Digital Innovation in Schools:

Using tenets of social constructivism through a design thinking approach to engage learners in digital computing and the development of meta-competencies in a Scottish secondary school

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List of Abbreviations Used in this Thesis

AI	Artificial Intelligence
ANOVA	Analysis of Variance
AR	Augmented Reality
CBE	Competency Based Education
CEO	Chief Executive Officer
CERI	Centre of Educational Research and Innovation
CfE	Curriculum for Excellence
CM	Comprehension Monitoring
CS	Computing Science
D	Debugging
DFC	Design for Change
d.school	Hasso Platner Institute of Design
DDTS	Digital Design Thinking Studios
DT	Design Thinking
DTS	Design Thinking Studio
E	Evaluation
EU	European Union
E4.0	Education 4.0
FIDS	Feel, Imagine, Do, Share
GDP	Gross Domestic Product
GDPR	General Data Protection Regulations
GTCS	General Teaching Council for Scotland
GVA	Gross Value Added
HE	Higher Education
HL	Hodges–Lehmann

IB	International Baccalaureate
ICT	Information Communication Technology
ILO	International Labour Organisation
IMS	Information Management Strategies
IQ	Intelligent Quotient
IT	Information Technology
LED	Light Emitting Diode
IoT	Internet of Things
MAI	Metacognitive Awareness Inventory
MC	Meta-competencies
MIT	Massachusetts Institute of Technology
MKO	More Knowledgeable Other
MR	Metacognitive Regulation
MMR	Mixed-methods Research
MS	Microsoft
MSP	Member of Scottish Parliament
OECD	Organisation for Economic Co-operation and Development
P	Planning
PwC	Price Waterhouse Cooper
QR	Quick Response
RQ	Research Question/s
SD	Standard Deviation
SRE	Self-reflecting eportfolios
SDS	Skills Development Scotland
SC	Social Constructivism / Constructivist
SPSS	Statistical Package for the Social Sciences

SQA	Scottish Qualifications Authority
UK	United Kingdom
USA	United States of America
VR	Virtual Reality
WEF	World Economic Forum
ZPD	Zone of Proximal Development
1IR	First Industrial Revolution
2IR	Second Industrial Revolution
3IR	Third Industrial Revolution
3D	Three Dimension
4IR	Fourth Industrial Revolution
21CC	21st Century Competencies
21CL	21st Century Learning
21CLD	21st Century Learning Design

Abstract

As the world undergoes significant digital technological advancements, many believe that traditional education systems are not providing the essential competencies learners require for the future (Istance & Kools, 2013; Joynes et al., 2019). With an ever-increasing critical digital skills gap (Meechan, 2021; S. Wright, 2018), today's learners must be encouraged to develop their digital prowess (Skills Development Scotland, 2018; S. Wright, 2018) and develop the meta-competencies required for the world they are to inhabit (Beetham & Sharpe, 2013; The Scottish Government, 2020; Trilling & Fadel, 2009).

Many feel compulsory education fails to provide learners with the requisite digital computing competencies (Istance & Kools, 2013; Joynes et al., 2019). Therefore, more engaging and effective alternatives to our current curriculum content delivery and high-stake examinations must be examined.

This proposal and research study examine an alternative method of developing digital computing competencies by employing a social constructivist (SC) approach using a design thinking (DT) model, also purported to develop the much-needed meta-competencies (MC) learners need in the future (Fairburn, 2010; Goldman & Kabayadondo, 2016; Koh et al., 2015). Internationally renowned universities such as the Massachusetts Institute of Technology (MIT), Stanford, and Berkeley use DT to develop MC; however, there is little research into DT studios in a compulsory educational setting (Carroll, 2015).

This opportunistic, single-case study details a school's journey to develop outcomes from a digitally focussed design thinking studio integrated into its curriculum, examining the perceptions and experiences of outcomes from learners and educators immersed in a two-week digital DT studio.

This study should be of interest to educators, policymakers, and parents.

Keywords: meta-competencies, 21st-century learning, digital education, design thinking, design thinking studio, innovation, creativity, immersion, metacognition, social constructivism

Chapter 1. **Chapter overview**

In this introductory chapter, the context for the study will be explored, and an overview of the current educational landscape provided. The critical challenges of the future of education will be discussed, along with the drivers for change. The aim and scope of the study presented in this thesis will be identified, as will its value and contribution to research and educational practice. It concludes with the chapter summary, which will summarise this chapter and provide an overview of the subsequent chapters in this research.

1.1 Background of the Study

As the world undergoes significant digital technological advancements, many believe that traditional education systems are not providing the essential competencies learners require for the future (Istance & Kools, 2013; Joynes et al., 2019). With an ever-increasing critical digital skills gap (Meechan, 2021; Wright, 2018), today's learners must be encouraged to develop their digital prowess (SDS, 2018; Wight, 2018) and develop the meta-competencies (MC) required for the world they are to inhabit (Beetham & Sharpe, 2013; The Scottish Government, 2020; Trilling & Fadel, 2009).

Unfortunately, the introduction and development of digital computing within our education systems has so far had an insignificant effect on learner achievement (Baker et al., 2019; Vincent-Lancrin et al., 2019). To compound this problem, there has been a steady decline in dedicated computer science educators in Scotland (The Scottish Government, 2019) and a similar decline in learners' uptake of computing science (CS) examinations (SQA, 2019). This has led to decreased uptake in Higher Education (HE) and jobs within the digital technologies ecosystem (Logan, 2020).

This would suggest that a more engaging and effective alternative to our current digital technologies curriculum, content delivery and high-stake examinations must be examined. This proposal and research study examines an alternative method of developing digital computing competencies by employing a social constructivist (SC) approach through using a design thinking (DT) framework to engage learners and effectively develop much-needed future MC (Fairburn, 2010; Goldman & Kabayadondo, 2016; Koh et al., 2015).

Internationally renowned universities such as the Massachusetts Institute of Technology (MIT)[1], Stanford[2], and Berkeley[3] use DT to develop MC; however, there is little research into DT Studios (DTS) in a compulsory educational setting (Carroll, 2015). This opportunistic, single-case study details one secondary school's journey to integrate a DTS into its curriculum, focusing on developing digital acumen. The research aims to investigate the perceptions and experiences of five separate groups of learners and educators, each immersed in a two-week Digital Design Thinking Studio (DDTS) in the academic

[1] MIT - https://mitsloan.mit.edu/ideas-made-to-matter/design-thinking-explained

[2] Stanford - https://dschool.stanford.edu/

[3] Berkeley - https://designthinking.berkeley.edu/

session 2018-19.

The following section will provide more depth to this introductory statement with a full literature review presented in Chapter 2.

1.1.1 Clear terminology

To ensure clarity, key terminology that is used in this thesis is defined here:

Competency: is more than just a ‘skill’; it is a ‘behaviour’ and an ‘attitude’ that learners need to apply, develop and master in various situations throughout their life. The holistic development of knowledge, skills, behaviours and attitudes is termed a ‘*competency*’ and provides the ability to do something successfully or efficiently.

competency = knowledge + skill + attitude + behaviour

Meta-competency: is learners’ abilities to have ‘competency’ over their competency and refers to the collective higher order, overarching qualities and abilities of an interpersonal, conceptual, and professional nature and includes learners’ cognitive, critical and reflective capacities. These overarching and collective competencies defined in the MC framework (Appendix 2) will be termed meta-competencies (MC) throughout this research.

Digital computing: a set of skills and knowledge required to enable the confident, creative and critical use of digital technologies and systems in an increasingly digital world.

Digital astuteness/literacy: the skills and knowledge required to live, learn and work in a society where communication and access to information is increasingly through digital technologies including internet platforms, social media, and mobile devices.

1.2 Our exponentially changing milieu

Many people believe that education aims to prepare our young people with the skills, knowledge, behaviours and attributes (meta-competencies) to thrive in the future (Trilling & Fadel, 2009). History tells us that every industrial revolution that brings new technological advances has also produced structural changes in societal, economic, and educational systems. When a society passes through a revolution, individuals and systems adapt accordingly. The First (1IR) and Second (2IR) Industrial Revolutions of the late 18^{th} and late 19^{th} centuries enabled mechanical means of production at a mass scale with increasing levels of efficiency. With the advancement of industrial machines (2IR), a human's physical skills became less critical, and knowledge and skills, Intelligence Quotient (IQ), became a more valuable trait. Consequently, the education system adapted accordingly, focussing on developing knowledge workers.

The move from the '*Industrial Age'* (2IR) to the '*Knowledge Age'* in 1991 (3IR), when for the first time in history, more money was spent on technologies than on engines and machinery (Stewart, 1997), stemmed an exponential rise in the advancement of digital innovation, for example, artificial intelligence (AI), internet of things (IoT), cybersecurity, machine learning, robotics, blockchain, automation, augmented reality (AR) and virtual reality (VR). Consequently, these technological developments can profoundly alter how we live and work, signifying a time when technological innovation is vital in society and economies. The exponential rate of change characterises it, and many believe that it could challenge our work, leisure lives, economic, political, and educational systems, societal structure and even raise fundamental questions about the nature of humanity itself (Bwalya et al., 2020; Ford, 2016; Schwab, 2016). The impact of this new '*Technological Age'* and potential for significant disruption is being proclaimed the Fourth Industrial Revolution[4] (4IR).

1.2.1 What is the Fourth Industrial Revolution?

Many believe recent technological disrupters have driven us into the 4IR (Bwalya et al., 2020; Ford, 2016; Schwab, 2016; Skills Development Scotland, 2018), which will create a period of change as disruptive as the previous industrial revolutions, if not more so. Global organisations such as the International Labour Organisation (ILO) (Nübler, 2016), the World Economic Forum (WEF) (Zahidi et al., 2020), McKinsey and Co (Hunt et al., 2019) and Price Waterhouse Cooper (PwC) (Berriman, 2017) believe it will significantly change the way we work and live, with implications for individuals, learning institutions and the education system as a whole. Just as 2IR initiated the replacement of human physical labour with machines, 4IR is triggering the replacement of human mental labour with AI, automation, and other digital innovations.

These innovative technologies bring many benefits and challenges that impact every facet of our lives, from shopping to work and learning. The goal for economies, governments, education systems, and industry to recognise these

[4] Fourth Industrial Revolution (4IR) is a term coined in 2016 by Klaus Schwab, Founder and Executive Chairman of the World Economic Forum

changes and harness them for a better future. With much of the world now utterly dependent on computing-based technologies for all aspects of economic and social organisation, education systems must adapt accordingly to ensure learners have the MC (Senova, 2020), particularly digital acumen, to thrive in the future. The workforce of tomorrow will be required to think for themselves, adapt to continual change and have excellent self-management, social intelligence, and innovation skills (Skills Development Scotland, 2018).

The 4IR brings many challenges exacerbated by the unprecedented global pandemic, COVID-19; the 'double-disruption' (Zahidi et al., 2020, p.5). These have collided to form the perfect economic storm, increasing global unemployment and facilitating serious concerns for economies worldwide. As Klaus Schwab, Founder and Executive Chairman of the WEF,[5] highlighted, "After years of growing concerns about technology-driven displacement of jobs, and rising societal discord globally, the combined health and economic shocks of 2020 have put economies into freefall, disrupted labour markets and fully revealed the inadequacies of our social contracts. Millions of individuals globally have lost their livelihoods, and millions more are at risk from the global recession, structural change to the economy and further automation" (Zahidi et al., 2020, p.3).

As the pandemic subsides worldwide, millions are faced with the new economic uncertainty that 4IR will bring (Partington, 2020). Worse yet, this change is permanent, and future generations are challenged to have the MC to thrive in a global, technology-enhanced employment arena. Proactive countries who

[5] World Economic Forum (WEF) - https://www.weforum.org/

identify this and modify and adapt their systems accordingly will develop the MC required for the jobs of tomorrow and ultimately thrive in the new technology-driven world (OECD, 2018).

1.2.1.1 Scotland's strategic response to 4IR

The Scottish Government acknowledged, "the way in which we respond to the impact of technology is one of the greatest public policy challenges of our age" (The Scottish Government, 2021, p.5). They identified that "Scotland's future will be forged in a digital world. It's a world in which data and digital technologies are transforming every element of our nation and our lives – people, place, economy and government" (The Scottish Government, 2021, p.4).

Therefore, in response to the devastating effects of the '*double disruption'*, the Scottish Government set up an '*Advisory Group on Economic Recovery'* in April 2020 to identify strategies for economic recovery. Their report delivered on 22nd June 2020 was titled '*Towards a robust, resilient wellbeing economy for Scotland'* (Higgins et al., 2020). It identified digital innovation as an important growth area of Scotland's future economy; however, the report lacked any guidance, strategy, or suggestions for accelerating this sector[6].

Fortunately, on 25 August 2020, this was followed by another government-led review entitled '*Scottish Technology Ecosystem Review'* (Logan, 2020). It was undertaken by the co-founder of '*Skyscanner*'[7], Mark Logan, at the request of

[6] Towards a Robust, Resilient Wellbeing Economy for Scotland: Report of the Advisory Group on Economic Recovery - https://www.gov.scot/publications/towards-robust-resilient-wellbeing-economy-scotland-report-advisory-group-economic-recovery/

[7] Skyscanner - https://www.skyscanner.net/

Kate Forbes, Member of Scottish Parliament (MSP)[8], the cabinet secretary for finance (Scotland). This report was refreshingly honest and direct in its delivery. It provides the previously missing clarity, strategies, and guidance on how Scotland's technology sector can facilitate its economic recovery post-COVID-19 and considering the current 4IR.

The review by Logan (2020) identifies that for Scotland to secure its economic future and compete globally, there needs to be a significant increase in start up technology companies with scaling to reach 'unicorn'[9] status. Successfully doing so would bestow various benefits, including economic growth, more jobs, and increased tax revenues (Beauhurst, 2019; Cotton, 2019). Logan (2020) suggests that this type of digital innovation is essential if Scotland is to compete globally in a future-facing economy with uncertainty, global recession, and automation.

"We need to ensure that our young people are equipped with the skills to thrive in the digital world" (The Scottish Government, 2021, p.11)

The review highlights the critical need for an effective '*technology ecosystem*' promoting digital computing and entrepreneurship competencies to help sustain and grow Scotland's economy and create learners ready for the future.

"Meta-skills and digital intelligence should be developed across the entire education and skills system in Scotland and maintained and further developed in the workplace… more radical change is required within the skills system to

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[8] Kate Forbes MSP - https://twitter.com/KateForbesMSP

[9] Unicorn - The term 'unicorn' refers to relatively large-scale private technology companies typically employing several hundred or thousands of people or valued in excess of $1bn (around £760m)

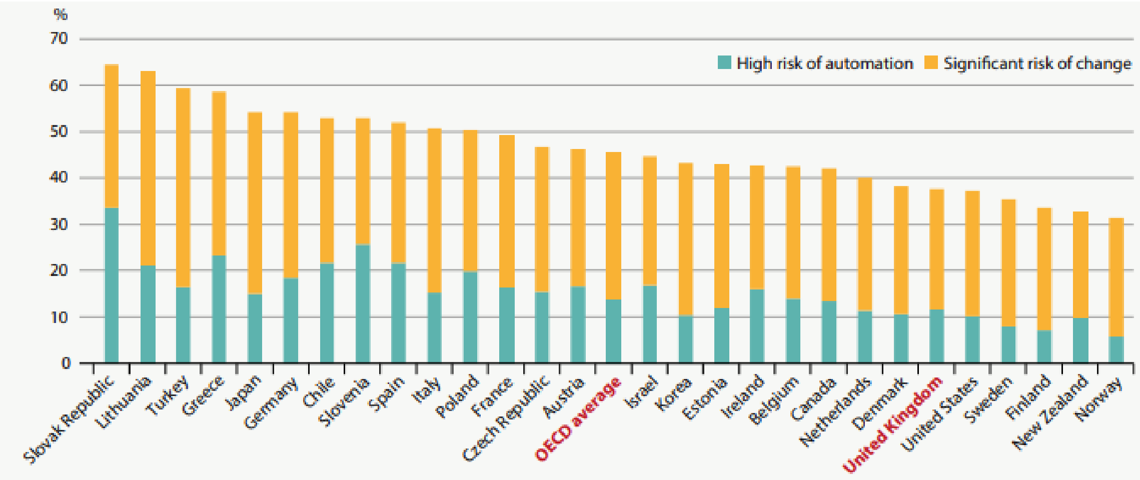
ensure individuals are highly skilled in these areas." (SDS, 2018, p.18)

Learners must be provided with the MC, particularly digital computing competencies they need for their future, for the jobs of tomorrow.

1.2.2 What are the jobs of tomorrow?

As 4IR gains momentum, businesses and society adopt more technological processes and systems. This significantly impacts employment, placing millions of jobs at risk of automation or technological enhancement. The jobs that will be automated are repetitive and routine and easily achieved by technology and automation (Kosslyn, 2019). According to McKinsey Global Institute (MGI) estimates, 39% of the activities that people are paid to do in the UK today could be automated by 2030 with the current technology available (Hunt et al., 2019). Recent OECD (2019) research suggests that, should current innovative technology become widespread, 32% of current jobs across the 32 countries analysed will see significant changes in how they are carried out. A further 14% of jobs could be completely automated (see Figure 1).

Figure 1 - Jobs at risk of automation and significant change – highlighting OECD and UK



Source: Nedelkoska & Quintini, 2018

The importance of digital acumen in the future is highlighted by one of the OECD's core beliefs that "technology is fundamental to any type of work in the future… Being tech-literate must be a given in order to adapt" (Rebernik, 2021, p.3). An aptitude for innovative technology will be a considerable advantage in the future employment market. Indeed, there has been a 150% increase in demand for roles within the digital technology sector from 2015 to 2018 (Burbidge, 2020).

"Technology is forecast to be the fastest-growing sector in Scotland by 2024, but success is dependent on skills." (Kate Forbes[10] – Digital Economy Minister, 2019)

The types of jobs required in the future will be harnessing technology and may require thinking 'outside the box', being creative, and being innovative. A publication from Nesta entitled '*Plan I – The case for Innovation-Led Growth'* highlighted that over "63 per cent of productivity growth in the last decade came either directly or indirectly from innovation" (Westlake et al., 2012, p.11). The development of digital, innovation, and entrepreneurship competencies are considered essential in light of the impending global domination of digital technologies (Logan, 2020).

"Human-centred work organisation is the ultimate barrier to job automation. The aspects of work that require key attributes of human labour, such as creativity, full autonomy and sociability, are beyond the current capabilities of advanced AI." (Newton et al., 2020, p.12)

Alongside digital innovation and entrepreneurship, there is a growing demand

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[10] https://blogs.gov.scot/scotlands-economy/2020/01/21/digital-skills-success-first-graduates-from-1-million-scheme/

for personal competencies (Gregor et al., 2020). Figure 2 shows a growing number of employers (95%) claim applicants lacked specialist technical and practical competencies and, more importantly, '*soft skills*' (Winterbotham et al., 2018).

Figure 2 - People and personal skills improvements required

Source: Scottish Employer Skills Survey, 2020

Google's own Project Oxygen (Dokuyucu, 2016) highlighted the importance of interpersonal and intrapersonal skills due to the increasing teamwork involved in working environments today. The Harvard Business Review found that "the time spent by managers and employees in collaborative activities has ballooned by 50 per cent or more" (Cross et al., 2016, p.1), highlighting the critical need for learners to leave school with vital emotional intelligence and not just subject knowledge.

