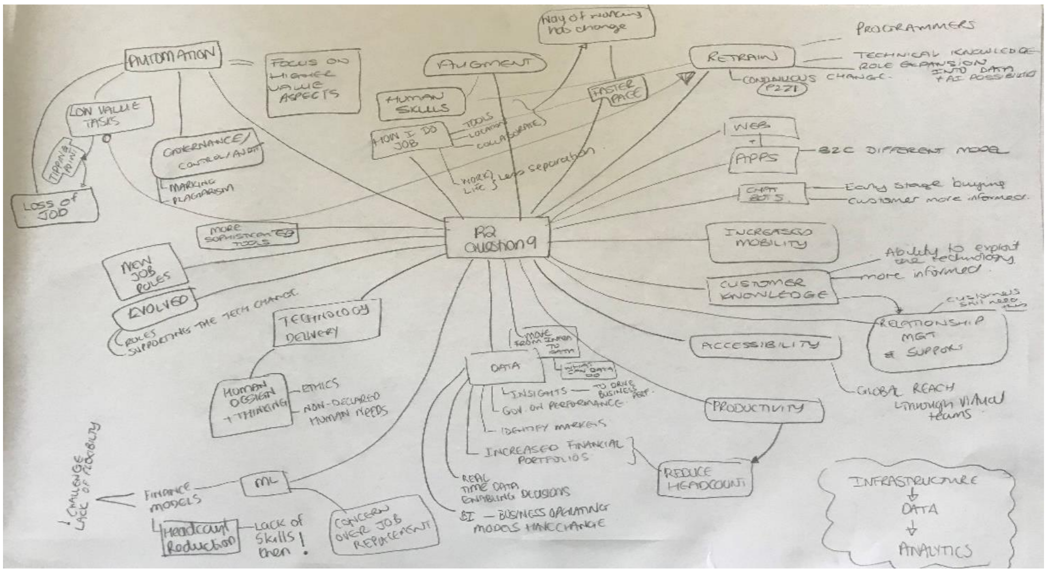
8.17 Delphi Questionnaire Round 2

Question #	Question
1	Please provide your name so that responses can be tracked across each round. Please note that you name will not be shared or published as part of the research a participant number will be allocated to anonymise responses.
2	What Industry or Sector do you or have you worked in? Select all that apply.
3	How many years work experience do you have? (This is the cumulative experience in the sectors captured in Question 2).
4	What is your existing or last Occupation/Job Title
5	What professional or technical occupations do you think could be created over the next decade as a result of AI related technological change? (List all or state not sure if applicable)
6	Looking at the next few years - Please rank the following job role groupings - in order of importance alongside technological change between now and 2025; (1 - the top being most important and 10 - the bottom being the least out of this list) See Briefing paper for the role groupings referred to (Page 5) Drag the role grouping in order of importance Industry Specialists (See Role Grouping 1); Legal/Compliance/Regulator/Ethical roles (See Role Grouping 2); Creativity roles (See Role Grouping 3); Data Specialists (See Role Grouping 4); Healthcare Professionals (See Role Grouping 5); HR & Learning & Development roles (See Role Grouping 6); Leadership, Management Roles & Organisational Specialists (See Role Grouping 7); Sales Specialists & Marketing Specialists (See Role Grouping 8); Technical Specialist & Specialist Engineers, Developers (See Role Grouping 9); AI Integration and human augmentation roles (See Role Grouping 10)
7	Looking further ahead - Please rank the following job role groupings - in order of importance alongside technological change post 2025; (1 - the top being most important and 10 - the bottom being the least out of this list) See Briefing paper for the role groupings referred to (Page 5) Drag the role grouping in order of importance Industry Specialists (See Role Grouping 1); Legal/Compliance/Regulator/Ethical roles (See Role Grouping 2); Creativity roles (See Role Grouping 3); Data Specialists (See Role Grouping 4); Healthcare Professionals (See Role Grouping 5); HR & Learning & Development roles (See Role Grouping 6); Leadership, Management Roles & Organisational Specialists (See Role Grouping 7); Sales Specialists & Marketing Specialists (See Role Grouping 8); Technical Specialist & Specialist Engineers, Developers (See Role Grouping 9); AI Integration and human augmentation roles (See Role Grouping 10)
8	Do you think there is a key professional job role missing in the list? If yes please state the job role/s or state Not Sure
9	Have any of your job roles been affected by technological change? If yes please describe the impact and when that was. If No please state No in the box
10	On a scale of 1-10 (1 being negative and 10 being positive) rate how you feel about the impact technological change will have on professional occupations in the future?
11	Rank in order of importance the key skills required by people in the future alongside AI related technological change? (1 - the top being most important and 10 - the bottom being the least out of this list) Ability to change & learn (Including resilience, motivation & Tenacity); Analytical, Interpretation, Problem solving & critical thinking ; Maths/ STEM / Specialist technical skills; Creativity, Innovation & Curiousity ; Empathy & EQ (Emotional Intelligence); Ethical adoption, Compliance & Legal ; Business value analysis, mapping & strategising ; Specialist indepth knowledge - non technical; Envisioning, Business value analysis and mapping ; Relationship Mgt, Collaboration, Decision making, Communication & Mgt;
12	What do you think are the key skills required by people in the future alongside technological change? Please list
13	Which sector/s do you think will be affected the most technological change?
14	Is there anything you would like to add in relation to technological change and the human future workforce? Is there anything that concerns or excites you about the future workforce?
15	Would you be happy to be contacted by the researcher to take part in a follow up interview?
16	If you are happy to be contacted by the researcher for a follow up 30-60 min interview please provide your email address:

8.18 Thematic Analysis Stage 1 familiarisation maps







8.19 Machine Learning Engineer Job Specification

Job profile

Machine learning engineer

If you are fascinated by computer science and want to be part of an exciting and continually developing industry, then machine learning engineering may be the ideal career for you

As a machine learning engineer, working in this branch of artificial intelligence, you will be responsible for creating programmes and algorithms that enable machines to take actions without being directed. An example of a system you may produce is a self-driving car or a customised newsfeed.

A key feature of this work is that you are providing computers with the ability to learn automatically and improve from experience, without being programmed.

There may be some cross-over with other disciplines, including:

- computational statistics
- mathematical optimisation
- data mining
- exploratory data analysis
- predictive analytics.

Responsibilities

As a machine learning engineer, you will need to:

- understand and use computer science fundamentals, including data structures, algorithms, computability and complexity and computer architecture
- use exceptional mathematical skills, in order to perform computations and work with the algorithms involved in this type of programming
- produce project outcomes and isolate the issues that need to be resolved, in order to make programmes more effective
- collaborate with data engineers to build data and model pipelines
- manage the infrastructure and data pipelines needed to bring code to production
- demonstrate end-to-end understanding of applications (including, but not limited to, the machine learning algorithms) being created
- build algorithms based on statistical modelling procedures and build and maintain scalable machine learning solutions in production
- use data modelling and evaluation strategy to find patterns and predict unseen instances
- apply machine learning algorithms and libraries
- lead on software engineering and software design
- communicate and explain complex processes to people who are not programming experts
- liaise with stakeholders to analyse business problems, clarify requirements and define the scope of the resolution needed
- analyse large, complex datasets to extract insights and decide on the appropriate technique
- research and implement best practices to improve the existing machine learning infrastructure
- provide support to engineers and product managers in implementing machine learning in the product.

https://www.prospects.ac.uk/job-profiles/machine-learning-engineer

8.20 Validation queries

Areas for further exploration/validation?
Data quality versus quantity comment and also the comment about the number of jobs - unclear whether this was negative or positive - explore further
Heavily IT dependant service. Impacted by security, stability and programming issues. Affected by hardware & mains services disruption & failures Will be impacted on with advancements & societal demands Hampered by financial constraints Explore further how these dependencies affect their professional job role - any new skills or retiring of previous skills for example?
Yes, my current role involves much more technology than previous jobs. The academic landscape and university culture are changing to reflect generation Z! The use of technology permeates subject disciplines AND the way in which they are taught. EXPLORE - skills required now and going forward
Gradual increase of use of technology in education over last 8 years. Impact - students less likely to attend all lectures, more able to use technology in the classroom. Greater access to technology, including pupils in school but issues with phone usage in schools restricts student teacher scope. EXPLORE - restrictions and what this means for skills from teacher and students?
The introduction of technology enhanced learning tools has had a significant impact on my role and my colleagues. It has improved teaching and learning across the HE sect**ors.** EXPLORE- how it has improved teaching and learning? What has this meant for skills required to carry out this work/ role?
Is there a specific area that excites them when referring to possibilities? Also the concern about human nature and priorities will not always for the common good - are there any specific things that you are concerned would be prioritised?
Singularity comment How real do you think this is? What has informed or shaped this concern for you?
All labour could potentially be carried out by machines What has informed or shaped this concern for you and how real is it for you and if it is the timeframe?
comment about "egalitarian free to learn society" Explore whether this new society would generate new jobs?
How are people trained or prepared when new technology is adopted?
How do you use technology?
Have you observed a particular characteristic in people that adopt and adjust to change quickly or easier than others?
Have you observed a particular characteristic in people that DON'T adopt or adjust to change quickly or that find it difficult?

What are your thoughts on technology? What exposure have you had to technology in the workplace?

8.21 Interview Template

DBA Research Interview Guide

Views on current augmentation within your role and sector?	Views on future potential augmentation within your role and/or sector?
Views on the worker characteristics and requirements for now and the future?	Timeframes? Any additional thoughts on professional work/ job roles alongside technology?

8.22 Interview Briefing Paper

University of South Wales
Prifysgol
De Cymru

INTERVIEWS

NOVEMBER 2019

FUTURE PROFESSIONAL WORK & TECHNOLOGICAL CHANGE

RESEARCH BRIEFING PAPER FOR INTERVIEWEES

RESEARCHER: CLAIRE CLEMENT

RESEARCH BACKGROUND

Over the last two hundred and thirty plus years the world has experienced three industrial revolutions. The first dating back to 1784 when mechanical equipment disrupted the way in which people lived and worked. About 90 years later, in the 1870s, the second introduced electricity and disrupted the workforce significantly with mass production factories. 90 years later, in the 1960s, the third introduced further automation as a result of advancements in electronics and information technology which disrupted the workforce again and displaced jobs. If advancements were to follow the same historical pattern, we would expect the next industrial revolution to occur around the 2050s. However technological advancements appear to be disrupting how people work and live much earlier than previous timelines, with Artificial Intelligent (AI) and automated solutions maturing and being adopted across business.

A potential explanation is that the third industrial revolution introduced technology which has enabled people to be much more connected. Computers along with advancements in processing power as predicted through Moore's Law and also Cloud computing have created a connected digital world and whilst Artificial Intelligence is not a new term, the ability to collate massive amounts of data and search autonomously through it at rapid speed has meant that jobs that used to be manual, repetitive and time consuming can now be automated with minimal or no human interaction at all. Tasks and activities that have historically been carried out by people are being displaced, driven by AI solutions. The potential AI brings through technological change could significantly change how we live, learn and work. Disrupting all sectors and industries.

This connected age has also created new areas of industry, looking back over the industrial revolutions, society was one of production which made and produced things. Today we are much more a consumer society where we produce much less and consume much more, consuming services and experiences. The growth of data has led to the emergence of a knowledge sector, embracing a data rich world where personalised service can be provided and processes and interactions automated. Society expects much more and at a much faster pace. Businesses need to stay competitive in a world where data is now a commodity and an asset. The customer demands a more personalised and real time experience.

Online connectivity, data and the personal insights this brings is driving a new model of existence, at home, school and work. The boundaries between all of these are blurring as technological change disrupts how we live. One area of disruption is in the workplace and where technology has the potential to displace or change the jobs that people do. This also drives changes to the types of skills required by workers alongside technology.