According to '*Shapers*' in the Medellin Hub[11], the gap between people's skills

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[11] Global Shaper Community, Medellin Hub - https://www.globalshapers.org/

versus the skills they need is becoming wider. They argue that traditional learning falls short of equipping young people with the digital, personal, and social skills they need to thrive in today's society (OECD, 2019; Skills Development Scotland, 2018).

"The content of many jobs will also shift towards uniquely human competencies, such as communication, interaction, and emotional connections." (Haldane et al., 2019, p.15)

The latest OECD research reinforces the requirement for human competencies and digital understanding, which is reinforced by Pierre Nanterme, Chairman and chief executive officer (CEO) of Accenture, who states that "well beyond today's talent shortages, digital innovations will continually and rapidly alter the demand for skills in the future. Incremental changes to our education and corporate learning systems will not be sufficient" (Nanterme, 2018, p.3). The 4IR means that it is now imperative for companies, education systems and governments to embrace change and focus on reskilling and upskilling because, ultimately, 4IR has the potential to create more jobs than it destroys. Disappointingly, the current competencies required are significantly deficient and are often referred to as the 'skills gap' (Wright, 2018).

1.2.3 What is the skills gap?

The changing economic landscape of 4IR is creating a widening skills gap. Businesses and employers cannot find employees with the requisite knowledge and skills for today's jobs, never mind the future. One in five vacancies is proving difficult to fill due to skills shortages, a figure which has risen steadily since 2005 (Winterbotham et al., 2018). Businesses and workplaces have identified a significant increase (2011-15% » 2017-24%) of skills shortage vacancies (SSV) in Scotland (see Table 1).

Table 1 - Density of skills shortage in Scotland and the UK (%)

Country	Incidence and density of skill-shortage vacancies (SSVs)			
	2011	2013	2015	2017
UK	16	22	22	23
Scotland	15	25	24	24

Source: UKCES Employer Skills Survey, 2018

The UK Employer Skills Survey 2018 identified the skills that need development among employees, including digital computing (49%), complex analytical skills (44%), management and leadership abilities (53%), as well as self-management (52%) (Winterbotham et al., 2018, p.92) highlighting the critical importance of developing these in the future workforce.

The skills mismatch is problematic today but could be even more devastating in the future. As duties presently carried out by employees are automated, and as the technological revolution shifts the production patterns and requirements for products and services, new tasks and jobs will also be created. Some will require entirely new skills. Cloud capability, cybersecurity expertise and social media marketing skills are examples of new digital competencies that have become important only in the last few decades (Zibi et al., 2020), highlighting that developing digital competencies is crucial; not only do they lead to significantly enhanced employability, but salaries in the sector are 26% higher than average salary levels, and these are rising quickly (Logan, 2020, p.25).

Strategic consultancy firm Accenture recently reported that failure to close the digital skills gap over the next ten years could cost the UK economy £141.5 billion in GDP (Gross Domestic Product) growth (Nanterme, 2018). Scotland's digital sector is its fastest-growing, contributing £4.9 billion in Gross Value Added (GVA) to the Scottish economy and employing around 100,000 people (Skills Development Scotland et al., 2019), making it a considerable contributor to its economy. This is supported by a report from SDS stating that the technology sector is forecast to be the fastest-growing sector in Scotland by 2029, growing 1.5 times faster than the economy overall (Skills Development Scotland et al., 2019).

"Digital skills are fundamental to the life chances of our people and the economic success of our country." John Swinney, Deputy First Minister and Cabinet Secretary Education and Skills, Scotland (The Scottish Government, 2017, p.9)

Therefore, despite the uncertainty of a post-COVID-19 pandemic economy and the exponential pace of technology adoption, companies envisage a 34% expansion in their workforce due to technological integration (Zahidi et al., 2020), acknowledging that with practical strategies in place, governments and businesses can realise and empower job transitions from declining to emerging jobs; the jobs of tomorrow. This involves workplaces, education systems and educators worldwide identifying, focusing, applying, and mastering the MCs, particularly digital computing, required by learners effectively and meaningfully. Many education systems globally have already started rising to this challenge.

1.3 Global educational trends

Some nations and establishments are already revolutionising their education systems to facilitate the development of essential MC (Bastos, 2017; Choo et al., 2017; Resnick & Robinson, 2017). However, Resnick (2017) argues that traditional discrete knowledge acquisition and examinations model disengages learners and kills creativity. Sir Ken Robinson concurs with this and believes our conventional 'industrialised system' of education hinders the development of 21st-century skills, like creativity (Robinson, 2017) and encourages education systems to re-examine their educational epistemology. Indeed, many believe "today's education and training systems are ill-equipped to build these skills" (Nanterme, 2018, p.20).

The traditional style of the curriculum with the focus on high stake examinations is deemed by many to be unsuitable for developing the MC required in the future. "Education can no longer focus on teaching you skills for only one job… 21st-century societies demand that we build better, more well-rounded citizens that can adapt to roles that will shift over time and are technology forward" (Rebernik, 2021, p.3).

21st-century learning has become an integral part of educational discourse. It is clear there is a distinct disjuncture between the centuries that have passed and the one we are in, and that current educational demands require new ways of thinking, teaching, and learning. There are many books and reports that criticise the current goals and practices of education and suggest that teaching and learning need to be fundamentally reconfigured (Care et al., 2018; Dede, 2010; Fadel, 2008; P21, 2021; Pellegrino & Hilton, 2012; Trilling & Fadel, 2009).

This significant shift in harnessing information, automation and globalisation has put pressure on school systems globally to adapt and respond to the growing needs of industries and workplaces and, more importantly, to learners' social futures and learning requirements. There is less necessity for learners to '*remember, understand, apply'* (skills that can be automated in some cases); instead, the focus is on their ability to '*analyse, evaluate, create*' (Bloom, 2018).

There is general agreement that young people need to think analytically, critically, creatively, solve complex problems, develop digital acumen, make evidence-based decisions, and work collaboratively (ITL, 2016; Mishra & Mehta, 2017). The Director-General of the International Baccalaureate (IB), Dr Siva Kumari, states that "education can not carry on as before but must become more skills-oriented rather than solely knowledge-based" (Worth Dan, 2020, p.1). The OECD (2018), in their publication '*The Future of Education and Skills 2030'*, reinforce the need for novel solutions in a swiftly changing technological world and identifies that learners of the future will not only need digital and technological acumen but a broader set of knowledge, skills, behaviours, attitudes and values, known collectively as '*competencies*' to flourish.

Many nations and institutions worldwide are preparing learners for an uncertain future (Koh et al., 2015; Nanterme, 2018) by shifting towards a personalised competency-based educational (CBE) model. This change in emphasis from subject knowledge to personalised MC development highlights a general direction of education. Various countries worldwide are looking to reform their education systems to 'develop creative, innovative students willing to take risks, try new things and think for themselves' - Chen Jining, Chinese Minister Educational reform, 2013 (Resnick & Robinson, 2017, p.3). Chen Jining called these learners '*Xstudents'* and took inspiration from the Media Lab at MIT, where every learner is considered an *'Xstudent'.*

Media Lab's associate director Mitchel Resnick encourages the creation of

‘*Xstudent’* and believes education should be a ‘*Lifelong Kindergarten’* full of fun and exploration through the four Ps: Projects, Peers, Passion and Play (Resnick & Robinson, 2017). Several educational transformations align with this view of learning which advocates that all education, indeed life, should be more constructivist in nature (Bates, 2015; Bruner, 1961; Dewey, 1938; Piaget, 2001; Vygotsky, 1978). Learning should replicate the hands-on, purposeful, interdisciplinary, learner-centred learning that takes place in preschool (Resnick & Robinson, 2017), where authentic learning is experienced through curiosity, questioning, critical thinking, problem-solving, collaboration, and investigating real-life problems that encourage learners to co-construct knowledge based on their previous experiences (Henriksen et al., 2018).

Global movements with programmes such as the Minerva Project[12] and the International Baccalaureate (IB)[13] focus on interdisciplinary, real-world problems and portfolios evidencing MC of learners. This CBE (Competency-Based Education) approach is harmonious with constructivism (Masciotra, 2015) and focuses on the development of MC in learners. Eton College, renowned for its academic excellence, has recently launched ‘*EtonX*’ (Henderson, 2021) to develop MC and attempt to bridge the gap they have acknowledged between academic success and life in the real world. Individual schools like ‘*Agora*’[14] in the Netherlands are examples of a growing number of schools with no classes, classrooms, curriculum, or age groups (Houben, 2021). Agora’s education system is centred around the learners’ talents, interests, and ambitions,

[12] Minerva Project - https://www.minervaproject.com/

[13] International Baccalaureate - https://www.ibo.org/

[14] Agora School – Netherlands - https://www.youtube.com/watch?v=9Fds4aNkgUQ

focusing on the learning process, intrinsic motivation, inspiration and individual competencies.

These '*in demand*'' competencies are rising in prominence and include 'critical thinking and analysis, problem-solving, and skills in self-management such as active learning, resilience, stress tolerance, and flexibility' (Zahidi et al., 2020, p.5). Many education systems worldwide, such as Australia, British Columbia, Ireland, Portugal, The Netherlands (OECD, 2021), are adapting their learning and teaching processes to develop a future-oriented learning and teaching process and a growing number of governments, policymakers, researchers, educators, and business leaders believe schools must develop MC for the future to better prepare learners for a lifetime of rapid change and complexity (Bellanca & Brandt, 2010; Bialik et al., 2014; Mishra & Kereluik, 2011; P21, 2021; Trilling & Fadel, 2009).

1.4 Scottish educational trends

Scotland was one of the first education systems in the world to embrace the 21st-century learning transformation in 2004 (OECD, 2021) when it launched Curriculum for Excellence (CfE) (Scottish Education Department, 2004) which aspired to be 'holistic, coherent, and future-orientated' (OECD, 2021, p.11). The change signified a move towards a learner-centric education system. It focused on applying and mastery of experiences and outcomes underpinned by constructivist principles that "sought to put the learning of children and young people at the heart of the reform from the beginning" (Priestley & Humes, 2021, p.16). There was a clear shift towards its four core capacities: **successful learners, effective contributors; responsible citizens;** and **confident individuals** (see Figure 3). CfE has been recognised globally as a 'remarkable curriculum', which 'remains an inspiring curriculum policy and practice in schools today. Its vision justifies rethinking curriculum intentions and shifting emphasis in teaching and learning towards a more holistic approach that encompasses knowledge, skills, attitudes and values held by society" (OECD, 2021, p.42).

Figure 3 - CfE's four core competencies

Source: Education Scotland

Yet, like other externally mandated reforms, a significant challenge for CfE has been the '*implementation gap'* (Supovitz, 2008) between policy intent and classroom practice (Scheer et al., 2012), resulting in many educators still practising content-driven, educator-centred, high-stake examination-oriented learning and teaching (Banaji et al., 2013; Bellanca & Brandt, 2010; Priestley & Humes, 2021). Many believe this excludes the quintessential qualities and MC required for the future and a love of learning (Henriksen et al., 2017; Levine, 2012; SDS, 2018). Instead measuring and incentivising the macro-level output of institutions (Nanterme, 2018).

Therefore, the ability of Scotland's education system to deliver the MC required is questionable, given that the epistemology of schools has changed very little.

In an age where knowledge is abundant, Scottish schools remain focused on content delivery and high-stakes examinations (Maclean, 2019) which are still focussed on the acquisition of ‘traditional’ subject-based knowledge such as history, mathematics, and modern languages. It is acknowledged that the development of knowledge is fundamental to the development of competences. Scottish education has several challenges to consider to fully realise its vision and ensure learners have the requisite MC and digital acumen.

Firstly, the **pedagogy** employed by educators, particularly in the senior schools, is still very traditional. Secondly, the standardised **summative examinations** are still the focal point of the school year. Thirdly, the **digital computing curriculum** is deemed ‘boring’ and ‘uninspiring’, resulting in a disappointing uptake. Lastly, the **essential ‘MC’** required by learners are not identified or prioritised. These challenges will be examined in the following sections.

1.5 The challenges

1.5.1 CfE challenge 1 - Pedagogy

Scotland’s CfE is underpinned by constructivist tenets, with the learners' previous knowledge and personalised knowledge construction paramount. However, this method did not resonate with many senior school educators who preferred to deliver education in the traditional transmission educator-based (educator-to-learner), predetermined (performance outcomes), agreed facts (high stake examinations) (Reeves, 1992) approach.

It is acknowledged that while many Scottish educators adopted professional autonomy and embraced the principles set out in CfE, my experience was that a considerable number of educators, particularly in secondary schools, struggled to adopt such an approach. They remained focused on national standardised discrete subject examinations, which did not embrace CfE principles (OECD, 2021, p.119). This resulted in the constructivist tenets of CfE not being fully realised in the senior secondary school, acknowledged by Mark Priestly and Walter Humes (2021) in their research into CfE reform, "while most teachers in the study welcomed the general approach of CfE, they did not all subscribe to the largely constructivist view of knowledge and learning, which was implicit in its recommendations. Secondary teachers, in particular, were inclined to retain transmissionist views of knowledge and learning, viewing their role as the "delivery" of content" (Priestley & Humes, 2021, p.6).

From my thirty years of experience developing, training, and working with educators at various stages from nursery to university level and all ages of learners, I found primary school educators more adept in effective constructivist pedagogy. This could be due to a various factors, their qualification is four years in length with a greater emphasis on pedagogy, working with young children is like trying to '*herd kittens'* and effective pedagogical strategies are paramount, or that senior school educators are focussed on delivering content to ensure learners do well in their examinations.

There are several barriers to the effective implementation of new practices in education. In some cases, educators lack the guidance, policy, motivation, or resources to make the necessary changes (Bell et al., 2013). In many cases, educators refrain from applying new practices because they have little exposure to constructivist methods (Jimoyiannis, 2010). Therefore, education systems, like CfE, must provide guidance and structure for educators to ensure engagement and MC development.

1.5.2 CfE challenge 2 - Assessment

One of the biggest hindrances to realise CfE's principles is continuing a traditional assessment policy. Although the principles that underpin CfE are focused on 21st-century methodology, the assessment structure did not undergo a similar change. It was described in the recent OECD review as a 'clash between 19th-century assessment and 21st-century curriculum' (OECD, 2021, p.118). The current assessment system differs extraordinarily little from previous decades. It follows a traditional standardised summative assessment methodology, which involves learning content and regurgitating knowledge back to the examination board for a grade (OECD, 2018). These summative assessments have remained a staple part of the senior school experience, and SQA argues the national examinations are "fully aligned with the aspirations of CfE" and "met the original purposes and aims of the curriculum" (Seith, 2021). The examinations are also valued by employers and further and higher education establishments.

The central premise of a CBE system is that assessment is linked to mastery and carried out when the learner is ready. However, CfE continued with the traditional summative high-stakes examination diet of discrete subject assessment focussed on individual academic performance. This focus on high-stake examinations predetermines the focus of senior school educators, which often involved teaching to the examination. Learning is measured by controlling context, task, and time whilst learners undertake a series of predetermined and moderated examinations, marked against clear and agreed criteria. Subsequently, learner performance is evaluated, attainment judged, and standards commented upon (Easen & Bolden, 2005; Silcock, 2003).

This traditional examination process seems counter-intuitive to developing the CfE's core competencies and is less engaging and motivating for learners (Crook, 2000; Pink, 2011; Sweller, 2003). Therefore, the aspirations focussing on developing the CfE's core competencies through the development of experiences and outcomes fell short because the examination system stayed the same and the pedagogy employed by teachers, overall, remained the same. The development of CfE's constructivist methodology is therefore hindered, in part, by the current system of high stakes assessment which '*forces*' educators to stick to the content that will be in the test and uses examination success to measure educational quality (Easen & Bolden, 2005; MacGilchrist, 2003). MacGilchrist (2003) also believes that short-term focus on attainment is at the expense of creating a love of lifelong learning. Hattie's (2008) meta-research in education identified the importance of learners being involved in and taking ownership of their learning. It is recognised that effective learners engage in metacognition (Hattie, 2008; Silcock, 2003) and are actively involved in their learning journey, including self-reflection, peer-refection, and self-assessment (Biggs & Moore, 1993; Ertmer & Newby, 1996; Silcock, 2003). While assessment methods remain traditional in Scottish senior secondary schools, it is little wonder that the pedagogy remains traditional and takes little account of societal and economic changes. In many ways, it still resembles education as it was last century (Robinson, 2017). This subsequently has a significant impact on the development of MC and the uptake of digital computing in Scotland.

1.5.3 CfE challenge 3 – Decline in digital computing in Scottish schools

The '*Technologies*' curriculum, of which digital CS is a component, is intended to be taught in discrete classes by a subject specialist in secondary school. Like many other subjects in Scottish senior secondary schools, computing is an elective subject that learners can study from Senior 3 (14/15 years). Unfortunately, learners are limited in their elective choices, with a continually narrowing subject choice, resulting in a lower than expected uptake for computing (see

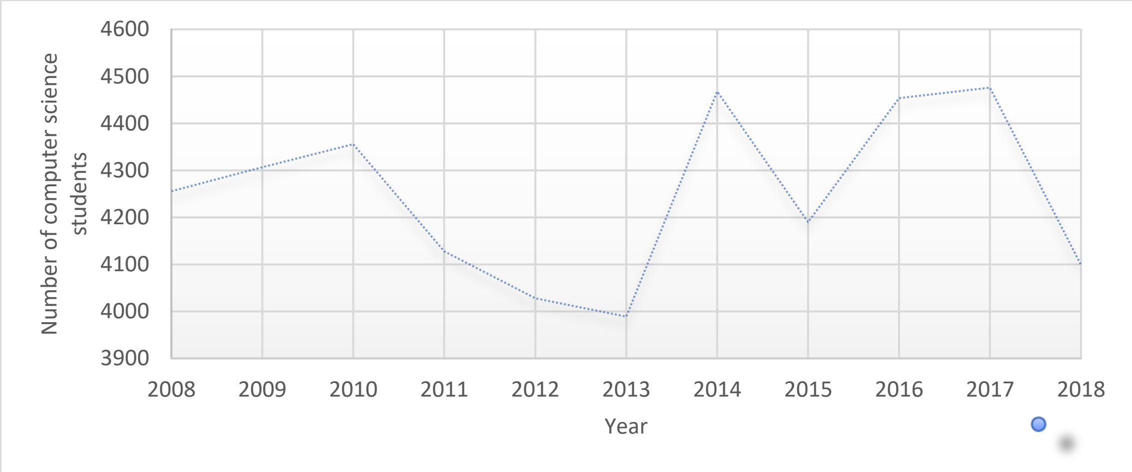
Table 2).

Table 2 - Typical number of curriculum electives chosen by learners for Scottish exams

Secondary school year	Learner age (years)	Scottish national qualification exams	The usual number of discrete subjects chosen by learners
Senior 3 - 4	14/15 - 15/16	National 5	7
Senior 5	16/17	Highers	3-5
Senior 6	17/18	Advanced Highers	1-3

Therefore, despite the needs of the future workforce, the aspirations of the future Scottish curriculum and the continued attempts by the Scottish Government to invigorate computing, it concerningly remains on a declining trajectory in Scotland (Brown, 2020), with fewer schools offering it as a subject, and the number of learners taking SQA (Scottish Qualifications Authority) qualifications in computing declining (SQA, 2019). Although this is not a problem restricted to Scotland (Passey, 2016, p.428), disappointingly, despite digital computing being a critically important MC for learners in the future, the number of learners taking digital computing as a subject and on to further or HE continues to frustrate (see Figure 4).

Figure 4 - Higher computing science learners in Scotland



Source: Scottish Qualifications Authority[15]

From 2016 to 2018, participation at the National 5 level in CS fell by 19% (versus mathematics, which fell by 1%). Meanwhile, participation in Higher CS fell by 8% over the same period (versus mathematics, which fell by 1%)[16].

"In Scotland between 2016 and 2018, there was a 15% decrease in young people studying Computing Science at Levels 3-5." (Skills Development Scotland et al., 2019)

Unfortunately, those interested in digital computing before commencing National 5 studies are put off the subject during those studies. Only 50% of learners who study CS at the '*National 5'* level choose to take CS at a '*Higher*' level, compared to 70% for history and geography[17], and of those that do take them, there has been a 10% drop in S5 Higher passes in the last four years (Jarvis, 2019).

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[15] Source: Scottish Qualifications Authority

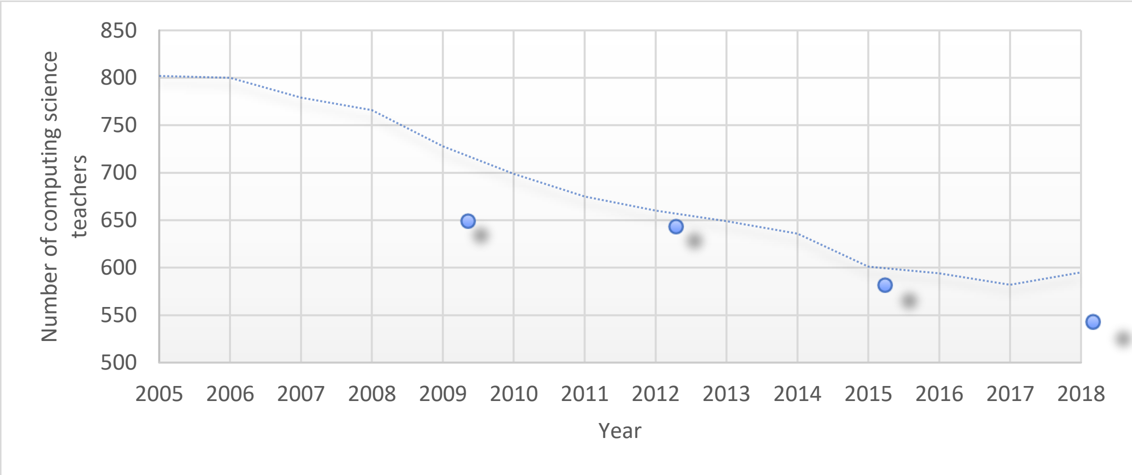
[16] Source: SQA Annual Statistics Report

[17] Source: SQA Annual Statistics Report

1.5.3.1 The decline in CS educators

As Scottish education faces these challenges, the digital skills gap widens. Despite the annual requisite for an additional 13,000 digital jobs in Scotland, apprenticeships and universities only produce 5,000 recruits each year (Watson, 2021). Developing talent is compounded by the fact that around 425 of Scotland's 2,500 schools (17%) do not have the educators required to deliver the learning outcomes of the computing courses on offer (The Royal Society, 2019; The Scottish Government, 2019) (see Figure 5).

Figure 5 - Dedicated computing science educators in Scottish schools



Source: [Scottish Teachers Census]

A recent teacher census shows the number of digital CS teachers in Scotland has plummeted over the past thirteen years, falling from 766 in 2008 to 595 in 2020 (Watson, 2021).

"Teaching numbers in the subject have fallen by about 20% in a decade, student rolls have also been dropping… there is a profound feeling things need to change" (Collier, 2021, p.15).

1.5.3.2 Decline in post-compulsory education

The Royal Society (2019) reports that first-year learners on initial computing educator training courses have dropped by 80% over the last nine years. This combination paints a gloomy picture of providing digital computing competencies required in the future economy.

These statistics highlight that learners are not engaged in what should be the most exciting and enjoyable subject in the curriculum; instead, it is considered boring (Logan, 2020). As Andrew Collier stated in a recent '*Future of Education'* article in The Scottish Herald, "Computing science is of vital importance to future careers and the national economy…. So how do we put the magic into a subject often seen as too boring?" (Collier, 2021, p.15).

The education system needs to do more to support talent development in digital computing (SDS, 2018; Winterbotham et al., 2018). These factors give serious concern to a subject deemed essential in the future (Davenport et al., 2019; Young, 2020; Zelenko & Hamilton, 2008).

Bryce et al. (2013, p.547) suggest meeting these challenges by addressing the specialist teaching supply, developing an appropriate innovative pedagogy, and creating stimulating teaching and learning material. Some feel that there is also the need to make digital computing part of the core curriculum like mathematics and literacy, "It is clear computing isn't being treated like the core curriculum subject it needs to be. Digital skills have never been more important, and a lack of them disadvantages young people in building lucrative future careers in a dynamic and ever-growing sector of the economy" (Collier, 2021, p.15). The classroom is the leading platform to instil interest in digital computing; it has been shown that interest is the primary predictor of whether a learner pursues their career path in digital computing (Regan & Dewitt, 2015). Loss of interest and negative attitude towards digital computing affect the future workforce and Scotland's continued development in a globalised society and economy.

However, in many ways, Scotland is '*seen*' to be performing well compared to other countries, and in theory, all learners from age three years and upwards have access to digital computing education (Robertson, 2019). However, there is a genuine concern about what is happening in schools which ultimately "depends on the extent to which the learner's school provides teachers who are familiar with the new aspects of computing at primary level or specialist computing teachers at secondary level" (Robertson, 2019, p.11) as well as the pedagogy and assessment methods employed.

1.5.3.3 Scottish Government response

To combat these challenges and worrying statistics with digital computing, the Scottish Government produced several national educational policy documents to give digital technology prominence in the curriculum in the last two decades (The Scottish Government, 2016). However, none of these policies has made digital computing the '*responsibility of all educators'* in Scotland; an accolade restricted to literacy, numeracy and health/wellbeing. They have also failed to address some of the fundamental challenges: computer graduates can command better salaries elsewhere (Davenport et al., 2019; Robertson, 2019), the curriculum is perceived to be uninspiring (Logan, 2020), and the pedagogy leaves learners disengaged (Bryce et al., 2013).

To re-emphasise Scotland's full potential in a digital world, '*A digital strategy for Scotland'* was released in 2017 (The Scottish Government, 2017) to "ensure its education and training systems expand its pool of digital skills and capabilities" (The Scottish Government, 2017, p.24). The aspiration was to equip Scottish “children and young people with the increasingly sophisticated and creative digital skills they need to thrive in modern society and the workplace” (The Scottish Government, 2017, p.24).

However, these strategies have made an insignificant impact. Although Scotland’s intentions were well placed when it introduced CfE and its subsequent policy revamps, a combination of a lack of trained educators, digital computing not being given the priority it needs, the continued focus on traditional high-stake examinations, lack of curricular and pedagogical change and discrete content delivery suggests it has not gone far enough to ensure that learners are excited by the digital computing curriculum.

1.5.4 CfE challenge 4 – Focus on MC’s development

Four aspirational core capacities underpin CfE: **successful learners, effective contributors, responsible citizens,** and **confident individuals.** However, there is no guidance, framework, pedagogical models, or policies to help educators develop the critical MC required in the future. There is also a lack of exploration in experiences that develop MC and engages learners in realistic, thought-provoking problems, working with others, and applying their knowledge, skills, and creativity to solve real-world problems.

Scottish education needs to be re-envisioned to equip its future citizens for a lifetime of rapid change and complexity. However, there will be little notable change without a suitable framework for educators to follow, adequate pedagogical training, a change in assessment, and a progression framework for the development of MC with exemplification for application and mastery.

DT has been proposed as a pedagogical framework that develops the required

MC to thrive in this new creative digital knowledge economy. Many believe DT can enhance collaboration, communication, problem-solving, critical thinking, empathy, self-management, creativity, and innovation (Carroll et al., 2010; Henriksen et al., 2017; Wright et al., 2018).

Internationally renowned universities such as Stanford, MIT, and Berkeley have started using DT models to develop MC. These establishments, despite still using their historical model of classical HE approaches, are exploring and realising the benefits of facilitating learner-centric and interdisciplinary studies through active, social, engaging, and meaningful projects (Logan, 2021). Of note is Stanford University[18], which had a large part in the creation, growth and success of Silicon Valley, a leading hub and start-up ecosystem for entrepreneurs and high-tech innovation. Stanford University's alumni have produced the most billion-dollar technology start-up (unicorns) of any educational establishment globally (MoJo, 2019; Walker, 2013). The University is acknowledged as a leader in pioneering new and better ways to achieve high-quality education. Learners are encouraged to "create and apply knowledge by thinking and doing, preparing for leadership in a rapidly changing world" (Stanford, 2021, p.1). This is facilitated at their world-renowned d.school, which utilises a DT approach.

1.6 Design Thinking

Many view DT as a pedagogical constructivist framework for developing twenty-first century MC (Koh et al., 2015; Tosca & Ejsing-Duun, 2017) through a human-centred problem-solving approach encompassing inspiration, ideation,

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[18] Stanford University - https://www.stanford.edu/

and implementation (Brown, 2008). The use of DT as a model in education has traction because it mimics the susceptibility of authentic learning. The argument is that the empathic, collaborative, iterative, hands-on, and visual design process supports the development of crucial MC in learners (Carroll, 2015; Stork, 2020; Susmitha et al., 2018).

The DT approach is not new but has gained popularity through efforts of Stanford's d.school[19] and American design firm IDEO[20] institute, whose CEO Tim Brown wrote '*Design Thinking'* in the Harvard Business Review (Brown, 2008), bringing the approach and its benefits to a much wider audience. DT is applied to various contexts, including management, software design, education, and engineering. It is seen as a collaborative, human-centred problem-solving process with its common purpose to foster creative thinking, innovation, and creative solutions.

With its focus on a human-centred approach and numerous benefits, including learner engagement (Kijima et al., 2021; Scheer et al., 2012; Stork, 2020; Wright et al., 2018), DT is increasingly being adopted in forward-thinking educational institutions. It has been found to improve the MC of learners, including creative thinking (Gannon, 2020; Rao et al., 2021), innovation (Meina et al., 2021; Rumahlatu et al., 2021), social intelligence (Kijima et al., 2021), confidence (Kijima et al., 2021; Lor, 2017; Rao et al., 2021; Stork, 2020), problem-solving (Govindasamy & Kwe, 2020; Gözen, 2016), and metacognition (Gözen, 2016; Scheer et al., 2012). It has also been shown to engage and raise

[19] Stanford - https://dschool.stanford.edu/

[20] IDEO - https://www.ideo.com/eu

attainment in lower-achieving learners (Chin et al., 2019).

"Design Thinking can serve as the missing link between theoretical findings in pedagogy science and the actual practical realisation in schools. It meets the crucial criteria for effective 21st-century learning by facilitating interdisciplinary projects, approaching complex phenomena in a holistic constructivist manner." (Scheer et al., 2012, p.18)

DTS are predominantly implemented at the university level; however, there is little evidence of a fully integrated DTS pedagogical model in a school setting (K-12) where you would hope to begin developing these MCs for life. Instead, they are reserved for HE and businesses. However, the real question is, can these studios be used to excite and engage learners at a younger age and crucially develop the digital and MC required for the future?

1.7 Purpose of the study

To date, much of the research published showing the value of DT in the learning process has been from Singapore (Koh et al., 2015) and the United States of America (USA) (Carroll, 2014, 2015; Carroll et al., 2010; Goldman & Kabayadondo, 2016). More empirical evidence is needed to define and evaluate the use of DT in schools, particularly the emphasis of digital technology on the process. Therefore, this study aims to explore the tenets of social constructivism (SC) as a theory of learning and how it might be employed in a DDTS to examine its implications for developing MC, motivating learners while identifying the advantages and challenges of such an approach. To achieve this goal, this study aims to explore the in-depth experiences and perceptions of five groups of educators and learners immersed in five separate two-week DDTS spread throughout a full academic year to identify benefits and barriers and contribute to future implementation and research.

This mixed-method research case study detailed in this thesis determines the effectiveness of using the tenets of social constructivist learning through a DT approach. It seeks to understand better the potential and use of DDTS for enhancing the digital computing curriculum and assessment processes, engaging learners, and developing the MC for the future. The overall research is also an attempt toward improving learner retention by mitigating the levels of erosion within the digital computing field.

1.8 Research questions

The research intends to investigate the phenomenon of developing a school of innovation, fusing the development of MC and digital technologies through a design thinking process underpinned by tenets of SC. It looks to identify how a DDTS can support engagement, develop digital computing and MC and be an effective pedagogical practice in school.

The following broad research question (RQ) drives the study:

'**What do learners and educators perceive as the benefits and barriers of implementing a digital design thinking studio?'**

This is captured through the following RQs:

RQ.1 - to what extent do learners think MCs are utilised during a DDTS compared with normal schooling?

RQ.2 – to what extent do learners think a DDTS develops digital computing competencies?

RQ.3 – do learners feel challenged and motivated by this type of learning?

RQ.4 – how do participants perceive formative assessment practices?

RQ.5 – to what extent do learners think a DDTS develops learners' metacognition?

1.9 Significance of the Study

Over 30 years ago, Gee et al. (1996) predicted that '*designer mentality'* would be a fundamental skill required in the knowledge economy. Nevertheless, despite similar claims that it would be beneficial in schools (Sharples et al., 2016), there is little research or evidence of DTS being adopted in primary and secondary education (K-12). Educational systems must adopt methods that will motivate, challenge, and provide the requisite MC to address exponential societal and economic changes. Therefore, this opportunistic, cumulative single-case study (Hamilton & Corbett-Whittier, 2012) will focus on investigating a DTS focusing on digital computing in a Scottish secondary school to gain further insight into this phenomenon.

The development of digital computing and MC has not been analysed to my knowledge by any previous SC-based research using DT in digital computing education. This thesis describes a unique research experiment based upon SC epistemology, using a DT framework within computing to identify its effectiveness in developing MC and engaging learners. Literature in computing education research suggests that the computing discipline faces a pedagogical shift towards a more socially active learning model in line with the principles of SC. However, no prior instances of SC epistemology-driven research were identified through my literature search involving a DDTS in a secondary school setting.

There is also a shortage of empirical research to inform educators of the potential benefits and barriers of a DDTS and a dearth of literature on how they might develop their own DDTS. This study addresses this gap in the literature by identifying the advantages and the challenges of implementing a DDTS. It looks to analyse the experiences and perceptions of learners and educators involved, particularly pupil engagement, and the scope for developing an MC culture.

This thesis provides a systematic and analytical strategy for mapping out and offering a critical review on DT in compulsory education. Challenges to implementing a DDTS in schools are discussed, and recommendations are made.

There needs to be a critical review and alternatives to the current digital education system to encourage learners to develop digital acumen and the much sought-after personal and social competencies required for their future. Ensuring lessons are learner-centred, relevant, engaging and linked to the real world is essential.

Educational systems would benefit from a taxonomy of the value added by using DTS and technology in learning environments; therefore, this research will examine if DTS in digital technology is a feasible alternative to current provisions and, as such, would interest policymakers, educators, parents, further education, and businesses.

1.10 Chapter Summary

This chapter has provided a context for the changing economic, societal, and educational environment brought on by 4IR and exacerbated by COVID-19. It argues for the importance of digital competencies as part of a broader array of MC needed for the future and the challenges facing Scottish education for the increased adoption and proficiency in digital computing and MC. DT as a framework for delivering social constructivist principles was recognised as an effective pedagogical model used in centres of excellence worldwide. It proposes this approach to engage learners, increase digital computing acumen and develop critical MC. The chapter rounds off by highlighting the purpose of the study, RQs, and the study's significance.

In the next chapter (2), a comprehensive literature review will identify in more depth the context of the study examining DT and its impact on education and examine critical educational aspects related to pedagogy and assessment and its correlation to SC. It further clarifies and justifies the theoretical framework adopted, SC, to underpin this study. Lastly, it will identify the critical MC required by learners and propose a framework for progression and development. Chapter 3 will examine the methods and methodology used in this research, followed by the findings from the study in Chapter 4, which are framed using the SC framework. Chapter 5 will critically analyse and discuss the findings, identify limitations, highlight contributions to theory and education and suggest areas for further research. Chapter 6 brings the research to a conclusion.

Chapter 2. Literature Review

2.1 Chapter overview

This literature review aims to dive deeper into this research's context by contextualising the why, what, and how that underpins this study. It opens by critically analysing the theoretical framework employed, namely, social constructivism, to elicit a framework of its tenets for practical implication. Next, it provides an overview of the MC required by learners for the future and proposes an organic MC framework linked to CfE for application, development, and mastery. This is followed by an investigation of the current DT landscape and a review of literature for using DT, specifically within a compulsory school context. The chapter concludes by highlighting the gaps in the literature.

2.1.1 Search terms

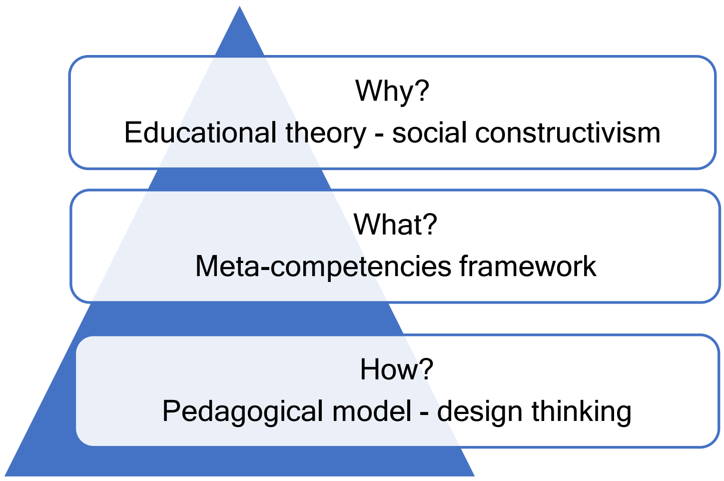
Initial planning began with a survey of recent practical publications detailing suggestions for innovative practice for developing digital competencies in secondary school-age learners. The search method began with thorough reading of abstracts to ascertain relevance to the study in terms of peer-reviewed material. In reviewing these texts, it was noted that the work of constructivism (Piaget, 1968) and SC (Vygotsky, 1962) was often referenced. Using this as a starting point, an initial reading of these theories led to repeated mention of the terms 21st-century learning, meta-competencies, and design thinking. This led to literature searches around these topics, beginning with SC, developed by Vygotsky (1968). DT was also explored from a compulsory educational standpoint. A review of 21st-century learning and the growing need for MC followed, particularly its impact in educational settings.

The literature search was carried out in line with Evidence for Policy and Practice Information standards (EPPI, 2018), and the inclusion, exclusion and search criteria are shown in Appendix 9. These searches revealed no empirical research studies on participants' experiences of a DDTS that were explicitly grounded in a theoretical framework of SC.

2.1.2 Structure of the literature review

There is a need for identifying the principles used in effective learning theory and a pedagogical model for its implementation. The following sections will identify the tenets of the underlying educational theory, SC, and the pedagogical model through which the tenets of SC will be utilised (see Figure 6). This will provide a framework to scaffold engaging and deeply meaningful learning experiences while developing their MC for the future. Each section is critically analysed and clarified in turn.