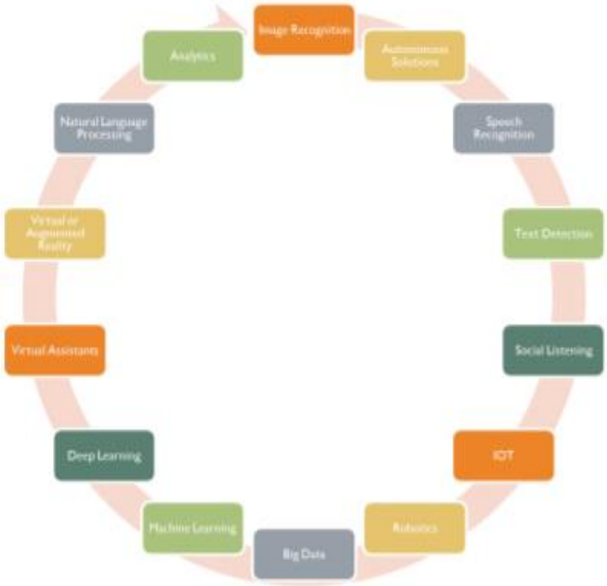
This displacement has already changed the workforce with tasks and activities changing, some say for the better enabling the workforce to focus on more interesting activities that add value and are more rewarding. Others claim that technology will lead to mass unemployment and that computers and machines will take over and are a threat to mankind. Some jobs are believed to be less likely to be displaced, those that involve creativity and empathy for example. It is claimed that jobs that involve repetitive modelling, forecasting or processing that can be replicated are more likely to be replaced by technology. However, these types of activities are claimed to make up part of people's jobs and the partial replacement of some activities by technology could drive displacement rather than eradication.

This research is exploring the future professional workforce as a result of technological change driven by AI and automated solutions. Whilst literature highlights a potential impact and the historical displacement of where technological change has disrupted the workforce, currently there is limited literature exploring what a potential workforce could look like along with the readiness and human skills that would support a future landscape. This research seeks to gather insight through expert perceptions and knowledge of the potential future readiness requirements. This would help inform training and development plans and strategies, along with course profiling and educational requirements for future organisations and students.

DEFINITIONS

TECHNOLOGICAL CHANGE

For the purposes of this research Technological Change will be defined as any change that is realised or adopted as a result of solutions that are not fully human and therefore constitute an element of artificial intelligence or an automated solution, (that solution could be partially automated or fully automated). High level examples include but are not limited to solutions or delivered change through: Big Data, Machine Learning (Supervised, unsupervised learning, deep learning and reinforced learning), Internet of Things (IoT), Autonomous solutions, Robotics, Virtual or Augmented Reality. The diagram below depicts some of the components/terms associated with for the purpose of this research included in the term Technological Change.



Source: *Created by the Researcher: Claire Clement (2019)*

WORK & ROLES

*For the purposes of this research professional work is defined as jobs (full or part time) that are carried out by people and classified in the UK Standard Occupation Classification (SOC) groups MG1, MG2 & MG 3; **MG2 = Professional, MG3 = Associate Professional and Technical or Managers, MG1 = Directors and Senior Officials roles**. For further clarity professional or associate professional and technical roles include roles that require academic study and/or workplace qualifications or certification/s to capture a level of competence and/or accreditation within that role. The Standard Occupation Classification (2010) defines the "general nature of qualification, training and experience for the three in-scope major groups as follows:*

Professional occupations	A degree or equivalent qualification, with some occupations requiring postgraduate qualifications and/or a formal period of experience-related training.
Associate professional and technical occupations	An associated high-level vocational qualification, often involving a substantial period of full-time training or further study. Some additional task-related training is usually provided through a formal period of induction.
Managers directors and senior officials	A significant amount of knowledge and experience of the production processes and service requirements associated with the efficient functioning of organisations and businesses

Source: https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010/soc2010volume1structureanddescriptionsofunitgroups#major-group-structure-of-the-classification-and-qualifications-skills-training-and-experience

INTERVIEW OVERVIEW

The Research aim is to explore future professional work alongside Technological Change. The research interview objectives are to explore:

1. The area of 'augmentation' where technology and the human worker could or do complement one another as part of that occupation/job role
2. The potential human capabilities/skills and requirements that would support future technological and human augmentation as part of future professional roles.

The interview will be approximately 30 mins and will be recorded to assist with transcribing after the interview. The format will be semi-structured to allow the interviewee freedom to provide their professional and expert views on the research and interview topic.

A copy of the interview transcript will be shared with the interviewee for validation purposes and participants after the interview via email or physical copy, participants are asked to confirm back to the researcher that the transcript is a true and fair reflection of the interview discussion.

DATA AND CONSENT

All responses will be anonymous, any transcribed data will be attributed to a participant number and no personal identifiable information will be published or shared as part of the research.

If you have any questions about the storing or use of your responses, please contact the Claire, the researcher for clarification.

PRE-REQUISITES & DEPENDENCIES

Prior to the interview a completed consent form is required to be submitted/returned to Claire Clement, the researcher.

A link to the online consent form is here:

https://forms.office.com/Pages/ResponsePage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAAa__dOWj-xUNUZMVktNRjRDNkNGSjlCU0ZFV0VaTU5SNS4u

Or you can scan the following QR Code:

INTERVIEW WITHDRAWAL, VALIDATION OR QUERIES:

You have the option to withdraw from the research by contacting the researcher, Claire Clement & requesting withdrawal.

A copy of the interview transcript will be shared with you for validation purposes after the interview.

If you have any queries on the research aim, objectives or any part of the interview please raise with Claire.

8.23 Interview Consent Form

Research Interview Consent Form

This form is to acknowledge and provide consent to be interviewed by Claire Clement as part of a Doctoral Research Programme conducted through the University of South Wales.
The Research aim is to explore future professional work alongside Technological Change. The research interview objectives are to explore:
1. The area of 'augmentation' where technology and the human worker complement one another as part of that occupation/job role along with,
2. The potential capabilities and requirements that would support future technological and human augmentation as part of future professional roles and
3. Validate themes that emerged from an earlier data collection phase and invite any further expert opinion on future professional work alongside technological change.