Figure 6 - Overview of learning processes and literature review structure employed in this study



2.2 Educational theory – social constructivism

In recent years, a plethora of educational research has highlighted the need for a paradigm shift toward constructivism (Barak, 2017; Krahenbuhl, 2016; Scheer et al., 2012), which can be “applied both to learning theory and to epistemology-both to how people learn, and to the nature of knowledge” (Hein, 1991, p.1). It is seen as a move away from instructor-led knowledge creation to learner-centred knowledge creation where learners take ownership of their learning and create knowledge from their own experiences through discussion, questioning and discovery with others, in turn facilitating self-regulation, active thinking, and the development of personal meaning (Brooks & Brooks, 2021). Developments in neuroscience and research have increased our awareness of how learners process, absorb, and retain knowledge, emphasising that the traditional system of education neither facilitates optimum learning environments nor prepares learners with the much-needed MC required for the future (Nanterme, 2018; Nava, 2018; Vallance & Towndrow, 2016; Zull, 2011). To examine the phenomenon of a DDTS in a school, this research must have an effective theoretical framework to underpin, structure and guide the study and build on previous knowledge.

Passey (2020) tells us the importance of ensuring an appropriate framework is chosen in research as it could “determine whether, how and to what extent a thesis or research study might contribute to a wider knowledge base” (Passey, 2020, p.95). Therefore, the importance of finding the appropriate theoretical framework to provide a strategic analysis of the research is crucial as it can “allow scholars to organize and synthesize knowledge and conjecture within a field and serve to describe, explain, and predict behaviour and experience” (Doolittle & Camp, 1999, p.2). As van Hover and Hicks (2017) assert, “paying attention to principles of learning as gleaned from such frameworks as social constructivism aids in the production of more nuanced and focused research and subsequent theory generation and refinement. Such understandings can then provide a baseline from which researchers can push, stretch and poach to explain what has been observed, and what can move the field forward" (p.282).

The initial theoretical framework utilised for this study was Piaget's constructivism (Piaget, 1968), as this lays the foundations that underpin Scotland's CfE (Britton et al., 2019; Paterson, 2018). However, as the study progressed in continual cycles of iterations and more literature was reviewed, the importance of the social interactions between the actors became evident, which steered me towards using Vygotsky's (1978b) SC to underpin the research.

Serious consideration was also given to constructionism (Papert, 1980), which is seen by many to be a derivative of constructivism (Ackermann, 2001) that argues meaningful learning occurs when individuals actively construct a meaningful product in the real world but is also co-created by interaction with others (Frisque & Chattopadhyay, 2017), "thus at the heart of constructionism lies the belief that learning occurs in the process of creating a product that can be shared with others" (Rob & Rob, 2018, p.5). Since learners would create an artefact and collaborate throughout the process, it might seem a prudent theory. However, while constructionism focuses on the artefacts created through social interactions, SC concentrates on an individual's learning because of their interactions as part of a group. Since this research concentrated on the learning process and participants' perceptions of their learning environment, SC was deemed to meet the needs of the study best.

2.2.1 Social constructivism

Constructivists see knowledge as what learners build on their own, based on the experiences they gain from their environment, whereas the SC sees knowledge as what learners do in conjunction with others, emphasising the collaborative nature of learning (Barak, 2017; van Hover & Hicks, 2017). SC (Vygotsky, 1962) is a form of constructivism that focuses on interaction, collaboration, and group work for effective learning (Adams, 2006; Barak, 2017). The principles underpinning many modern pedagogies focus on the tenets of a SC-learning approach that advocates educator autonomy to facilitate interactive, learner-led, relevant, real-world, collaborative learning (Britton et al., 2019). SC-learning does not require a real-world problem as its focus, but this can be a valuable feature. Effective SC asks the educator to employ teaching methods focused on learners working together to share ideas, look for answers to problems, or create something new to add to their existing knowledge (Knapp, 2019).

SC asserts that language and culture are the frameworks through which people experience, communicate and comprehend reality. According to Vygotsky (1962), language and culture play a vital role in human intellectual development and how humans view the world. Learning concepts are conveyed through language, interpreted, and understood through experience and interactions in a cultural setting. Accordingly, learning is viewed as a social, cultural, and motivational process derived from subconscious discourse and communication with people who are meaningful to the learner (Lemke, 2001). Knowledge is socially constructed and co-constructed since it takes a group of people to have a language and a culture to build cognitive structures (Palincsar, 1998).

In SC, Vygotsky (1962) rejects the assumption that it is possible to separate learning from its social context. He argues that the construction of knowledge is a product of social interaction, interpretation and understanding, firstly between people before becoming internalised (Daniels, 2001) and that the creation of knowledge cannot be separated from the learners' social environments, which is particularly important in this study which is examining learning in a '*new*' social environment with different aspirations and boundaries. This teaching strategy may include class discussions, small group discussions, learners working in pairs on given projects or assignments, sharing ideas, brainstorming causes and effects, answering problems, or creating something new to add to existing knowledge (Idaresit Akpan et al., 2020). Implicit in SC is the importance of the learners' experiences, and it is argued that there is no knowledge independent of the meaning experienced by the learner within the community (Hein, 1991). Lemke notes that social interactions are 'central and necessary to learning and not just ancillary' (Lemke, 2001, p.296).

Many promote SC as an alternative approach to the current academic-attainment focused education system. With its focus on a collaborative learner-centred environment, it is deemed by many to promote the development of MC (Adams, 2006; Aubrey & Riley, 2018; Barak, 2017; Keaton & Bodie, 2011). There is detailed research highlighting increased engagement in learners and that adopting SC approaches can improve learner achievement (Bond et al., 2020; Doolittle & Camp, 1999). Taylor and Cox (1997) found that adopting SC principles provided higher learning achievements for learners than a control group, while Barak et al. (2007) found that higher-order thinking was significantly developed through collaborative challenges and discourse among learners. Watson (2001) explored the potential of SC approaches with learners who have trouble with schooling and found that it "can promote effective teaching in pupils of all ages and levels of abilities and across the curriculum" (Watson, 2001, p.146), suggesting that even learners that are disengaged find SC learning appealing. Idaresit Akpan et al. (2020) highlighted that the SC approach stimulates learners' interest and promotes high self-esteem and improved retention through self-discovery and construction of knowledge (Idaresit Akpan et al., 2020). Doolittle and Camp (1999) and Tam (2000) concur and argue that a shared learning experience can enhance learners' knowledge retention.

The use of SC has implications for the classroom experience as learners are encouraged to discover lesson contents by themselves and in groups organised by the educator for effective collaboration or cooperative learning (Weber et al., 2008); however, for successful adoption of SC principles, or indeed to provide clarity in helping structure and analyse this research, it is crucial to identify and examine the key tenets of SC.

SC principles, ideas and tenets are among those most cited in educational circles today; many current scholars and reformers ground their work in SC theories. Nevertheless, these ideas are notoriously difficult to grasp. As O'Donnel (2012) argues, there is no SC theory and that it "is difficult to pin down [as] it is at once a philosophy of education, and orientation toward curricular design, a pedagogical strategy, and a description of how individual psychology operates" (p.80). Therefore, an understanding of the basic tenets of SC is essential to ensure that this study, which intends to carry out an analysis of learning, has a clear framework from which to work. To do this, a synthesis of SC papers identifying its tenets has helped provide much-needed clarity (see).

2.2.2 Literature for tenets

Various literature was examined to gain a sound understanding and a clear, practical framework to guide this study (G. Brooks & Brooks, 1993; M. Brooks & Brooks, 2021; Doolittle & Camp, 1999; Hein, 1991; Honebein, 1996; Lebow, 1995; Masciotra, 2015; Poplin, 1988; Savery et al., 2001; von Glaserfeld, 1989).

To assist this research, the range of tenets for SC highlighted above were clarified and classified to provide a clear and transparent framework to structure the research and analyse the findings (see).

Table 3 - Tenets of social constructivism

Social constructivist classroom	Source:
Past experience - Optimise and extend learners' prior knowledge.	(Brooks & Brooks, 1993; Hein, 1991; Masciotra, 2015; Poplin, 1988; van Hover & Hicks, 2017; von Glaserfeld, 1989; Watson, 2001)
Background - Provide the learner with context/big picture.	(Brooks & Brooks, 1993; Poplin, 1988; Savery et al., 2001; von Glaserfeld, 1989)
Active - Ensure learners are actively engaged in their learning.	(Brooks & Brooks, 1993; Lebow, 1995; Masciotra, 2015)
Real World - Select authentic, personalised learning tasks, which can be valuable but is not essential.	(Hein, 1991; Honebein, 1996; Lebow, 1995; Masciotra, 2015; van Hover & Hicks, 2017; von Glaserfeld, 1989)
Facilitator - Scaffold learners to support complex learning and provide opportunities for processing deeper understanding.	(Honebein, 1996; Lebow, 1995; Savery et al., 2001; van Hover & Hicks, 2017)
Engagement - Encourage interaction, collaboration, active participation, and co-construction of knowledge by articulating ideas, asking questions, elaboration, and dialogue.	(Brooks & Brooks, 1993; Doolittle & Camp, 1999; Honebein, 1996; Idaresit Akpan et al., 2020; Lebow, 1995; Poplin, 1988; van Hover & Hicks, 2017; von Glaserfeld, 1989; Watson, 2001)
Reflection - Focus on learning, not performance, using feedback, reflection, and metacognition.	(Barak, 2017; Hein, 1991; Poplin, 1988; van Hover & Hicks, 2017; von Glaserfeld, 1989)
Learner-centred - Encourage personalisation, autonomy and initiative.	(Honebein, 1996; Idaresit Akpan et al., 2020; Lebow, 1995; Masciotra, 2015; Savery et al., 2001; Watson, 2001)
Media - Utilise raw data and primary research.	(Brooks & Brooks, 1993; Watson, 2001)

To provide further clarity, the tenets of SC from Table 3 are categorised under educational headings: **Context, Learning, Pedagogy, Engagement,** and **Assessment**.

Figure 7 – A proposed model of categorised tenets of social constructivism

Using this collation of the fundamental tenets underpinning SC, I devised a model (Figure 7) to help frame this study, highlighting the process for effective learning. It starts with the **context,** the catalyst for the learning process, followed by the **content** used and **pedagogy** employed by educators. This is reinforced by the **engagement** and social interaction of the learners and reinforced through formative **assessment** procedures. A comparison of SC tenets with traditional classroom practice is prudent to clarify the research and highlight avenues for investigation (see Table 4).

Table 4 - Learning process - traditional compared with social constructivist

Traditional learning process	Category	SC learning process
Strict adherence to a fixed curriculum is highly valued.	**Context**	Learning is personalised and extends learners' prior knowledge through real-world, authentic, personalised learning tasks.
Materials are primarily textbooks, and workbooks are focussed on acquiring knowledge.	**Content**	Learners are given the context/big picture and utilise raw data and primary research to develop competencies.
Educator's role is directive and authoritative (educator to learner). The teacher is active, and learners are generally passive.	**Pedagogy**	Educators encourage autonomy and initiative while facilitating and scaffolding learners to support complex learning and provide opportunities for processing deeper. Learners are actively engaged in their learning.
Learners primarily work alone.	**Engagement**	Learners work collaboratively, co-constructing knowledge by articulating ideas, asking questions, elaboration, and dialogue.
Assessment is through testing and correct answers.	**Assessment**	Focus on learning, not performance, using feedback, reflection, and metacognition.

This comparison helps highlight some areas of real difference worth investigating and which can contribute towards the RQ to help analyse the phenomenon under investigation in this study. Are learners engaged and challenged by this approach to learning? How do educators and learners feel about reflection and peer review in their assessment process? How do learners feel about this learner-centred learning approach with the educator as a facilitator? What are the benefits and barriers to such an approach?

Furthermore, crucially, is it developing the essential digital computing and MC? This study will contemplate the questions above and adopt the tenets of SC to frame the research.

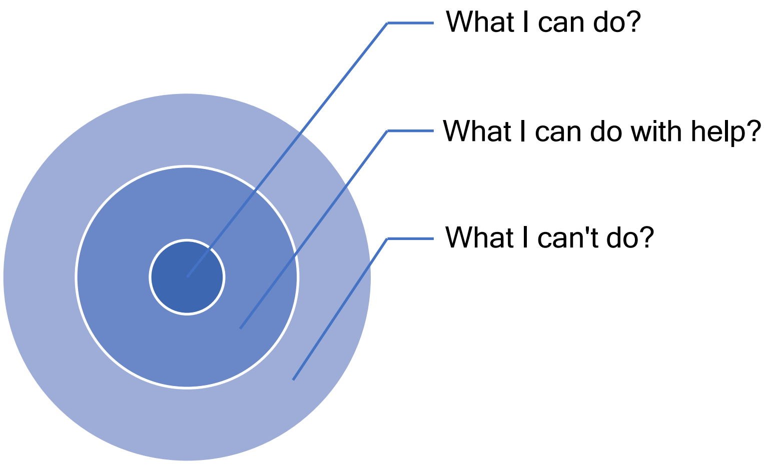
Having identified the principles to analyse this research, a brief review of each SC tenet follows.

2.2.2.1 Context

Past experience - optimise and extend learners' prior knowledge.

Learners must take responsibility for their learning by actively participating (Hattie, 2008; Masciotra, 2015) and building on their previous experiences to create new knowledge. Educators help learners identify '*where they are'* and then look for opportunities to optimise and extend this. This continually pushes learners just outside their comfort zone and into an area of growth and development, "this period of perplexity, of learning, Piaget called disequilibrium" (Poplin, 1988, p.403), while Vygotsky describes this as the zone of proximal development (ZPD) (see Figure 8).

Figure 8 - Vygotsky's Zone of Proximal Development



The ZPD refers to the distance between what a learner is currently capable of doing (comfort zone), what they can do with support (learning zone) and what they are unable to achieve on their own (anxiety zone) (Fosnot, 1989). Educators need to push learners from their comfort zone into their learning zone without leaving them in the anxiety zone. This process allows learners to safely apply and master new learning, challenging them while identifying and mastering the next steps in their learning journey. This identification, development, application, and mastery are key to the personal development of MC in learners.

Real-world - select authentic, personalised learning tasks.

The importance of choosing authentic, real-world tasks for learners is crucial (Hein, 1991; van Hover & Hicks, 2017) "because learning is self-selected, self-motivated, and self-constructed, the best predictor of what learners will learn next is what they already know and what interests them" (Poplin, 1988, p.407). This can be problems solicited from learners used as learning activities, or it can be a problem that learners "will adopt as their own" (Savery et al., 2001, p.4). Dewey (1938) terms this "the 'problematic' that leads to and is the organiser for learning" (Savery et al., 2001, p.4). Essentially, learners must have a purpose for being there, and "they are naturally drawn to learn things related to their developmental levels, interests, and problems" (Poplin, 1988, p.406).

In their mixed-methods study, Hess and McAvoy (2015) found that authentic SC learning tasks can positively impact learning. Their study found that learners' prior knowledge directly influences how they experience and discuss controversial issues. This authentic learning optimised the learning process — highlighting that knowledge construction is enhanced when the experience is set in a real-world context. Anderson et al. (1998) have several criticisms of SC. They argue that knowledge acquisition does not have to be real-world and actively acquired and can also be obtained through direct instruction. Ackermann (2001, p.2) counters this claim by ascertaining that knowledge construction does not necessarily have to be hands-on, but learners should actively construct their knowledge.

2.2.2.2 Content

Background - provide the learner with context/big picture.

It is vital for learners to be given the big picture and have all their learning activities anchored to a larger task or problem to see the value and purpose of what they are doing (Brooks & Brooks, 1993; Poplin, 1988). The purpose of any learning activity should be clear to the learner, and they should be clear in identifying the relevance of specific learning activities concerning the larger task (Honebein, 1996).

Media - utilise raw data and primary research.

Traditional classrooms tend to see textbooks/workbooks as the core resources, whereas a social constructivist learning environment utilises real-world raw data and primary research (Brooks & Brooks, 1993; Watson, 2001) as well as engaging media, such as video, computer, photographs, and sound, to provide richer more relevant experiences. Learners who interact with sensory data use these real-world experiences to connect with previous knowledge and provide them with the “opportunity to and use this experience to construct their own world” (Hein, 1991, p.2).

Representing knowledge in different media can help learners make connections as each learner sees the world differently and has different previous experiences; therefore, “by combining several types of media in a learning environment, the designer allows learners to see the world in different lights, so that their understanding of facts, concepts, procedures, and principles is rich and multi-faceted” (Honebein, 1996, p.22).

2.2.2.3 Pedagogy

Facilitator – scaffold learners to support complex learning and provide opportunities for processing deeper understanding.

As well as the importance of social interaction and the ZPD, Vygotsky’s (1978) other fundamental principle is the ‘*More Knowledgeable Other*’ (MKO), which posits the development of knowledge through someone more familiar with the subject being studied. This could be an educator, consultant, peer or coach (Savery et al., 2001; van Hover & Hicks, 2017) through interaction, discussion and knowledge sharing among learners. This is of particular importance, given the changing dynamic in this study of the educator and learner role, where the educator is assuming the position of facilitator and guide, allowing learners ownership and autonomy but also being cognisant of where and when to intervene and support, while allowing peer interactions and self and peer feedback to prevail.

“Instead of a knowledge transmitter, the teacher becomes the facilitator of the learning process.” (Bellettini et al., 2018, p.198)

Educators also need to be adaptable and realise no given task has only one solution and one way of arriving at it as each ‘*problem*’ may be seen differently by learners, which prompts educators to explore the learner’s mindset and ‘adapt the instructional activity to provide occasions for accommodations within their grasp’ (von Glaserfeld, 1989, p.137). Educators must value and challenge learners’ thinking by not taking over and telling them what to do or how to think. Learning should be achieved by scaffolding to support complex learning and provide opportunities for processing deeper understanding and experiences in the ZPD ‘*learning zone*’ (Fosnot, 1989). By scaffolding learning, learners can gradually control their learning and ultimately gain full autonomy (Torrance & Pryor, 1998).

This epistemology and pedagogy of a SC approach can also bring challenges for educators. As much as they want to allow learners to construct knowledge for themselves, there can be a desire to teach the objective truth as this is perhaps how they experienced learning (Hein, 1991, p.3). Educators are shaped by their previous educational experiences, and Kaufman (1996) argues that it is “unrealistic to expect teachers to initiate constructivist settings in schools if their prior educational experiences, including teacher education programs, do not include constructivist-based experiences” (p.40). As illustrated with CfE, if educators deem SC to be too far from their own “current values, development, and intuitions, it is likely to be rejected (or) ignored” (Poplin, 1988, p.406). Despite CfE educational policy promoting constructivist principles, there is a lack of uptake, particularly in senior schools.

Kaufman (1996) suggests that to facilitate SC practices, educators need to be exposed to “interdisciplinary exploration, collaborative endeavours, fieldwork opportunities for experiential learning, self-observation, evaluation, and reflection” (p.40). Poplin (1988) suggests this can be resolved by introducing its principles in bite-sized chunks (p.406). Others suggest that using a process that encapsulates the principles provides educators with the necessary framework (Straker & Wrigley, 2014). Another train of thought is the complete immersion in the process, with days, if not weeks, dedicated to delivering this type of learning (Neve & Keith-Marsoun, 2017). In essence, Bellettini et al. (2018), who looked at professional learning capacity in Italy with in-service educators focussing on developing computational thinking through social constructivist approaches, argued that “educators need to know the basics (of the subject) to be able to teach it as well as aware of constructivist methods” (p.203).

Learner-centred – Encourage autonomy and initiative.

As part of adopting a facilitator role, educators need to conceive learning activities that provide learners with a level of autonomy in the learning process (Idaresit Akpan et al., 2020; Watson, 2001). The educator is responsible for guiding learners to pursue topics and questions that are relevant or interesting to them to encourage engagement, “since the questions are relevant to a learner’s interests, there is a high level of self-direction” (Honebein, 1996, p.18).

This creates ownership and a passion for what has to be learned and “exerts incredible force on what is learned and how and when it will be learned” (Poplin, 1988, p.409).

Learners play a substantial role in identifying their issues, directions, goals, and objectives. It is not just ownership of what they study but the process for working on the problem. It is essential that learners “take primary responsibility for determining the topics or subtopics in a domain they pursue, the methods of how to learn, and the strategies or methods for solving problems” (Honebein, 1996, p.11). Frequently, educators give learners ownership of a problem but then dictate the process or outcome required. With this direction, learners will not be engaged in authentic thinking and problem-solving. Educators must allow learners autonomy over what and develop initiative over how they solve their problems.

Despite the number of educators identifying the benefits of an SC approach in learning, some, like Kirschner (2006), take a critical stance toward learner-centred learning and suggest little evidence to support this approach. It is argued that many learners, particularly novices, do not contain the skill-set for taking ownership and ‘*learning by doing*’ (Kirschner et al., 2006; Mayer, 2004; Sweller, 2003). Kirschner et al. (2006) advocate direct instructional guidance and dispute that having learners construct their solutions to problems drawing on their unique, prior experience is ineffective. On further analysis of Kirschner's (2006) claim, Hmelo-Silver, Duncan and Chinn (2007) argue that the research points towards a model of ‘*discover learning*’ that does not employ guidance or structure and conflicts with the tenets mentioned previously that advocate the use of context, facilitation andscaffolding, and Taber (2017) argues that this "does not reflect the more common understanding of the application of constructivism in education" (Taber, 2017, p.401).

Active – ensure learners are actively engaged in their learning.

Learners should be active in their learning; SC promotes activity that does not necessarily need to be 'hands-on' but should actively engage the learners in constructing their knowledge, promoting critical thinking, and learning (Ackermann, 2001, p.2). "Pedagogical practices conceived within a social constructivist perspective consist of active, experiential learning situations" (Masciotra, 2015, p.11).

2.2.2.4 Engagement

SC is underpinned by the need for a socially negotiated and agreed-upon truth resulting from interaction, active participation and co-construction of knowledge by articulating ideas, asking questions, elaboration, and dialogue (Brooks & Brooks, 1993; Idaresit Akpan et al., 2020; Lebow, 1995;) where "learning is determined by the complex interplay among learners' existing knowledge, the social context" (Tam, 2000, p.52). This contradicts Anderson et al.'s stance, which argues that not all learning must occur in social scenarios and can be an individual experience (Anderson et al., 1998).

An effective learning environment allows for collaborative learning groups as "the quality or depth of ones understanding can only be determined in a social environment where we can see if our understanding can accommodate the issues and views of others and to see if there are points of view which we could usefully incorporate into our understanding" (Savery et al., 2001, p.6). Vygotsky (1978a) argues that it is only through social interactions that there is intellectual development and that working collaboratively has the “power to foster cognitive development and thus to empower learning” (Bellettini et al., 2018, p.198). Working in groups has been found to motivate learners to allow for deeper conceptual understanding (Hess & McAvoy, 2015).

Motivation is a critical element in learning; Hein (1991) argues that “not only is it the case that motivation helps to learn, it is essential for learning” (Hein, 1991, p.4). Therefore, for meaningful learning to occur, learners must be actively engaged in group work, questioning, and continually challenging their thoughts and opinions through interaction, discussion, and knowledge sharing (Palincsar, 1998).

However, learners must practice active listening (Rogers & Farson, 1987) to ensure they listen to and consider the multiple perspectives and opinions of those around them, appreciating and investigating new ideas while reflecting and sharing their learning to help continually develop their metacognitive prowess (Doolittle & Camp, 1999). Listening carefully to what others have to say is a “powerful tool to grasp pupil’s point of view and cognitive processes, and help them reflect and elaborate new models and strategies” (Bellettini et al., 2018, p.198). As von Glaserfeld (1989) noted, other people bring alternative views to challenge our current thinking, which creates a perplexity source that stimulates new learning.

2.2.2.5 Assessment

The underlying principles of SC claim that learners are active in their construction of knowledge through metacognition (Vaughan & Schoeffel, 2019). Metacognition is considered an essential aspect of learning and focuses the learner on thinking about what they know, what they need to do and when they need to do it (cognition), and the ongoing task of planning and evaluating their learning (regulation) (Stover et al., 2016). Rather than examining performance through high stake, summative, standardised examinations, the focus is on learning, using feedback, reflection, and metacognition (Barak, 2017; Hein, 1991; Poplin, 1988; van Hover & Hicks, 2017; von Glaserfeld, 1989) as learners "become deeply involved and gain deeper understanding… through the process of constructing, programming, and explaining their own representations" (Kafai, 2012, p.24). Educators should empower learners by "promoting metacognitive reflections about how their understanding is developing" (Bellettini et al., 2018, p.198) through displaying their work, articulation, informal conversations, debate, or personal learning journals, which Poplin (1988, p.406) argues helps guide learners in their next steps. This facilitates autonomy and independence in learners who take ownership of their learning journey (Hattie, 2008). Learning ceases to be judged, making it more motivational and engaging, particularly for learners who see themselves as failures within the current examination system (Palmer, 2005). The aim of learning changes from passively memorising content to regurgitating in an examination to become aware of the realities of others. Therefore, learners must develop competencies in communication, feeling, collaboration, and leading (SDS, 2018), aligning with the MC they will require in the future.

"Social constructivist assessment techniques involve direct feedback from a subject in an interactive dialogue based environment, where future actions are formulated in response to the nature and sentiment of the feedback." (Frisque & Chattopadhyay, 2017, p.1)

Several critics of this assessment process advocate that it can be difficult to assess learning accurately without performance data with all learners going "off in their own direction, making their own meaning" (Dick, 1991, p.42). Educators are often more focused on meeting specific performance-based outcomes or mastering the content required for a national examination (Tam, 2000, p.58). Tam (2000) also argues that it is exceptionally "difficult to evaluate" (p.58) learning using constructionist approaches.

Others like van Hover and Hicks (2017, p.281) argue that it is challenging for educators to analyse SC learning. It is a "challenging, complex task to make the invisible visible".

However, one method to help make learning visible is to provide a learning framework of MC with experiences, outcomes and exemplification for learners and educators to identify where they are, where they are going and how to get there. The next section seeks to provide this.

2.3 Meta-competecies framework

As well as digital technological expertise, learners must have the 'right' MC to prepare them for their future world of work. The jobs of tomorrow are focused on innovation, creativity, and emerging technology; therefore, having the MC and knowledge in these areas will be essential for future generations (OECD, 2018). In a world where change is the only certainty, the continual enhancement of MC and life-long learning is crucial.

"Future skills, also known as soft skills, real-world skills or 21st-century skills, are essential to success in life" (Henderson, 2018, p.1).

To ensure education provides learners with the MC they need for the future, various global organisations have identified the skills, abilities and learning dispositions that are increasing in demand for success in 21st-century society (see Table 5). However, despite ongoing global interest in the MC needed for life and work in the future, there remains a lack of consensus on fundamental questions about what constitutes these general capabilities and how we implement them.

2.3.1 What meta-competencies do learners need?

Several global future competency frameworks (see Figures 9 to 16) have been created from groups and individuals who offer a range of suggestions for what is broadly labelled 21st-century learning.

Figure 9 - Key Competencies for Lifelong Learning Framework (EU, 2018)

Figure 10 - Learning Framework 2030 (OECD, 2018)

Figure 11 - Assessment and Teaching of 21st Century Skills (ATC215) (Care et al., 2018)

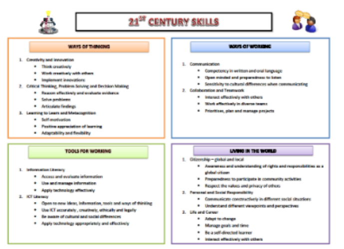


Figure 12 - P21 Framework for 21st Century Learning (P21, 2021)

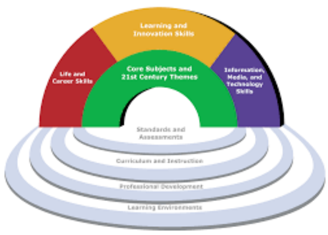


Figure 13 - 7 Survival Skills (SS) of the 21st Century Framework (Wagner, 2008)

Figure 14 - 21st Century Skills (WEF) (World Economic Forum, 2015)

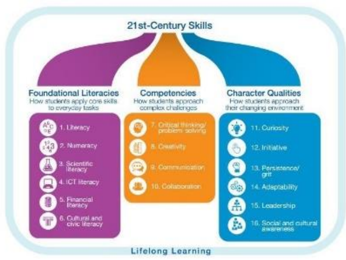
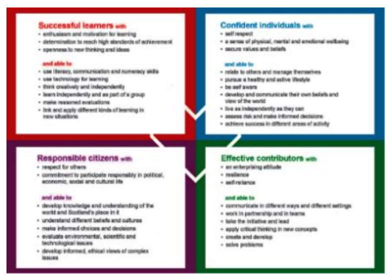


Figure 15 - National Research Council (NRC) Skills Framework (2012)

Figure 16 - Scotland's Curriculum for Excellence (CfE) Framework

(Scottish Education Department, 2004)



Although varied in structure and terminology, these global frameworks have all captured similar fundamental competencies required by learners in the future. They highlight the critical demand for competencies, particularly digital technology and interpersonal, which are predicted to increase over the next decade (Mamabolo & Myres, 2020; Nanterme, 2018; Wright, 2018). While we cannot envisage an increasingly unpredictable future, we can endeavour to prepare learners for the world they will inhabit. Critics of 21st-century learning include Mishra and Kereluik (2011), who analysed ten 21st century learning frameworks and argued that critical thinking, problem-solving, communication and collaboration have been around for centuries and are not new. Indeed, it could be argued that many of the tenets of 21st-century learning are indeed historical. However, I would argue that they are now an explicit measure of future success and need to be central to educational systems and developed with purpose.

There are a few challenges with this; firstly, the terminology and structure employed in the frameworks vary significantly, leaving educators unclear about precisely what they mean (Mishra & Kereluik, 2011) since there are no clear framework correlates with Scottish national curriculum policy and guidelines. Secondly, educators have no practical or pedagogical advice on cultivating them in learners. These challenges are addressed by providing: 1) **identification of the top twenty crucial MC** and 2) an **MC framework** linked to CfE with examples of experiences and outcomes linked to each MC to provide development opportunities and exemplification for educators.

2.3.2 Identification of the top twenty crucial MC

With so many disparate '*skills for the future*' frameworks, it is essential to analyse and determine the essential MC required. Therefore eight relevant 21st-century educational frameworks (see Figures 9 to 16) were identified in the literature from global organisations that could be used to analyse the top critical MC required for today's learners. The eight '*skills for the future*' frameworks appear to identify similar skills and competencies; however, they were challenging to assimilate due to the variances in terminology and categorisation. They were assimilated into a 'new' framework to identify the crucial MC, which allowed for comparison and analysis (Appendix 1). It is beyond the scope of this chapter to discuss this in-depth; however, Table 5 highlights the top MC identified as essential for learners from this full systematic analysis.

Table 5 - Table identifying top twenty MC from analysis of eight global frameworks

Rank	Meta-competencies	Number of mentions in the analysis
1	Collaboration	6
	Critical thinking/problem-solving	
	Digital literacy	
	Literacy	
	Personal and social, emotional	
	Responsibility	
7	Citizenship	5
	Communication	
	Creativity	
	Cultural literacy	
	Initiative	
12	Flexibility and adaptability	4
	Metacognition	
	Numeracy	
	Science	
16	Curiosity	3
	Health and wellbeing	
	Information literacy	
	Leadership	
20	Persistence/grit	2

The top twenty MC correlates with the WEF's '*Future of Jobs'* survey identifying the MC (see Table 6) that employers see as rising in prominence in the lead up to 2025 (Zahidi et al., 2020).

Table 6 – WEF – Future of Jobs - Top 15 skills for 2025

1. Analytical thinking and innovation
2. Active learning and learning strategies
3. Complex problem-solving
4. Critical thinking and analysis
5. Creativity, originality, and initiative
6. Leadership and social influence
7. Technology use, monitoring and control
8. Technology design and programming
9. Resilience, stress tolerance and flexibility
10. Reasoning, problem-solving and ideation
11. Emotional intelligence
12. Troubleshooting and user experience
13. Service orientation
14. Systems analysis and evaluation
15. Persuasion and negotiation

Source: Future of Jobs Survey, 2020, World Economic Forum (Zahidi et al., 2020, p.128)

These competencies are considered essential for the types of roles available in the future, "Tech will dominate, but with a human touch" (Zibi et al., 2020). They emphasise digital, empathetic, and caring roles (Tozer, 2020), essentially what computers cannot do.

"Schools, universities and training providers need to give young people..a holistic skillset, covering the relevant technical skills and soft skills that employers demand." (Furnell, 2020, p.1)

Although many educators acknowledge that their learners need to be equipped with the competencies necessary to prosper in an unknown future with an unknown future job market, with jobs that do not exist, technologies that are not yet invented, and global challenges and problems not yet revealed, they are unaware of how to develop the MC learners required for the future and how this correlates with their current curriculum directive.

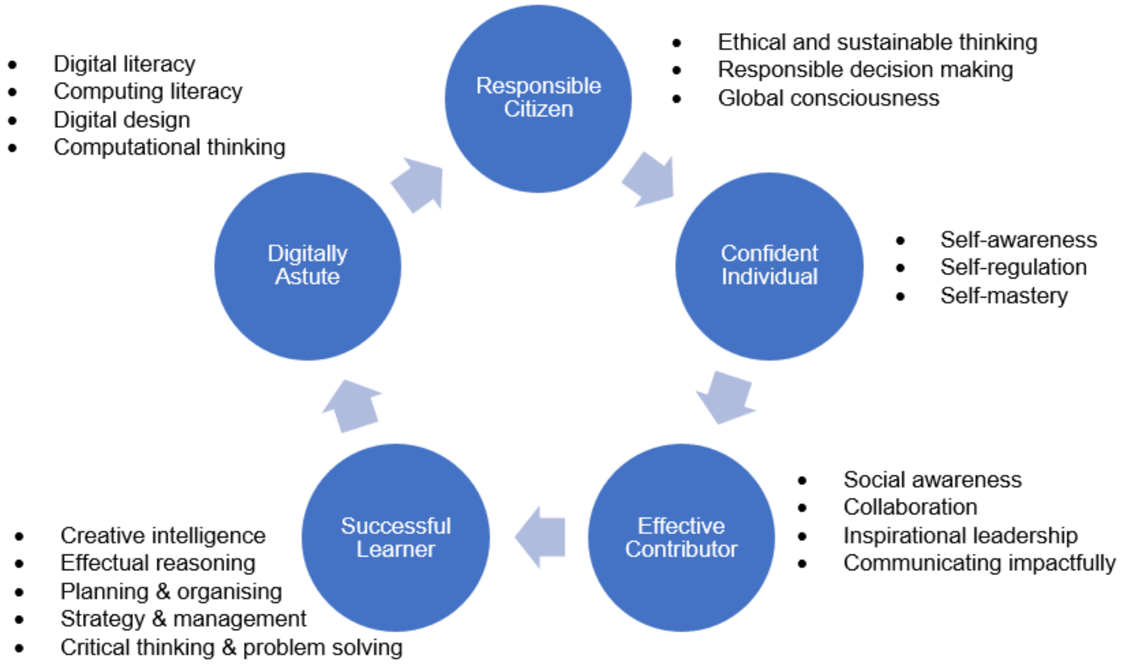
2.3.3 MC framework linked to Curriculum for Excellence (CfE)

To encapsulate the identified MC in a framework that correlates with current Scottish educational curricular policy and guidelines, the MC were categorised under CfE's four capacities: **Successful Learner**, **Confident Individual**, **Responsible Citizen** and **Effective Contributor**. In addition to these, another capacity was added to highlight the importance of digital technology as an essential capacity: **Digitally Astute** (see Figure 17).

2.3.4 Meta-competencies framework

One of the greatest challenges facing educators is a lack of a clear framework of outcomes and experiences to help educators move learners to the next stage of MC development. The lack of agreement on what constitutes the future MC learners require, and a practical framework for application, development, and impact is currently missing. This results in an ad hoc approach to developing, applying, and mastering MC (OECD, 2021, p.34). The top twenty crucial MC were utilised to create a '*new*' MC framework linked to CfE's capacities (see Figure 17).

Figure 17- Overview of the key capacities in the new MC framework

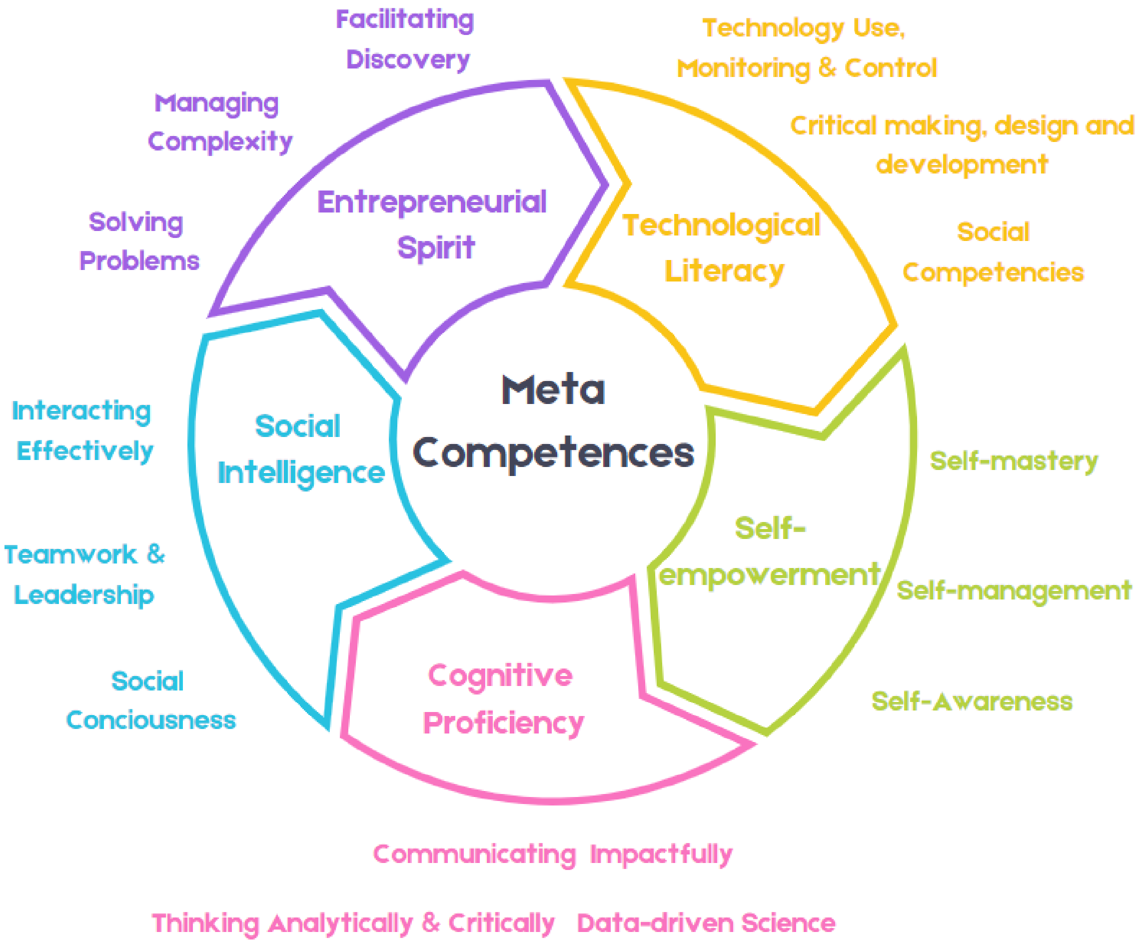


This proposed framework identifies and provides a structure for developing the CfE's capacities in learners, which is currently lacking (OECD, 2021). It is designed as an organic[21] framework created from the assimilation of the top twenty crucial 21st-century skills identified from researching the eight global 21st-century frameworks (Figures 9-16) with the full breakdown of experiences and outcomes. Exemplification can be found in Appendix 2. The framework was constructed with a focus on the inclusion of the crucial MC required for the future. It also looked to identify other areas of educational significance through research and to categorise these, for example, entrepreneurship and sustainability. Further research and discussion with the school-based educator focus group saw continual brainstorming and iteration. Initially, the MC framework was not aligned with CfE and had the headings of entrepreneurial spirit, technological literacy, cognitive proficiency, self-empowerment, and social

[21] Organic framework – this is a starting point for MC development. It can be found in full in this https://docs.google.com/spreadsheets/d/11eSAuaA6MlkLDrNBDRbk1e6PKIdwb_zxq1KHNkRv83Y/edit#gid=1217982267

intelligence (see Figure 18).