Section 1 ...

1. Please confirm that you consent to the researcher recording and transcribing the interview for research purposes in line with the Research aim and objectives. All data transcribed will be anonymised and no data that could identify you will be published as part of the research. (Tick the consent box and sign, print name and date below)

   You will be sent a copy of the interview transcript following the interview for participant validation. *

   ◯ Yes I consent

2. Please sign confirming your consent *
   Enter your full name in the box below - entering your name confirms electronically your consent to participant in the interview:

   Enter your answer

3. Date *

   Enter your answer

4. Please confirm your current or last occupation *

   Enter your answer

5. Please select the most appropriate option to capture your experience (this is the cumulative experience across your career) *

   ◯ Below and including 5 Years
   ◯ 6-10 years
   ◯ 11-15 years
   ◯ More than 16 years

6. Please confirm your primary industry? If Other please state *

   ◯ Healthcare
   ◯ Public Office
   ◯ Technology Including Communications
   ◯ Manufacturing
   ◯ Financial Services and Insurance
   ◯ Retail/ Commerce
   ◯ Education
   ◯ Construction
   ◯ Defence / National security / Public Safety
   ◯ Other

7. Interview withdrawal, validation or queries
   You have the option to withdraw from the research by contacting the researcher, Claire Clement & requesting withdrawal. A copy of the interview transcript will be shared with you for validation purposes after the interview.
   If you have any queries on the research aim, objectives or any part of the interview please raise with Claire.
   INFORMATION ONLY - NO RESPONSE REQUIRED

   Enter your answer

8.24 Transcription updates

Should have transcribed	Transcribed
Great for	Grateful
Agile	Angela
Tech	Tank
I.T.	it
First sprint	Sort of Spring
This, that and the other	Sandhya bird
Their, there	Always 'there'
Then	There
Obviously	Our success
Interview someone	Enter someone
Sense check	Send check
Role	Roll
Isolation	Felicia
Brilliant, just	Britney Spears
And that	Not
In effect	That act
The knock-on effect	They're not going to affect
Swansea	Juanzi
Is there	They're
You are	Your
Have an alexa in the house	Have an election house
Made	Make
Augmentation	Orientation
Fore runners	Foreigners
In person	Embarrassing

8.25 Interview transcript example

The transcript has been anonymised and is included as an example.

Claire Clement Researcher 0:02

Today is December the first 2019. I'm Claire Clement, and I am interviewing participant number five. For the recording. Can you just confirm I know you've completed through the consent form. Can you just confirm you're still happy for this interview to be recorded and also transcribed?

P5 0:18

Yes, I am, thank you.

Claire Clement Researcher 0:18

Thank you. So today we're here to talk about future professional work, and technological change. You've had a copy of the briefing document, are you happy with what I mean by the terms, technological change, and also professional occupations?

P5 0:24

Yes, all good thanks

Claire Clement Researcher 0:30

Thank you for taking part in the previous phase, which was a two round Delphi study. And this is following on from that to explore some of the themes that emerged from that Delphi questionnaire. Specifically, what came out was an area of augmentation where people use technology of some sort. It could be any sort of technology a software programme, it could be a robot, it could be really advanced, or it could be something as simple as email to complement their day to day job. So, what I would like to discuss today is how technology has complemented the work you do and how you use technology to support you in your job, your professional role.

P5 1:22

Okay.

Claire Clement Researcher 1:23

The other area that I'd like us to discuss is, is an area and get your views on things like skills and capabilities, what also came from I came out of the questionnaire was rather than just being specific technical skills, there's also something around the way people approach work and their capabilities and perhaps more of an approach rather than a specific skill. So, I'd also like to get your thoughts on that area as well today.

So, first of all, just to recap on some key comments that came from your survey, which was great, thank you for that. It supported the augmentation link is that you said that technology is far more involved now in your job role than it was previously. So be good to get your view and just elaborate a little bit on in what ways has technology come into your role/job over the years,

P5 2:22

Okay, well as my role has always been in higher education, I've just seen how technology, we call it TEL, technology enhanced learning now is much more mainstream across the sector. So, there is an expectation that lecturers use technology to enhance our learning. And I think there's two reasons why one is because you've got cohorts now coming into higher education with a set of skills and a pattern of working on mobile devices, being immersed in technology in their day to day lives anyway. So, for them not to have an enhancement of that, and yeah further their skills in that would be seen as going backwards really. And so that's not to say that everyone who goes through HE has a set level of skills, but most people now, you know, because of the technological change. Most people do have a set of skills. So, it's, it's working with those skills,

Claire Clement Researcher 3:41

What kind of skills would that they be?

P5 3:43

So, for example, I'd say kind of like it's not incidental skills, but soft skills that kids, adults, research soft research skills where you know, they may not be it may not be at a high level. So, you'd be googling but you know that you've got sources now online. Whereas before that you can research you can find out stuff, before you, you just wouldn't be able to access that information, you'd have to go to a library, you'd have to speak to somebody who had a specialist knowledge. Whereas now, you know, the default is Google and what comes with that is, I don't know, I don't want to kind of veer off this.

Claire Clement Researcher 4:31

It's fine. It's good to know that

P5 4:32

What comes with that really is, okay, you've got lots of kids or people coming in knowing that they've got this amazing, powerful source, Bank of information within the internet, but it's actually then it's teaching them the research skills and how to distinguish good and bad information, what they do that information, how relevant is for their life and you know, all the implications. of that.

Claire Clement Researcher 5:02

I think it's a quick question on that. So, when you sort of, so I get that historically, people would have had to access specific experts or go to a library. Now, it's far more digital and I you say the access to information is huge. But they still need to learn skills as to how to interrogate and use those search capabilities. So, from your perspective, how did you transition? You know, what readiness did you have? And how did you approach that sort of move to a digital way of learning that and as opposed to how it was?

P5 5:36

Yeah, that's interesting, because from when I did my degree, what year was the internet? When did that start?

Claire Clement Researcher 5:46

About 1990s when it all kicked off however it wasn’t really mainstream until a few years later.

P5 5:53

No. So I think we just used computers for word processing, but it was still technology, we used to save on a floppy disk and print out. But sorry what was the question again?

Claire Clement Researcher 6:10

So how would How did you manage that transition? Do you remember having any sort of readiness and knowing your job when you're teaching and showing people? How to perhaps optimise and get the best out of a digital search engine? How did you learn that yourself? You know, did you have courses? Do you or did you just crack on? How did you approach it?

P5 6:33

Yeah, I think, for me personally, it was see what's going on and I'm not one of these old in a set in one way. I think I am an early adopter. And if I see something is beneficial, I'll just take it on, but I won't do that without being informed. I won't just go for the glitzy woo shiny. This is some new technology in a way I little get a little bit cynical. I think one let's have a really, Do I want to adopt this? Do I want to invest in understanding this tool and learning specific skills about it? If Actually, it's not going to enhance my practice yet, for example, I'll use 'mentimeter' which is like a polling mobile phone polling device to get some first question and answer session and work and I could do that as effectively in the in the session with post it notes, good old fashioned post it notes or paper and pen and that and that's got a different dynamic, but for the anonymity, and then for what I do with that information afterwards. There's no shadow of a doubt that the technology has enabled me to do something more than I could with the old school, paper and pen. So the answer to your question is in making that transition I'm more saturated in technology now because of the environment I'm in and we, you know, we've got to be modelling it, we've got to be finding out the latest this, that and the other but I am not thrown by any fear of, of technology and I might actually I play devil's advocate and I make out as if all Gosh, this, this new shiny thing and that new shiny thing, but actually, I, I know what I like to using it and why I use it. And there are people who describe the latest version of this particular thing. And it comes down to justifying it, okay, why using it or because it's new? Well, if it isn't any better than another thing or then don't use it.

Claire Clement Researcher 8:52

So, and I think that's something actually that has come up from other interviews is that sort of realisation of the value and justifying, you know, you mentioned the early adopter. Would you say that there's a mindset that you have? You know, obviously, you're not, as you mentioned there, you don't have fear of adopting it. But you've got to have, you've got to buy into the value of it.

P5 9:16

Absolutely. Yeah.

Claire Clement Researcher 9:18

And that link to the change curve.

P5 9:20

Yeah. And so in the change curve, when you got what was at the end, the laggards at the end, and you have new and you kind of got the early adopters, but in a way you want the next batch of people don't know.

Claire Clement Researcher 9:36

But it's sort of the but you go there's that fear phases, and then there's acceptance. And normally when people adopt change, it's they have to buy into it, which is you know, why it resonated, really the change curve. I raised that really, because of the things that you mentioned there was you're not in fear technology. You are an early adopter, but you have to buy into it. Which I think is a really positive thing.

P5 9:59

Yeah. like with anything in life, you've got to be informed and you've got to balance it out and see what the value is in these things and what the output will be.

Claire Clement Researcher 10:15

And do you think that the students that you're seeing coming through do you think they have or adopt that same mindset, or do you think they have a different approach?

P5 10:23

I think they're more playful. I think it comes out and I don't like the term what they call the natives you know, what they call technology natives

Claire Clement Researcher 10:39

But to think then, do you see individuals who, perhaps rebel or don't adopt the change quite as quickly, or the technology quite as quickly as others. Do you see that?

P5 11:02

Yeah, definitely. It's like anything in life? Definitely.

Claire Clement Researcher 11:05

So, do you think if you if you could think of, perhaps a group of individuals or perhaps an individual that you've observed, adopt technology really quickly and sort or thrives in that environment? And then versus an individual who perhaps doesn't adopt it quite as quickly? Do you think there is a different approach or skill set or, you know, a view that those two groups have?

P5 11:32

I don't whether I could not generalise? My don't know whether I could identify to specific groups, but in my line of work, you've got researchers who may not necessarily understand teaching, and you've got researchers who understand teaching and I think for me, that's probably if I have to try and do two groups of people. You've got researchers who obviously they focus on their own research, they, they will be using technology in their own research, but because they don't really understand too much or have much experience in teaching, then they wouldn't necessarily they'd they wouldn't bring technology into their teaching practice. Whereas you've got others who are, you know, working research, basically everyone is working research will have to be using technology even if it is on the internet and for publishing work and stuff. But you've got the people who understand that they need to engage their audience, that they've got 600 students for an hour, and this day and age standing at the front and dictating information, won't cut it. You know, people don't read information, don't Just want to hear it verbally, they've got a visual, they've got to be able to have autonomy and look up their own and do their own research, they've got to give their own voice and there's a big move and this does is relevant to the technology, technological change is, you know, where students have been given more voice. So actually, what empowers them, giving them more tools, more digital tools to enable them to do that.

Claire Clement Researcher 13:33

So on that is a couple of things there which is really good and to sort of focus on is what I picked up and it again, shout if you think I'm misinterpreting what I heard or what you said, is the technology, the two sort of areas you said then there's some that understand teaching and some that don't. Would you say that's understanding the context that they have to learn and so you can have all the tools but if you don't understand the application of it, you're going to be sort of limited?

P5 14:06

I'm thinking more of the skills of teaching. Not so much context as in their field or their discipline as a subject, but because my job is about getting researchers to be able to teach Well, that's really more my perspective because I don't know when it comes to subject specific stuff that's beyond my role

Claire Clement Researcher 14:34

From a skills perspective then and they obviously they can understand what they're researching because that's their area they want to research but the interpersonal skills and how they interact, no technology really can help them with that. Would you say?

P5 14:49

I think the opposite, I think I'm not saying everyone should be I need to pull a rabbit out of the hat. But people who don't understand about teaching and the engagement and giving, you know that the cohort, a range of experiences for them to learn about their discipline. I don't know where the barrier is, but maybe they haven't seen it. They haven't been. Because they've been, you know, in a mindset of just doing their own research, they haven't been exposed to all these tools, seeing the value of them, right. And what we're seeing is the more they see that the more shared in their colleges, the more they understand that then, okay, the light bulb starts to go on and they kind of and the technology absolutely will enhance their teaching.