Figure 18 - Initial draft structure of the MC framework



I was cognisant that many similar 21st-century frameworks, for example, the SDS's meta-skills framework, firstly did not align with CfE or correlate with their current curricula and, secondly, did not contain practical guidance for learners and educators. Therefore, I decided to align the framework with CfE's capacities and use terminology and a structure familiar to Scottish educators to help minimise barriers to its implementation and adoption by both educators and learners, for example, focusing on experiences and outcomes. The scope of this study does not allow a deep dive into the framework itself; an overview is provided for illustrative purposes (Appendix 2).

The framework will identify MC development in learners for this study. Learners' MCs must be explored, identified, and structured to support and guide educators in monitoring and developing these attributes. The development of MC is a personal journey, unlike traditional standardised curriculum-focused education systems. This involves personalised autonomous application, mastery and adaptation to real-life and work situations. Having ownership involves a learner's capacity to develop new competencies by acting in situations and by reflecting on those actions, which not only provides them with autonomy over their learning journey (Hattie, 2008) but develops their metacognition (Stephanou & Mpiontini, 2017), growth mindset (Dweck, 2012), and love of lifelong learning (Resnick & Robinson, 2017). It requires learners to reflect on their previous experience to make sense of the situation, apply their learning in new scenarios and develop proficiency in that competence through application in various situations (Masciotra, 2015). Education "needs a transition from transferring knowledge to developing individual potentials" (Scheer et al., 2012, p.8).

2.4 Pedagogical model - Design Thinking (DT)

The justification for using DT in education is grounded in the outcomes of previous studies that point to the approach's positive impact on learners. DT centres around problem-solving that enhances the learners' deeper understanding of real-world needs, challenges, and issues (Goldman & Kabayadondo, 2016) while providing a framework for participants to address complex, global issues by identifying diverse solutions (Scheer et al., 2012). Carroll et al. (2010) propose DT as an approach to learning that focuses on developing learners' creative confidence through a hands-on project that focuses on empathy, promoting a bias towards action, radical collaboration, encouraging ideation, and fostering active problem-solving. This emphasis on developing critical MC in learners has spurred educators to investigate DT in education. However, critics of this approach liken DT to ‘syphilis’. They argue that DT can rot the brain of learners as training learners in this approach generates unfounded confidence with no real gains in creativity (Vinsel, 2018).

While DT has existed in HE for some time in graduate and postgraduate courses, the impact on schools did not begin in earnest until the early twenty-first century. In 2002, MIT opened its D-lab with its focus on developing global issues through discovery, design, and dissemination; yet its focus is still predominately on older learners. One of the earliest HE establishments to bring DT to younger learners was the Hasso Plattner Institute of Design, commonly referred to as ‘d.school’ (design school) at Stanford University. It was founded in 2004 by several professors, including David Kelly and Bernard Roth, aspiring to fuse DT with HE interdisciplinary subjects, e.g., law, engineering, business, social sciences, and humanities. By 2007, ‘d.school’ had opened a new ‘Innovation lab’ to develop DT in K-12 (age 3-18 years) education. Since then, there have been various pockets of research, including government initiatives in Singapore, China, and Denmark (Koh et al., 2015; Resnick & Robinson, 2017; Tosca & Ejsing-Duun, 2017).

DT supports learners’ academic performance by contributing to critical thinking, social development, teamwork skills and skills of negotiating and constructing meaning (Carroll et al., 2010) and has grown in popularity in compulsory education in recent years since internationally renowned educational establishments, for example, Stanford (d.school)[22], MIT and Berkeley endorse the use of DT to develop MC in learners.

“We develop hands-on innovation, creativity, and design thinking skills and methods to lead change.” Berkeley University Website[23]

Although historically found in industry, the DT process is synonymous with the tenets of SC, collaborating to co-construct new knowledge in teams, analysing, and sharing/presenting both the learning experience and the learned knowledge (Pande et al., 2020).

Using a DT approach encourages learners to tackle real-world problems, re-frame them in human-centric ways, brainstorm in groups to identify ideas and then adopt a hands-on approach in prototyping and testing (Carroll, 2015; Przybilla et al., 2020). The learner is at the centre of the learning, pursuing their ideas and working in teams with educators to frame and guide the learning journey. This approach allows learners to pursue their interests and passions and develop new ways of thinking while motivating and engaging them (Resnick & Robinson, 2017).

DT is an ideal framework to ensure the principles of SC are employed through a structured and transparent process and allow for the development of MC.

‘in educational contexts, design thinking can be learned through pedagogical approaches that involve problem-based learning, project-based learning, and inquiry because they provide a solution-based approach of hands-on processes

[22] Stanford d.school - https://dschool.stanford.edu/

[23] Berkeley - https://designthinking.berkeley.edu/

to solve instructional problems. These design activities are anchored in contexts and support social construction of knowledge and metacognition.' (Stork, 2020, p.43)

Research suggests DT fosters collaboration, empathy, and a deeper understanding of others enhances problem-solving, creativity and innovation (Brown, 2008; Mcdonagh & Thomas, 2010) through its collaborative, human-centred, iterative, empathetic, trial-and-error, hands-on approach (Carroll, 2014). The visual design process supports the development of MC (for example, adapting, communicating, feeling, creativity, critical thinking, curiosity, resilience, adaptability, initiative) needed to thrive in this uncertain creative knowledge economy (Wright et al., 2018). By encapsulating a digital computing focus into the DT process, we can integrate the critical development of digitally astute learners.

2.4.1 Design thinking model

The literature identified several DT models applied in expected areas such as digital design, engineering, art, business, and universities (Dunne & Martin, 2006; Dym et al., 2005; Istek & Senturer, 2000; Kay & Uehira, 2009), these are shown in Figure **19** to Figure 25Figure 25.

Figure 19 - IBM Design Thinking Model

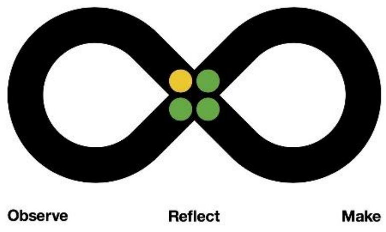


Figure 20 - ZURB Design Model

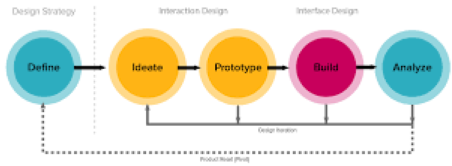


Figure 21 - Google Design Sprint

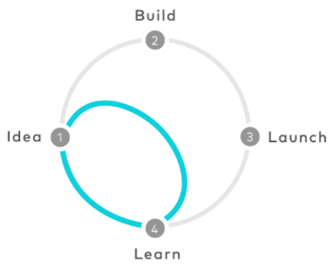


Figure 22 - Double Diamond Model - British Design Council (2005)

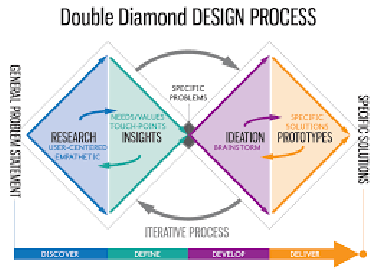


Figure 23 - IDEO Design Thinking Model

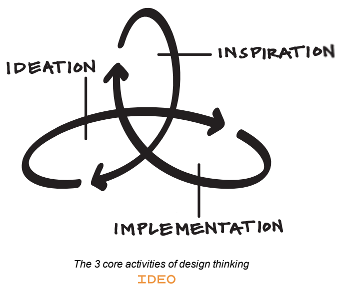
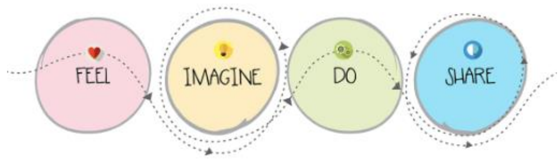
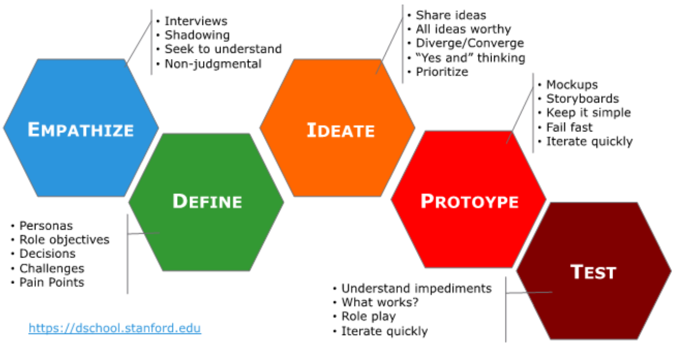


Figure 24 - Design for Change – Feel. Imagine, Do, Share (FIDS) Model



One of the most popular DT frameworks in circulation is Stanford's d.school (see Figure 25) which consists of processes: empathise, define, ideate, prototype and test.

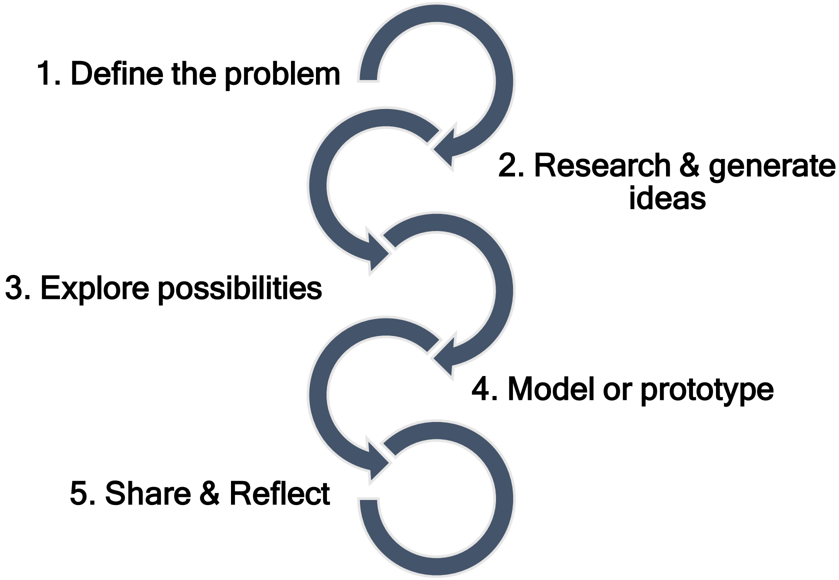
Figure 25 - Stanford d.school design thinking process



Source: Hasso Plattner: Institute of Design at Stanford

IDEO (see Figure 23) is another popular framework that promotes inspiration, ideation, and implementation (Brown, 2008); however, although it captures the DT process, it can be an ambiguous framework for an educator to embrace. The DT frameworks promote a similar process where learners define the problem, investigate and research, generate ideas, make the prototype, present solutions, and test. However, although they have a similar process, some are overly simplistic, while others are more complex or customer-orientated as they are explicitly designed for industry (Barry & Beckman, 2007). Carroll (2010), in her DT research in a school in the USA, applied the Stanford d.school model (see Figure 25), which encompasses all of the key features but crucially neglects to explicitly promote 'share' and 'reflect', which are essential components of SC. Sharing with the group and reflecting is vital in helping learners co-construct knowledge through critical evaluation and self-reflection. They need to help learners take ownership of their learning, i.e. metacognition and self-regulation (Hattie, 2008). Therefore, I have used the models above to create a DT model specifically for schools that explicitly promotes the critical component of learner reflection and aims to be concise enough for an educator who is a '*design novice'* to use it (see Figure 26).

Figure 26 - Proposed Design Thinking Model for Schools



While embracing the essence of DT, this model orientates toward an educational setting, identifying steps for DT novice educators while promoting the sharing and reflecting self-evaluation aspect. This model will be the one employed in this study, and the following is a summary of each of the iterative phases.

1. **<u>Define the problem</u>**

The first stage in the design process encourages learners to develop various perspectives and understand the problem, challenge, and context. This encourages empathy.

2. **<u>Research and generate ideas</u>**

Learners then solve the problem and generate meaningful ideas using various information and perspectives. They are encouraged to use their initiative and decide what resources and strategies are required to gather the information and interpret it into meaningful insights to generate actionable solutions.

3. **<u>Explore possibilities</u>**

This phase encourages learners to brainstorm collaboratively to develop their ideas by opening their minds, being imaginative, and generating various ideas to solve the challenge.

4. **<u>Model or prototype</u>**

Learners bring their ideas alive and make them physical, interactive, and testable. Building a tangible artefact solidifies ideas, develops concepts, and creates challenges. Prototyping allows learners to share their ideas with others, identify their abstract imaginations, and bring their ideas into the physical world.

5. **<u>Share and reflect</u>**

Learners share and interpret feedback to iterate, refine, and build on throughout the process. Feedback is obtained from peers, educators, experts, from everyone involved in the problem context.

Although presented as a linear, step-by-step format in the model above (Figure 26), the DT process is a very unpredictable, messy process as ideas formulate, iterate, and develop (Melles et al., 2011; Mosely et al., 2018; Stables, 2013).

2.4.2 Meta-competencies through design thinking

While there is little literature available on DT, specifically at primary and secondary levels, there is a growing interest in using DT in an educational environment, in part due to an increasing number of educators, employers and researchers who believe that DT as a pedagogical framework might be one way to develop crucial MC (Jobst et al., 2012; Koh et al., 2015; Scheer et al., 2012; Wrigley & Straker, 2017). As Carroll (2015) claims, “design thinking, with its focus on empowerment and agency, is a powerful tool to meet the needs of 21st-century learners by providing a human-centred scaffold for problem definition and problem-solving. Students need to know how to be empathetic towards others, identify problems, and generate creative solutions" (Carroll, 2015, p.62). A study reinforced this through Harvard's Project Zero[24] initiative (2012, 2015) as part of the Design for Change (DFC) methodology (see Figure 24): Feel, Imagine, Do, Share (FIDS). This research has resulted in several research papers focused on educational DT. Using the FIDS DT approach, DFC's research found improvements in participants' confidence, academic scores, empathetic thinking, and problem-solving. More importantly, many participants felt the process developed crucial MC - empathy, collaboration, communication, and leadership competencies. It also identified more learners wanting to participate every year with a significant shift in learner attitudes; they felt more proud, motivated, hopeful, and excited.

A similar study by Stanford University (Rao et al., 2021) using DT with 195 middle school learners found that it increased confidence and significantly increased the production of ideas and divergent thinking. A further DT study of 248 learners in eight schools in Columbia, in collaboration with the Terpel Foundation, found that using DT increased empathy, planning, collaboration, creativity and critical thinking, all crucial MC. A DFC study in France sampled 159 learners and found that using DT generated a resilient and robust sense of personal effectiveness at schools and increased self-efficacy by 11%.

The DT process can deliver SC pedagogy and develop much-needed MC at

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[24] Harvard Project Zero - http://www.pz.harvard.edu/

each stage. Table 7 highlights the potential correlation between the three aspects of this research.

Table 7 - Design thinking process correlation with social constructivism and meta-competencies

SC tenets (why)	Correlating MC (what)	DT process (how)
Context *Past experience* *Real-world*	Critical thinking and problem solving Ethical and sustainable thinking Social awareness	Define the problem
Content *Background* *Media*	Computing literacy Digital literacy Planning and organising Self-regulation Responsible decision making	Research and generate ideas
Pedagogy *Facilitator* *Learner-centred* *Active*	Inspirational leadership Self-mastery Creative intelligence Strategy and management	Explore possibilities
Engagement *Collaboration*	Effectual reasoning Computational thinking Digital design Collaboration Self-awareness	Model or prototype
Assessment *Feedback* *Reflection*	Communicating impactfully Global consciousness Self-mastery	Share and reflect

The co-construction of knowledge through socially collaborative, reflexive, authentic problem-solving aligns DT with SC. As such, I have structured the following sections using the tenets of SC to analyse current literature concerning DT in a school setting.

2.4.3 Context

The context of the DT project is crucial as this will determine learners' first impressions, construction of knowledge, development of competencies, and engagement levels. Optimising and extending learners' prior knowledge through authentic, personalised learning that is less concerned with the content, 'the design thinking process can contribute to new modes of knowledge production that are attentive to context rather than content' (Stork, 2020, p.44).

Ideally, the starting point in any DT project is identifying the '*wicked problem'* (Rittel & Webber, 1973), one that is difficult or impossible for learners to solve. Dorst (2015) calls these '*contemporary problems'* that cannot be solved using a conventional problem-solving methodology and argues that DT is fundamentally different from other problem-solving frameworks based on deductive, inductive and normal abductive reasoning (Dorst, 2015). Instead, learners are encouraged to find rich solutions to the complexity of "open, complex, dynamic and networked" challenges (Dorst, 2015, p.121).

"The challenges we face now as a society - climate change, fake news, wealth inequality, biodiversity loss, systemic depression - are only increasing in their scale and complexity. The skills we need to address these issues adequately cannot be taught with the education model we've inherited." (Rebernik, 2021, p.2)

This was illustrated in a study conducted in Canada by Aflatoony and Wakkary (2015), who found that learners transferred and applied DT techniques in real-life problem-solving. Engaging learners empowers their problem-finding, problem-solving and critical thinking techniques (Aflatoony & Wakkary, 2015). Enticing learners with engaging authentic, real-world social human-centred issues (Bransford et al., 2000; Kelley & Knowles, 2016) facilitates learners' ‘*need to know’* (Hmelo-Silver et al., 2007; Ito et al., 2020). Sparking an interest in learners is what Stables (2013) identifies as a ‘*successful project’* as it is challenging enough to create enthusiasm, excitement, and passion, yet it is still achievable for learners.

The challenge and the uncertainty of the situation enable learners to embrace ambiguity (Collins, 2013). Learners are encouraged to move away from the pursuit of absolute answers and to engage in logical reasoning through exploration of impartial and imperfect answers (Collins, 2013) and “adopt the premise that there are many right ways to solve problems and that there are many right answers to questions” (Honebein, 1996, p.19). Brainstorming collaboratively presents multiple ideas and promotes the importance of moving from one solution to the next, combining, exploring, and thinking up new possibilities (Sharples et al., 2016). It also helps to dispel the myth that there is only one correct answer, encouraging a growth mindset (Dweck, 2012).