Claire Clement Researcher 15:57

So therefore, you absolutely see the technology complimenting and augmenting them

P5 16:01

Absolutely

Claire Clement Researcher 16:02

as opposed to them, they can't just get up there and present and use the humanistic skills they do need the technology to optimise it, okay.

P5 16:10

And not only that, we're sort of talking about teaching that happens to be in a room and physical room. You know, we touched on the online learning and the virtual rooms or the virtual learning environment that holds information, say Blackboard, Moodle, Canvas, whatever you're using.

Claire Clement Researcher 16:38

So then, with regards and the key skills then because augmenting that technology and with the sort of teaching, what would you say is the key skill or capability that people need to be able to optimise that sort of augmentation.

P5 16:58

So, as a teacher, as somebody facilitating the learning what skills do they need?

Claire Clement Researcher 17:07

Yes. So, if you're if you're a professional, you're there, you're using technology to augment your role which is teaching. How do you know what human skills do you need to be able to optimise the technology? Is it 50:50 or 70:30? What's your thoughts on how much of it is human skill? How much is it is technology?

P5 17:32

Really interesting question. I think the reality is probably 30 skills, human skills. 70 technology, but the perception is probably flipped. Okay. And that's why you get people who are reluctant to try something that's bit whizzy and they're fearful and they just say I just haven’t got time. I know my stuff. I know my research and my subject I know my tools for my research but when it comes to teaching, I haven't got time to be doing that and, you know, actually when you show somebody something

Claire Clement Researcher 18:16

And what do you think that benefit is, would you say, take the best scenario, you're optimising the technology and you've got you know, 70% technology driven and 30% human skills. What, what's the impact of that is you get more productivity, is it more satisfying from a job perspective?

What would you say is the outcome that you get from optimising that augmentation?

P5 18:49

I think from an educational point of view, you've got the quality of the acquisition knowledge acquisition the investigation, collaboration, even discussion, because it allows people to discuss and give them a voice when they may not be able to articulate their thoughts comfortably in a room that you know, of 10, let alone 600.

Claire Clement Researcher 19:18

on that last one, so would you say that if I said some people would say that technology can be exclusive rather than inclusive. But there's also an argument there, you said that if somebody is a bit shy, they may be more inclusive in a in a virtual environment?

P5 19:38

Absolutely. I had that I don't know what the research basis for that saying that it's in exclusive because technology actually is I would say is the opposite and assisted technology, which I don't actually know a lot about, but for starters, technology certainly enables people who wouldn't be able to join in to join in the learning and how to know, if somebody wants to learn. It's not in my particular job but say somebody wants to learn at three o'clock in the morning on their own. They can do that now.

Claire Clement Researcher 20:26

Connectivity has removed the boundaries of 9 to 5.

P5 20:29

Absolutely and if you're an environment, go back to like, a classroom environment and you wanted to give you wanted to use technology and, okay, the basic, I suppose would be, you might exclude people like on social economic, through a socio economic lens saying you think well actually, you can't assume that everyone will have a mobile device will You know, you as an HE institution, you have mobile devices, you just tape them to your session. You know, people use them. They share they, there isn't really an excuse anymore.

Claire Clement Researcher 21:13

No, I agree, sort of. It's levelled out a bit, isn't it? The access to technology has really progressed.

P5 21:20

And if you're using technology as an institution, then it's your responsibility to provide that anyway. So that makes it inclusive

Claire Clement Researcher 21:29

So, one of the areas that sort of ask you about is in your role. Is there a particular area that you actually think could not be replaced by technology, which is sort of some people would call it a human comparative advantage? But is there an area that stands out to you that a robot a programme software could not do?

P5 21:50

Absolutely. And it's quite a hot potato at the moment in universities with mental health, wellbeing and it is the pastoral meeting somebody in the flesh. There is space for having that Skype, virtual, zoom whatever using when you know you're not physically with someone but actually for wellbeing in the pastoral side of things, you being in a room with someone, you will never replace that. So, you know, it would be really dangerous to replace that

Claire Clement Researcher 22:29

So, would you say from your professional view the biggest, it is the biggest human comparative advantage? Is that human to human interaction?

P5 22:41

Yeah. Because I see that with the students and their lecturers, that student you know, lecturer relationship, the mentoring that goes on for students support, there are all these fantastic resources, they can do these self-help quizzes, they can know where to access information but if people are going through a tough time if they're stressed if they have got pressure and I've seen this in my previous role when I was a lecturer so I could have those meetings with students and now I'm getting it with lecturers who I see on a one to one the most part so my job, because I really value that where, you know, they can have a coffee and just talk through some of their issues. Once you formalise that, for a quick example, you know, I'm having really bad student feedback. I've tried this, that and the other my lectures still don't look good. If that was put in an email, all the subtle nuances, the feelings, there is limited amount of empathy that I can give that person, if I meet them for coffee and I see how important it is to them and when you start discussing stuff, and really and unpicking it. Face to face is invaluable then.

Claire Clement Researcher 24:08

Yeah, no, absolutely. And I think that's the, the key thing really, is that one of the other interviews that I did, what came up was, you can't standardise the non-standard. So when you have that interaction, the value that comes from the human to human sort of interface is that you're not quite sure what's going to come up and I think that's why I think it's such a strong competitive advantage for people.

P5 24:33

Yes, and your immediate reaction is immediately heartfelt. You would react to somebody face to face; you haven't got that layer of filter before you even start. I'm just using it as an example. But you know, you have to think, and you know, you miss that spontaneity

Claire Clement Researcher 24:54

It is that cognitive you see thinking but it's also would you say again, I don't put words in your mouth, but it's that EQ and that empathy that people have with people that you wouldn't get from technology?

P5 25:13

Absolutely. Yeah and you can't get that from an email when somebody has constructed that what you get from them in face to face because all that that they say that the emotional intelligence. The other stuff that's going on just by looking at someone's face, maybe their gestures, take a little something uncomfortable that body language, none of that you can get from technology, you could get it from a Skype and you probably sense some of it but the fact that is going through a filter, which is the you know, the skype whatever, then you think about raw response.

Claire Clement Researcher 26:00

Looking forward? Do you think there will be a time where technology could do facial recognition and could interpret know that there is technology that does what's called sentiment analysis?

P5 26:12

It is there already, now,

Claire Clement Researcher 26:13

but I suppose the bit that I'm picking up, it could identify it, but it's the so what follow on action that is still key for humans.

P5 26:23

Yeah, it doesn't matter what I don't think, well, I would hope maybe it's based on my own sort of value system but doesn't matter Technology is amazing and it does enhance our lives and you know, I can see the value in robots being there for older people and responding and you know, all of that but actually a person with skin you know, absolutely is, is irreplaceable.

Claire Clement Researcher 26:53

So then, just thinking now more about looking forward. So that was the great that you saw, we covered off What you think technology couldn't replace so what things do you think technology could mature into and helpful in your job? What do you think technology wise job yet then your sector industry?

P5 27:14

Well, I can see it. I mean, OU Gosh, they've been doing it for years. They are fore runners, but I could see it replacing a lot of the attendance, you know. Why should students get up drag their sorry arses to a lecture at nine in the morning and they can just get online.

Claire Clement Researcher 27:42

Going back to your last comment about you know, that interaction, do you think it was you know, get all your students that might go for the online, but do you think it would ever be completely online? Do you think the human nature would be I need that face to face contact, having done an OU course myself, I still went in once a month, every month for a tutorial, which was in person?

P5 28:09

Yeah. Because otherwise be complete breakdown of society and people need community. They need to be with others. But if you sort of saying how can I see technology affecting at the HE Sector by that actual attendance which I think will still be there, but it will cut into that.

Claire Clement Researcher 28:34

Do you think people will allow that because I completely agree with you, I can see the potential is absolutely there? You could virtualize almost anything. I suppose the secondary question that raises in my mind is, do you think people will allow it to go that far? And it's quite subjective and personal.

P5 28:51

I don't think it's as simple as people are allowing it to happen because you see the quality of materials, little example I give a lecture. I didn't know, the same lecture, say six times. And for me, I'm saying doing the same material, these cohorts, right? Well, actually, if I've got some really good quality material that I can record myself giving the same general message and then my material gets updated and there is research to back up the fact that you don't just have material running, people like to see somebody so even if you've got slides behind you, it's not good enough just to have your voice you've got they've got to see your eyes. You've got to see your facial expressions. So actually, it's not so much people stopping it because if that allows me to do more of my research frees me up, bring it on. Why not, I'm a bit fed up with the 600 students that I'm having to, you know, I prepare all this stuff and then 20 turn up

Claire Clement Researcher 30:14

Do you think on that so I get you got 600 students and you 20 may turn up? But from you mentioned earlier about pastoral care, there is that bit isn't there around what is the role and as that role goes forward and also do you think so whilst at the moment students may say, it's great, I can do it all online. But if I use the scenario, the analogy of the self, self-serve checkouts and supermarkets at the moment, there's a lot of people boycotting those because they're saying they actually want to be served by person. They're unhappy with people being put out of jobs and they're unhappy. Actually, nine times out of 10 and unless you've got one or two items, it's not actually quicker.

P5 30:56

Yeah, but that comes back to me saying how community and people no matter what people because of the, because we're social beings. So, we will always want community with people in the flesh. Although, part but that's our limited understanding now. I mean some kids so I suppose it depends on age, who you are you're interviewing some kids might say, I am really fulfilled with the community that I've got my online community I've never met anyone who understands me like this particular group that I tap into and that I suppose the unknown of like, actually, you know, I'm saying from my own experience

Claire Clement Researcher 31:40

That's quite interesting actually might be worthwhile me interviewing some younger people to get their views on, you know, how they see technology in the workplace in the future. But I would also think about I'm just considering really what you said about the age but because that has actually come up, but from a societal perspective, if people aren't having interaction in the classroom, do you think then we run the risk of having given that we're saying a human comparative advantage is that empathy is that interaction. If the generation coming through university is not engaging in that interaction, are we then developing a lack of those key skills?

P5 32:26

I'm not sure because my sort of work is so narrow in this big picture. But I would say with online learning, and you've got people coming into your rooms, you've got your skyping-in and you can see their face, you're putting them in a room, you've got them, you've given them a task, you actually you've got to control the behaviour of as you would if it was a real room that given people you know, the keys to be able to enter in like 15 minutes before so they have access and they settle and introduce themselves then. So, they've still got to present although maybe that more complicated they've got to present their online self haven't they, I was just thinking about that it is really complex.

Claire Clement Researcher 33:18

Yeah, just thinking about that. So, would you do an all virtual class or is it mixed? Is it physical? And some people watching it back later or actually skyping in as it's happening? What kind of scenarios

P5 33:34

Are there are lots of different formats? So, you you've got all of those,

Claire Clement Researcher 33:39

but do they mix? So, is it one or the other? So, do you ever run a lecture where you've got people in the room, but you've also got people virtually on Skype real time? Okay. So then does that then create more work for you in that not only have you got the preparation for the physical aspect, you've also got the online preparation to make sure online have got it?

P5 33:58

Yeah. And personally to give you a corker of an example, which I think is absolutely ridiculous is when you have these tweets meetings or tweet meetings, they call them and you've got eight or 10 people in a room, we've actually had this eight or 10 people in the room with their, with their laptops, tweeting into the discussion, whatever. Thinking that other people are going to be involved and actually, no one else is involved.

Claire Clement Researcher 34:30

Is that disruptive and also then you got you comes back to the people online feel like they're being heard and included. But then as a lecturer, does that not give you a sort of you try and listen and pick up in the room what's going on, but you've also then got to watch this digital channel that's coming through.