“Iterative process of design may lead to Dweck’s growth mindset since designers are encouraged to develop new solutions and test them many times throughout the process. The possibility of failure always exists in the design process, and when faced with failure, designers start the process over.” (Noel & Liub, 2017, p.5)

Through brainstorming and subsequent discussions and debates, learners form multiple opinions and solutions, which they must analyse to assess the potential impact. Designing multiple solutions in parallel leads to a fuller exploration of the problem (Chin et al., 2019). Still, it allows learners to take calculated risks and make mistakes that they grow and learn from in a safe environment.

“Design thinking creates a place for students to grow through failure.” (Mapuana et al., 2021, p121)

However, a study from Mentzer et al. (2015) examined the difference between high school learners and expert engineers in a DT project with fifty-nine high school learners from four states in the USA and thirty college engineers. Their intervention found that high school learners “had little understanding of the problem from client’s perspective” and could become “fixated on a single solution” (Mentzer et al., 2015, p.417). They recommended that DT be taught from a younger age to develop empathy while encouraging learners to look for alternative solutions to help critically evaluate their explanations.

Immersing learners in a DTS environment has been shown to enhance the learning experience. It turns the focus of the class away from the teacher toward the learner, creating a learner-centred teaching approach (Shreeve, 2015). The use of immersion studios, where participants are absorbed in the DT experience for hours, days or even weeks, has been the backdrop for several DT studies, although it has never been, to my knowledge from a literature search, the focus of participants’ experiences. The informal, immersive learning experience offered by these types of studios has been shown to have several benefits: nurturing interest and motivation, optimistic attitudes, positive career aspiration, and raising confidence and self-efficacy (McLaughlan & Lodge, 2018; Riedinger & McGinnis, 2017). Learners who typically struggle in school can show success in informal immersive environments due to a lack of formal assessment, different rules, structures and participatory learning activities, autonomy, and the opportunity to explore in unconstrained, comfortable, and meaningful ways (Riedinger & McGinnis, 2017). A qualitative study by Wright et al. (2018) using three-day immersive DTS in the Australian outback found that educators participating with the teenage learners felt that the DTS was an "exciting way to introduce innovative ideas, new activities and experiences, tertiary education opportunities, professional mentors and non-traditional career pathways" (p.45). There is further sporadic research focussing on DT as an immersive experience as part of a summer school (Goldman & Kabayadondo, 2016; Stork, 2020) in extra-curricular activities (Cook & Bush, 2018; Mentzer et al., 2015) and in the development of educators (Timoštšuk & Tinn, 2015; N. Wright et al., 2018). Indeed, in Wright's (2018) research in Australia, she utilised a 3-day DT immersion studio to enhance the DT experiences and argues that using an immersion studio where learners have no other distractions is an effective way to engage and educate learners. In a more recent paper, Wright and Wrigley (2019) claim an urgent need for methodologically rigorous evidence to show the value and effectiveness of a culture of DTS education. Meredith Davis argues for DT to be used in schools to expand the pedagogical repertoire of educators (Davis, 1998) as it offers educators new pedagogical tools to innovate curricula (Noweski et al., 2012); that immersive participation in a DTS reframes the relationship between the learners and the educator.

2.4.4 Content

Learners require an enhanced capacity for innovation and adaptation to change (Boyatzis, 2008). To facilitate this, learners need to be provided with the context and have a global contextualisation and a holistic systems thinking approach (McLaughlan & Lodge, 2018). Markauskaite and Goodyear (2017) endorse the need for creative, interdisciplinary, collaborative problem-solving pedagogies to address the future global challenges that include food scarcity, climate change, migration, and renewable energies, to mention just a few. This correlates with Pink's (2008) analysis of the complex nature of contemporary problems that have moved past the '*knowledge age*' into the '*conceptual age*' where learners' complex problem-solving and creativity competencies will be essential.

The ability to see conceptually involves understanding interrelations and how systems work within a larger context over time. It also requires learners to 'see' the big picture and work across several disciplines simultaneously. This investigation across domains (Genone, 2021) or interdisciplinary approach (Dewey, 1913) is essential to ensure learners are self-regulating and challenged in a real-life scenario (Scheer et al., 2012). Indeed, since all the significant problems of tomorrow are problems that any one speciality cannot address, learners need to be comfortable working in an interdisciplinary manner (Gow, 2012). However, this can prove problematic for educators whose environment does not facilitate this or who find this difficult. Scheer (2012) identified that many educators have a "negative classroom experience with project work or interdisciplinary teaching, due to constantly feeling uncertainty and chaos, as well as a lack of process to follow" (p.8). This could be resolved by having a DT framework that provides educators and learners with a framework to scaffold learning. Providing a DT framework can be used with learners of all ages, as Tosca and Ejsing-Duun (2017) demonstrated with their study of 2nd-grade learners (8 years old). They found that having a DT framework facilitates interdisciplinary learning, systematically supports young learners through the DT process and heightens digital literacy in learners (Tosca & Ejsing-Duun, 2017).

The DT process uses various media, raw data, and primary research.

Throughout the DT process, learners use digital technologies to research and generate ideas, locate relevant information and data, or produce solutions through design artefacts, physical, textual, or conceptual, using software and hardware.

“making prototypes, artefacts, services, and products by using digital technology towards a more innovative world is a method for creating new knowledge and opportunities.” (Stork, 2020, p.45)

Indeed, early iterations can help accelerate the learning process, and digital tools can facilitate this and bring thoughts and ideas to life. Thomke (2003) recommends rapid model prototyping and experimentation early on, for example, using CAD design, three dimensional (3D) printers, and laser cutters. This allows learners to produce something tangible as “design intends to offer a concrete solution to a complex problem that is socially ambiguous and neither easy nor certain to comprehend” (Rauth et al., 2010, p.2). Using these digital tools and design software can be helpful, encouraging an innovative culture that allows for continual iteration, promoting adaptation and flexibility. Indeed, Kelley and Sung (2017), in their study of 5th-grade learners, found that those exposed to DT spent 34% more time on computational thinking, a critical component of digital technologies.

2.4.5 Pedagogy

An increasing body of research in neuroscience confirms how models such as DT lead to faster and deeper learning. A study at the University of Chicago (2015) used brain scans to highlight that hands-on learning actuates sensory and motor-related areas of the brain, exemplifying learners who learned this way, experiencing by doing, for example, understanding more and scoring better on tests. This was reiterated by a Princeton University study into active learning (Theobald et al., 2020). It was also the focus of a digital DT study by Haller-Seeber et al. (2020) that explored the use of the ROSSINI[25] platform to improve young learners' introduction to robotics through a DT process. They hoped the intervention would enhance participants' communication, collaboration, critical thinking, creativity, and problem-solving competencies. In Tyrol, Austria, the study involved forty-eight upper primary-aged learners (age 7-12 years). It was built around five core concepts: DT, computational thinking, upcycling and waste management, free software and open hardware, and DIY (Do It Yourself) rapid prototyping to build a robot. Their study examined the learners' motivation for joining the voluntary robotics programme and found that the learners were primarily motivated by hands-on experience. However, although a claim that DT underpinned the project, I would question if this project focussed more on problem-solving with a specific end directive provided for learners.

Advances in technology and neuroscience highlight the importance of experiential, active, hands-on learning. In 2015, The Dartmouth Centre for the Advancement of Learning[26] conducted a review of research on the known outcomes of experiential learning and found that learning through the immersive, experiential, hands-on application (rather than absorbing knowledge by listening or reading) was more effective in developing MC, such as complex reasoning, critical thinking, creativity, and socio-emotional intelligence where

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[25] Rossini - https://cordis.europa.eu/project/id/818087

[26] Dartmouth Center for the Advancement of Learning - https://dcal.dartmouth.edu/

learners are active participants, not passive recipients of knowledge. Nanterme (2018) advocates that when learning is active and engaging, the brain forms new connections more effortlessly, particularly when learners are ”forced to solve a problem rather than being taught the solution as making and correcting mistakes also improves skills retention” (Nanterme, 2018). As they work and learn, they can pivot and change the course of their project depending on what opportunities arise.

“If pupils are encouraged to follow-up their ideas, they are more likely to see relationships between ideas and concepts, and to become problem finders as well as problem solvers.” (Watson, 2001, p.141)

Nikoomanesh argues for DT to help train learners in problem-solving (Nikoomanesh et al., 2014). Learners experience failure and improvement through listening, pivoting, and acting resourcefully, thus constructing knowledge and conceptual understanding (Rowe, 1987). Carroll (2010) argues that DT “provides a powerful alternative to this model by challenging students to find answers to complex and difficult problems that have multiple viable solutions and by fostering students’ ability to act as change agents” (p.38). Roger Martin[27], a Business School Professor from the University of Toronto, calls this ‘*integrated thinking*’ the ability to take advantage of opposing ideas and opposing constraints to generate new solutions (Martin & Austen, 1999).

Throughout the DT process, the educator supports teamwork and dialogue, acting as a guide and encouraging learners to express new ideas and ask questions (Barak et al., 2007). Learners are immersed in complexity and

[27] Roger Martin - https://rogerlmartin.com/

continually must identify goals and strategies for moving forward, implement these, evaluate how it is going and modify their approach and thinking accordingly, effectively providing learners with increased autonomy. This echoes Vygotsky's (1978) scaffolding, where teachers and peers support learners to an appropriate level of performance, and Scheer et al. (2012) assert that DT gives 'faith in the creative abilities through a process to hold on to when facing difficulties during the project' (p.18). This process of engagement with peers provides opportunities for learners to share their thoughts, listen, negotiate ideas, and construct knowledge collectively, expanding their zone of proximal development as they have an opportunity to "test their ideas, analyse and synthesise the opinions of others, and build a deeper understanding of what they are learning" (Weber et al., 2008).

Carroll et al. (2010) examined the role of DT in K-12 classrooms to establish how to integrate DT with academic content, an area of critical importance if DT is to be merged into education systems. Their study examined the use of DT to teach '*systems*', a component of the geography curriculum. Their study found that their intervention did not integrate into the academic curriculum as successfully as they had hoped and was complicated because the project team had little knowledge of classroom standards in geography. In contrast, the classroom teacher had limited experience with DT. The team felt that this led to a disjointed experience for the learners. Carroll et al. (2010) argue that the function of DT is to enhance classroom instruction to support learning but raise a fundamental question: what are the most effective ways to integrate DT into practice? Although the DT process of collaboration, iteration, brainstorming, prototyping, and presentation was present in this study, I would question that rather than focussing on '*teaching content"* from a particular discipline, like geography, perhaps an interdisciplinary approach with a real-world '*hook*' for learners, the authentic '*wicked problem*' would help engage them in the process. Some establishments and governments have already adopted a move from the traditional discrete subject approach towards a real-life interdisciplinary approach where learners are solving real-world problems like the Interdisciplinary School in London[28] that starts with '*super concepts*' and '*systems thinking*' that involve pertinent global issues, then teaches learners the disciplines and methods to tackle it, developing a growth mindset (Dweck, 2006) and competencies for the future. Finland also embraced interdisciplinary learning. In 2015, they examined their educational epistemology and although they still have traditional discrete subjects, they have started delivering reform, integrating their discrete subject teachers with the development of 'transversal competencies[29], through multidiciplinary learning modules which has been termed by some as the 'phenomenon' (Mattila & Silander, 2015) approach.

"Phenomenon based teaching and learning use the natural curiosity of children to learn in a holistic and authentic context. Holistic, real-world phenomena provide the motivating starting point for learning instead of traditional school subjects. The phenomena are studied as holistic entities in their real context, and the information and skills related to them are studied by crossing the boundaries between subjects. Phenomena are holistic topics like human, European Union, media and technology, water or energy." (Phenomenal

[28] London Interdisciplinary School - https://www.londoninterdisciplinaryschool.org/

[29] Finland Education Website - https://www.oph.fi/en/education-and-qualifications/national-core-curriculum-basic-education

Education Website, Finland)[30]

Finland has founded a global reputation as a progressive educational nation due to its continued impressive international education system rankings (PISA, 2018). Learners are taught relevant, real-life ‘topics’ through interdisciplinary pedagogy, focusing on real-world problems and working in teams to investigate, facilitated by the educator.

Reframing the role of the educator and learner is crucial in the DT process; it involves a shared learning journey where educators are mentors, facilitators, and guides in the process. Carroll (2014) explored this use of mentors in her ethnographic qualitative study called ‘Shoot for the moon!’’ which involved 215 learners in San Francisco who looked to extend the knowledge base surrounding DT in K-12 education and the role of mentors in the process. Carroll (2014) made the following assertions: mentors found it challenging and rewarding, saw themselves as role models, and felt that the DT process provides opportunities that foster growth and develop a mentoring relationship. They also became more adept at realising they did not have all the answers and found that “powerful learning occurred when they could admit they didn’t know something” (Carroll, 2014, p.29). However, the mentors acknowledged challenges with their ability to respond to what occurred in the moment and found that responsiveness and flexibility were essential. The mentors commented that “the design thinking process had rigour and was rich in opportunity for building 21st-century thinking skills” (Carroll, 2014, p.28).

Many see igniting an interest in learners, particularly towards future careers, as

[30] Phenomenal Education - http://www.phenomenaleducation.info/

critically important. Several studies suggest DT can aid learner mastery in core areas such as Science, Technologies, Engineering, Arts, and Mathematics (STEAM) (Carroll, 2014, 2015; Doppelt et al., 2008; Kelley & Knowles, 2016; Kijima et al., 2021; Levy, 2013; Ozturk, 2021). Indeed, exposure to DT has positively transformed young adolescents' perceptions of innovators and scientists (Goldman & Kabayadondo, 2016). Nikoomanesh et al. (2014) argue that DT can make a lasting impact on life and career skills. Kijima et al. (2021) carried out a mixed-methods study with 103 females aged thirteen to eighteen years over four years. They initiated a three-day DTS in Tokyo, Japan, to study its effect on encouraging female learners to consider a career in STEAM. They found learners had an increased interest in engineering; greater confidence, more positive perceptions of STEAM, higher levels of empathy and pro-social factors, more varied outlook on career options, and argue that this short intervention had a strong influence on the female learners' mindsets, self-image, and perceptions of STEAM. A further study by Wright et al. (2018) found that DT "facilitated life and career aspirations beyond the traditional scope of careers" (N. Wright et al., 2018, p.47). A study by Haller-Seeber et al. (2020) examining the use of DT to develop STEAM learning in school-age learners over ten weeks found that DT provided a theoretical and pedagogical frame in which STEAM thrived and reinvented the role of the educator (Haller-Seeber et al., 2020) which reinforces Carroll's (2014) argument that "young people cannot choose a specific STEM career or field of study if they are not made aware of the diverse range of possibilities and the paths they need to achieve their goals" (p.17).

STEAM roles will require creativity and innovation as learners must think outside the box to remain relevant in a computer dominated world. The very essence of DT is to think up new ideas and test them out co-operatively; therefore, it is no surprise that the studies carried out in these areas have reinforced this premise (Noel & Liu, 2016; Tschimmel, 2019). To promote creativity, learner-centred approaches are favoured because they allow learners to collaborate, work on authentic problems, and engage with the community (Tosca & Ejsing-Duun, 2017, p.241). Existing research has shown that DT is a powerful approach that boosts creativity (Jobst et al., 2012; Koh et al., 2015; Rauth et al., 2010), launches innovation (Dogara et al., 2020), in turn building a creative self-efficacy in learners (Tierney & Farmer, 2002). Rauth et al. (2010), in their DT research, interviewed eighteen DT experts from d.school in the USA and Germany and found that various stages of creative skills, knowledge, and mindsets can be achieved through repeated DT projects, culminating in a capability that they termed '*creative confidence*' (Rauth et al., 2010, p.6). This creative confidence focused on a recent quasi-experimental study (Rumahlatu et al., 2021) with 432 learners from four high schools in Ambon, Indonesia. The study found that using a DT approach improved learners' creative thinking skills, concept gaining, and digital literacy. A further mixed-methods case study by Anderson (2012) of 125 upper primary and early secondary school learners in four rural Australian schools found that using DT as an effective multidisciplinary pedagogical framework helped foster creativity and innovation. The study argues the importance of developing and tracking learners' competencies to strengthen their creative skills and innovative mindsets (Anderson, 2012). The importance of DT in developing creative problem-solving competencies in learners was identified by a regression analysis carried out by Gözen (2016) with eighty-nine primary age learners in Ankara, Turkey. Gözen identified that DT might influence the creative performance of learners and argues that educational activities for competency development in DT may allow children to produce creative solutions for real-life problems and should be incorporated into educational programmes. In Latvia, Freimane (2015) compared responses to the same design brief to disparate groups – one a group of 1st-year master's level design students and the other school children aged 11-14 years. Freimane affirmed that both groups could create new and innovative product concepts, understand the systems approach to DT, see no difference in both groups, and claim that DT should be incorporated into education for younger learners (Freimane, 2015).

2.4.6 Engagement

Several studies have identified using DT to increase learners' motivation and engagement as an "exciting way to introduce innovative ideas, new activities and experiences" (N. Wright et al., 2018, p.45). DT is purported to increase engagement as a "way of thinking and being that could potentially enhance the ontological and epistemological nature of schooling" (Razzouk & Shute, 2012). Madeline Levine (2012), in her book 'Teach Your Children Well', claims that internal motivation is correlated with positive outcomes such as higher academic achievement, retention, and fewer emotional problems and that curiosity, persistence, and engagement are the drivers of lifelong learning (Levine, 2012). Indeed, disengagement can profoundly affect cognitive development and learning outcomes (Ma et al., 2015) and predict learner dropout in secondary school (Finn & Zimmer, 2012). Engaging learners in a love of learning is crucial for future success; therefore, it is essential to select activities that motivate and engage them.

A few studies examine learner engagement using DT in schools (Atchia, 2021;

Carroll et al., 2010; Doppelt et al., 2008; Noel & Liu, 2016). Noel and Liu's (2016) literature review examining the use of DT with younger learners argues for the use of DT as it "would, in fact, benefit all children and lead to their greater engagement at school and future success in their professional lives" (p.510). However, they only cite one study from Carroll (2010) as evidence that found that "design-thinking projects promoted engagement by allowing students the opportunity to express their opinions" (p.49). A recent study by Atchia (2021) examined educators' self-refections of their current teaching practice compared with a DT thinking approach. This self-evaluation was an attempt for educators to take ownership in transforming constructivist learning into action. In examining three areas - learning strategy, assessment, and resources - learners were much "more engaged in the practical task using the design thinking process compared to the traditional recipe approach" (Atchia, 2021, p.11). A further case study from Doppelt et al. (2008) examining thirty-eight eighth-grade learners (thirteen to fourteen years old) from two science classes (high and low ability) on the effect of DT on engagement and achievement found that the class that was perceived to be low-achieving learned more and were more engaged. Learners who previously had difficulty paying attention in class were "attentive and fully engaged" (Doppelt et al., 2008, p.33). This correlates with Carroll (2010), who found that DT "has the potential to engage students in ways that are inclusive of their diversity, makes school learning relevant to real, pressing local and global issues… where they can develop agency, confidence, and identity as change agents as they respond as innovators to the interdisciplinary nature of design challenges" (p.16).