P5 34:48

I wouldn't do that. I've never done both never. And to be honest, not many people do that. It's normally one or the other. But in this tweet thing, that tweet meet. The idea was that you had all these different People ready expecting external people involved, get involved. And they didn't. So, after 10 minutes Personally, I said, right, there's just shut the computer down and talk. But they persevered for the hour not talking to each other and doing online and I thought it was absolutely ridiculous,

Claire Clement Researcher 35:23

What we have from a professional perspective, I have been in meetings where you have people in the room, people online, people online, because there's always a little bit of a delay in the in the conference, even if it's video conferencing, the conversation in the room sometimes moved on and someone's raised a comment online. And it's that that as well can be quite disruptive and also quite inefficient. And we've had scenarios before where people have actually raised complaints where they think they haven't been included, because they're not in the room.

P5 35:52

So, do they feel that if they're not, that was Skyping that's I feel that's alright. Well if the meetings I've been in the do that that was managed over. Okay, but then we don't have the online comments going on

Claire Clement Researcher 36:09

We have the comments going on as well. And that's something that you think well actually it creates and someone said it another Interview

P5 36:15

You don't have an equal voice then

Claire Clement Researcher 36:16

no and also you're trying to but in because there's the normally is a little bit of a delay in internet connection it's a little bit flaky sometimes, someone else I interviewed raised it and actually says sometimes they feel that technology creates noise, and again something that you said resonated that whole mental health. There's that bit if people don't feel they're being heard and sometimes the technology can help but it can also prohibit so and it's quite interesting. I'm just conscious of time. So, with regards to future work and skills, is there anything that's Top of Mind obviously hopefully you've done the questionnaires. You've got a good view of what I'm researching and honestly there's augmentation and complementing work and skills. Is there anything that's top of mind for you that you'd like to sort of raise and contribute to the research?

P5 37:25

What I think is it might be a bit broad but yeah but back to the mental health thing and the wellbeing of you know the technology serving you or are you serving it I think man because you know, we've allowed it in, but we don't necessarily control it and you know, addictions or the that the validation of your own life in a virtual world and actually, even if it's in education or socially, you know, it's just so complicated. There's that whole other thing with mental health and your identity going on that. I don't particularly understand it but there's you know, I do get a little check of, you know, when we just accept and more and more into our homes and, you know, I don't know, I suppose with anything new what long term impact is it going to have on us, at the moment we're seeing all the benefit absolutely wants to drag around town, and they can do online shopping. Communication to our, kids and relatives. Phenomenal. But we don't hear our kids ever. say and I'm bored because it's a constant stimulation. So, I don't know.

Claire Clement Researcher 39:02

Yeah, that's really valid actually. And I've completely agreed with you that whole wellbeing piece. I think it's, you could relate to an analogy, relate back when smoking was trendy way back when was it 50, 60s nobody actually realised the knock-on effects later on and that does stick in my mind. Everyone, you know, again, someone else in another interview said, the access to all this information, you've got everything at your fingertips, but people are on YouTube watching videos of cats and people falling over. So, as a society, there is probably another PhD in that really, what's, what's driving people's social interest. Yeah, it's that thirst for learning. You could probably go and learn anything you want at the moment, but people don't. Some people do but most people don't.

P5 39:54

And they don't you don't know what you don't know if they don't have those research skills, they can't interrogate the information. You can learn whatever you want, but don't necessarily know what you're learning is robust and the right thing. Which is really scary.

Claire Clement Researcher 40:16

I read a recent book called The AI delusion, I would highly recommend it is a brilliant book, and it stood out for me. My personal view was because it gave a different slant on technology. It actually said that, you know, talking about data as being you talk about AI, you talk about data. It actually said that if you interrogate the data long enough, it will confess it will confess whatever you want it to. I suppose that's quite an interesting thing in that you look at young people coming through, and there's again, someone else mentioned it. It does seem to be this naivety when it comes to online. It was online, it's on my phone, that has got to be true. Whereas if somebody said it to their face, they Maybe it comes back to perhaps skills and approach or actually be good to get your view on this. Do you think you're seeing people? Do you think people are as challenging now to things they see as they perhaps were five years ago?

P5 41:27

In some ways yes and more of a cause. You've got information, you know, if you're, if you want to find out what's going on politically got information so you can be well informed. And then you can actually start to give you a bit of ammunition then to inform the discussions and think what actually so it gives you more of a voice so then you're, you know, whereas before, you've only been relying on this one event, yeah, but you've been relying on the beliefs of people around you and you know, your parents and relatives and whatever. Yes. Yes, definitely and finding out news about what's going on you can dig deeper.

Claire Clement Researcher 42:17

Do you think people do dig deeper? You may and you know, I would because to be honest, we kind of have that researcher mentality but some of the students you're seeing coming through, do you think they do research and to look into things?

P5 42:31

So, I think it's wide enough now that Okay, before you've got all these sun readers, right, there we are. That's the go to, but what I would I suppose I would think that there's so much going on, you start researching something or you look at something and it links you on and on and on. Well, there's either something really unscrupulous about that thread and Technology is very dangerous, based on the data and algorithms taking you in a certain direction. But I'd hope that the connectivity on your social media platforms, that there'll be enough voices that you wouldn't get everyone saying the same sort of thing, but this is massive!

Claire Clement Researcher 43:25

Yes, do you trust where it goes? Yeah, I'm just conscious of time. It's been really, really interesting and thank you some great insight. The next steps just quickly, I will transcribe the interview, and I'll email the transcription across to you. Could you just do a quick review of it to check and if you could just confirm back to me that you are happy? That it is a true reflection of our conversation. That would be great. Thank you very much. Participant number five

Transcribed with support from Otter ai - try it out via this link - https://otter.ai/referrals/WYFZ5PKQ

8.26 Chronology of major Technological Change

Source: Compiled by the Researcher 2019[6]

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[6] *The logos represented in this thesis do not endorse the products or services in any way and merely capture the technological timeframe of their creation to demonstrate technological evolution over time and publicly available logos have been utilised to depict the evolution of technological change.*

8.27 Literature Review chronology of authors mapped