Bond et al. (2020) carried out recent systematic mapping research of 243 studies published between 2007 and 2016, analysing learner engagement in educational technology in a HE setting. They identified several engagement and disengagement indicators in cognitive, behavioural, and affective domains (see *Table* 8). Table 8 features tenets of SC and DT process in the engagement column; for example, learning from peers, self-regulation, and participation correlates with the Skinner and Belmont (1993) definition of learner engagement from their study on 'Motivation in the Classroom' which specified that learners who remain involved choose tasks they find challenging in their learner zone, initiate action, display intense effort, concentration, show enthusiasm, optimism, curiosity, and interest.

Table 8 - Mapping research highlighting indicators of student engagement and disengagement (Bond et al., 2020)

	Indicators	
Domains	**Engagement**	**Disengagement**
Cognitive	Learning from peers Deep learning Self-regulation Positive self-perception Critical thinking	Opposition, rejection Pressured Unwilling and avoidance Feeling overwhelmed
Behavioural	Participation/interaction/engagement Achievement Confidence Study habits Attention/focus/responsibility	Half-hearted Distracted Unfocused, inattentive Absence Poor conduct, giving up
Affective	Positive interactions Enjoyment Positive attitude towards learning Motivation Enthusiasm	Frustration Disappointment Worry Boredom Disinterest

Source: Mapping research in student engagement and educational technology in higher education (Bond, 2020)

Working together collaboratively is in all three engagement domain columns - learning from peers, interaction, positive interactions - which suggests it is a positive strategy for encouraging engagement in learners (see Table 8). Collaboration and teamwork also actively develop interpersonal skills, particularly when learners approach problems and tasks in diverse ways

(Sharples et al., 2016; Silva et al., 2016), facilitating the development of empathy, a crucial 21st-century competence (Levine, 2012), which Chen et al. (2015) argue is a learned skill. Cronin and Weingart (2007) argue that this is ideal for developing conflict and persuasive skills as learners co-construct knowledge. As part of defining the problem, learners are encouraged to learn about the audience for whom they are designing, think about others, their differing views, embrace diverse perspectives and start their decision-making process (Jefferies et al., 2013; Sharples et al., 2016). DT allows participants to work successfully in multidisciplinary teams to solve real-life problems and consider multiple perspectives (Bellanca & Brandt, 2010; Rauth et al., 2010). Carroll (2015) concurs with this analysis and found that the most valuable learning in her DT research was "the importance of caring, engaging, taking risks, and trusting as relationships are built. There must then be a willingness to be vulnerable, fail, and learn from what doesn't work. This leads to being resilient, optimistic, and ultimately, empowered" (p.69). The DT process encourages learners to engage in collaborative learning, which facilitates engagement by allowing learners to express their opinions which challenges them to think in new ways and take risks (Carroll et al., 2010).

Contrary to current thinking on the development of risk-taking and perspective-taking in DT, Rao et al. (2021) carried out a randomised field experiment with 255 middle school learners from eight schools in the Agastya region in India. Using a DT framework with learners, they claim their study revealed no significant effects on perspective-taking or risk aversion. However, their intervention did see an increase in confidence, primarily among females, and a significant increase in ideational fluency and elaboration in divergent thinking.

DT can make ideation fluency and divergent thinking strategies explicit through discussions, which develops their decision making, planning, monitoring and evaluating procedures and facilitates autonomy and agency in learners (Haller-Seeber et al., 2020; Mapuana et al., 2021). This allows learners to “control and affect their own learning” (Lindgren & Mcdaniel, 2012, p.345). Consequently, developing self-management in time allows learners to gain confidence in their abilities and develop a belief “in their own capacity to master difficult material through sustained, thoughtful effort” (Jackson, 2003, p.583), encouraging learners to “actively construct knowledge” (Gorzelsky, 2009, p.67) and “determine their own course of action” (Vaughn, 2018, p.63). The use of agency and autonomy support self-regulation and the development of cognitive, intrapersonal, and interpersonal competencies (Pellegrino & Hilton, 2012). In a recent study, Mapuana et al. (2021) found that DT “supports student agency by supporting self-efficacy, promoting perseverance when faced with challenges, and allowing individualism with a collaborative setting. It provides students with a method for developing critical thinking and problem solving while exploring creative elements to develop creative knowledge and skills” (p.121). DT shifts the focus from individual work to team collaboration through interviewing, needs finding, data synthesising, and prototyping. Learners are encouraged to take charge, negotiate, and challenge others while being flexible and adapting perspectives quickly. Differences in thinking and learning approaches help develop learners’ leadership and interpersonal skills, e.g. listening skills, verbal and non-verbal communication, negotiation, problem-solving, decision-making, and assertiveness (Cronin & Weingart, 2007). Working collectively on a project of personal meaning towards a common goal encourages professional teamwork and leadership skills (Camburn & Spillane, 2006; Coburn & Honig, 2008). Learners should have a sense of purpose that drives them on and motivates them throughout the project, which can be helped with ownership and autonomy, building their perseverance, self-belief, self-efficacy, and growth mindset (Cirks et al., 2018; Dweck, 2006).

2.4.7 Assessment

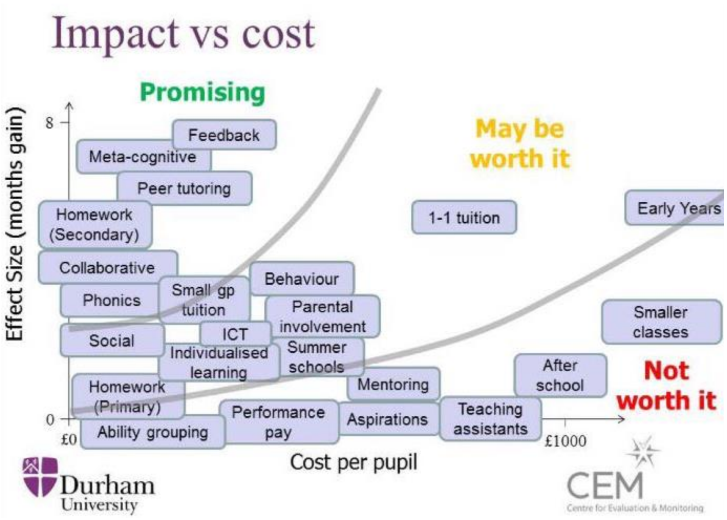
Assessment through an SC pedagogical model involves learners co-constructing knowledge and assessing their development and progress. One of the fundamental objectives of 21st-century education is learning '*how to learn'*, a skill referred to as '*metacognition*' (Flavell, 1979; Schraw & Dennison, 1994). Developing metacognition aims to help learners think about their learning more explicitly, often by developing specific processes for planning, monitoring, and evaluating their learning (Hattie, 2008). Research has shown that metacognitive ability leads to deeper learning, academic improvement, stronger learning transfer, and personal accomplishment (Akyol & Garrison, 2011; Bransford et al., 2000; Dede, 2010). Encouraging learners to develop their metacognition and manage their learning is one of the considerable intellectual challenges as they leave school and enter college, university, or the workplace (Pascarella & Terenzini, 2005).

Ever since the Education Endowment Foundation[31] cited metacognition (see Figure 27) as the highest impact strategy educators can use in the classroom, there has been an increased focus on what it is and how it can be developed in education as these approaches have a 'consistently high level of impact, with learners making an average of seven months' additional progress' (Higgins et

[31] *Education Endowment Foundation - https://educationendowmentfoundation.org.uk/*

al., 2013).

Figure 27 - Summary of educational strategies and their impact versus cost

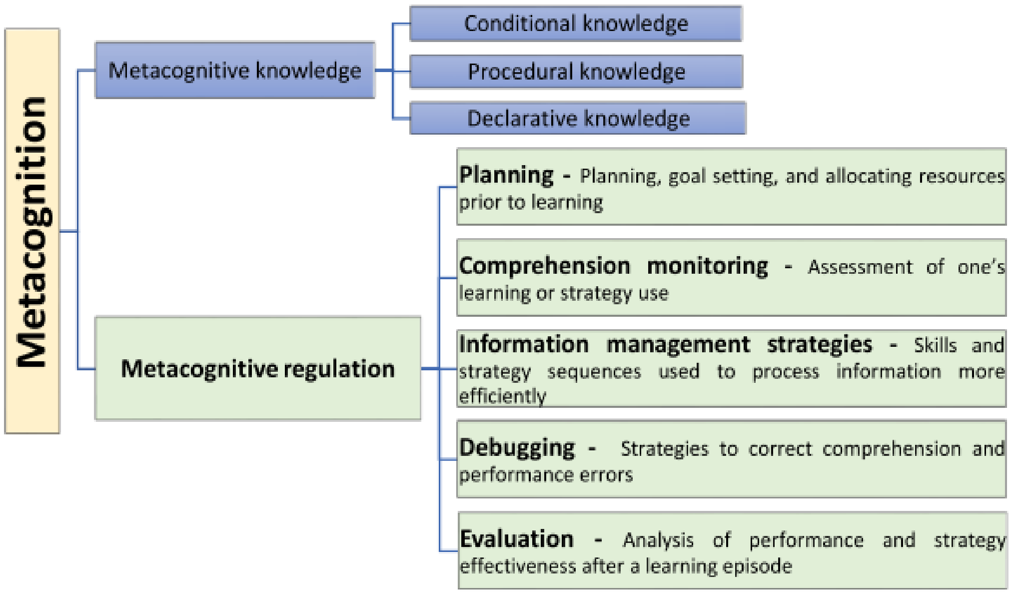


Source: Sutton Trust – Educational Endowment Foundation and Learning Toolkit

The importance of involving learners in their learning journey and not just '*telling*' them what to do, has been acknowledged as having a significant impact on their progress (Hattie, 2008) and is fundamental to promoting lifelong learning (Abrami & Barret, 2005). There are several pedagogical strategies recommended to educators to facilitate metacognition development in students: examination wrappers (Soicher & Gurung, 2017); dialogue - reciprocal teaching (Palinscar & Brown, 1984); thinking - reflection portfolios (Costa et al., 1992) and DT (Kavousi et al., 2020; Olewnik et al., 2019; Soleas, 2015).

DT is underpinned by an iterative feedback and reflection model, making it ideal for helping develop metacognition and enabling learners to become cognisant of their learning and thinking processes (Clark & Eyon, 2009). Once they are aware of their thinking processes, they are better placed to monitor, assess, control, and change those processes (Gleaves et al., 2008). Learners can then begin to recognise and evaluate their strengths and weaknesses (Cheng & Chau, 2009; Hattie, 2008), known as self-regulation, which is related to metacognition. This makes DT a powerful active learning model that can help learners reflect on their thoughts and encourage them to explore, question, connect ideas, and persist with their learning (Costa et al., 1992), effectively developing metacognition. As shown in Brown's framework (see Figure 28), metacognition has direct application to academic learning settings (Baker & Brown, 1984) and the iterative DT process as learners plan, monitor, implement strategies, adapt their thinking and evaluate their progress.

Figure 28 – Brown's (1987) framework of metacognition



Source: Metacognitive framework adapted from Brown (1987)

Learning is inevitably iterative due to being both incremental and interpretive (Taber, 2017, p.405). This makes the task difficult for educators who must try and identify progress and development. In their paper, Carroll et al. (2010) raise the fundamental question, how can we effectively assess using this method? The standardised high-stake examination still in use today contrasts with the development of individual competencies, personal growth and development.

"We need to build a robust system for the accreditation of learning where learners can evidence their progress in multiple ways, not just what they can remember in a final exam.” (Hutchison, 2021, p.9)

The ability of learners and educators to identify their progress by setting goals and knowing where they have come from and how they ended up is an essential metacognitive process. Therefore, effective teaching is an interactive process where the educator constantly seeks feedback from learners on their understanding and adapts ongoing scaffolding and teaching accordingly (Taber, 2014). Despite the emphasis in recent years of the importance of formative as opposed to summative assessment (Black & Wiliam, 2010), our learners’ ‘*futures*’ are still decided, for the most part, by their attainment during their national diet of examinations. The DT process integrates an iterative learning process through continual discussion and dialogue with peers and educators, facilitating a continual cycle of self-evaluation, peer evaluation and feedback, culminating in a final presentation to an ‘*interested*’’ audience where learners share their learning journey. Despite the importance of formative assessment and the development of learners’ metacognition, there are very few empirical studies researching its use through a DT model in a school setting; however, there are several studies focused on HE (Elliott et al., 2020; Kavousi et al., 2020; Olewnik et al., 2019).

The only school-age research into the use of metacognition and DT is a desk-based study based on the experience of Soleas (2015) as a secondary science educator in Canada. He proposes some useful tools for developing metacognition and argues for the use of DT as it can be easily taught over time through reflection, exposure, and scaffolding (Luther & Barnes, 2015). Soleas argues that DT helps with structuring the process of developing metacognition and should be taught in schools as “it is my assertion that assignments that combine the educational value of multiple frameworks including metacognition and design thinking makes for a class climate that promotes inclusion and richness of student learning” (p.10).

Despite the dearth of empirical studies researching metacognition and DT, there is a growing body of research examining the importance of developing metacognition in other areas, as high performing school systems worldwide promote its development, for example, Hong Kong, Singapore, and Finland (Cheng & Wan, 2017; Retna, 2016; Vainikainen et al., 2015; Vainikainen, 2014). In 2018, Perry et al. examined over fifty studies to ascertain the effect of metacognition in schools on learners’ outcomes and well-being. Their review found convincing evidence indicating that when metacognition is effectively taught in schools, there is a significant positive effect on learner outcomes, although they acknowledged that one of the biggest challenges of studying metacognition and learning in classrooms is how actually to measure it in action (Georghiades, 2012; Perry et al., 2018) which correlates with Razzouk and Shute (2012) who found ‘no valid performance-based assessments of design thinking skills’ (p.34).

The process of metacognition involves learners constantly iterating in a cycle of self-reflection. To identify learning and growth, this must be captured in a format that can be shared and reflected upon throughout and on completion of the DT project, for example, through a portfolio, blog, diary, or learning journal, which can be used as a record of their personalised learning journey. The goal is not to master a topic but to gain enduring competencies and dispositions. Continuous self-evaluation, reflection, and identifying areas for improvement are critical steps in a learner’s learning journey (Hattie, 2008).

“Learners are engaged by controlling their learning within a social context, where they have opportunities for collaborative discourse and opportunities to self-reflect” (Black & Wiliam, 2010).

Allowing learners to share and gather feedback throughout the project provides them with an overview of their learning journey that can be shared in the final presentation, which can take the format of a talk, lecture, slideshow, presentation board, movie, or audio file, which is shared with the class, other learners, parents, faculty, community, or local organisations. This audience then acts as a ‘*focus group’* and gives feedback, highlights observations, asks questions, shares ideas, and offers important insights for learning and motivation (Black & Wiliam, 2010). Throughout the process, learners discover knowledge for themselves through social engagement and feedback, allowing them to refine their work and talk about their learning journey with others, thus helping learners with their self-discovery of strengths and weaknesses (Rosenshine, 2012). This is based on the idea that the assessment process is conducted ‘*for learning’* and not ‘*of learning’* (Black & Wiliam, 2010). The DT process can develop learners’ metacognition (Kolodner et al., 2003; Salmon, 2010) by planning, organising, and taking ownership of their learning.

“design thinking is defined as a kind of skill framed by metacognitive phases of production and investigation, engaging a person in opportunities to perceive, visualise ideas from imagination, experiment, create and prototype… gather feedback, and redesign.” (Gözen, 2016, p.2)

However, this has led to some criticising DT and claiming that it leads to incremental thinking due to iterative feedback, mostly from peers (Norman & Verganti, 2014). It is still impossible to establish causal relations between metacognitive instruction, improvement in metacognitive competencies, and learning outcomes (Muijs et al., 2014, p.240). The importance of this, combined with the dearth of research available, prompted me to question if learners feel that DTS help develop their metacognition. Therefore, as part of this research, a group of learners, in addition to analysing their self-reflecting eportfolios (SRE) and semi-structured interviews, will perform a pre-and post-Metacognitive Awareness Inventory (MIA) to capture any perceived increase in their metacognitive ability.

2.5 Identifying gaps in the literature

The literature identified a critical need for learners to possess digital competencies to thrive in the future and a host of other MC currently not prioritised in Scottish curriculum and assessment. Several studies recognised DT as an effective practical pedagogical process that promotes the development of MC (Noweski et al., 2012; Stork, 2020; N. Wright et al., 2018) in learners, for example, creativity (Rauth et al., 2010; Rumahlatu et al., 2021), and problem-solving (Chin et al., 2019; Gözen, 2016). However, the question is, to what extent are the top twenty essential MC required by learners developed through a DT process?

With the decline in digital computing in Scotland, it is essential that learners are motivated, engaged, and challenged in this area. Several studies have identified DT as an engaging process (N. Anderson, 2012; Atchia, 2021; Doppelt et al., 2008) for learners; however, only two studies focussed on the development of digital competencies using a DT framework (Haller-Seeber et al., 2020; Tosca & Ejsing-Duun, 2017). These examined the process of introducing robots to learners (Haller-Seeber et al., 2020) and how DT can assist educators and learners when exploring the unknown (Tosca & Ejsing-Duun, 2017). As an aside, I would question if both '*digital DT'* studies were implemented using a DT pedagogy as they had no '*real-world'* problem to solve, and learners were guided towards an '*expected*' outcome.

Although a body of research has emerged in the last ten years to support the claim that DT provides an effective pedagogical framework, as an educator, I am left with various unanswered questions: Can I use DDTS to develop digital technology competencies in learners? Do learners find a DDTS motivating, engaging, and challenging? How many of the essential MCs can the DT process potentially develop? How do learners feel about self-assessment and peer assessment? Does immersion in a DDTS develop metacognition in learners? What are the practical implications of implementing DDTS in a school; the benefits and barriers of developing such an approach?

Although the advantages of constructivist learning are well documented (Gunduz & Hursen, 2015; Krahenbuhl, 2016; Olusegun, 2015), the practical implications for implementation are limited to one DT empirical case study focused on transforming constructivist learning into action (Scheer et al., 2012). There is currently no research in a school setting underpinned by a SC theoretical framework that I have found from a literature search.

It is important to address the correlation between SC as a learning theory and DT as a practical pedagogical model for implementation and the impact on educators and learners. No research exists examining MC development in learners or the benefits and barriers of implementing a DDTS studio in a school.

2.6 Chapter summary

Analysis of the literature identified a crucial need for learners to possess digital competencies to thrive in the future, with a host of other competencies currently not prioritised in Scottish education. The literature provided data for identifying, developing, and implementing a MC framework encompassing the future competencies required from learners. The use of SC as an effective learning theory was established, and literature was critically examined to identify and categorise SC's tenets, which were then used to underpin and frame this research. Lastly, the use of DT as a practical pedagogical implementation model to deliver SC principles was determined. The gaps in the literature were also discussed. The following chapter will focus on the method and methodology employed throughout this study.

Chapter 3. **Methodology and methods**

3.1 Chapter overview

This chapter discusses the RQ and objectives, which will help explain the methodology and research design decisions. It further presents a synopsis of the research design, the study context, and the population and, as such, establishes the case for the chosen methodology. Concerning the study's design, the rationale for adopting a mixed methods research (MMR) case study approach is examined, as is the collection, analysis, and ethical consideration of using qualitative and quantitative methods to gather and analyse data. I acknowledge my position as an insider researcher and the need for reflexivity, and the chapter concludes with a summary.

3.2 Introduction

The methodology of this research was selected based on the research context, objectives, and questions together with the research paradigm. I adopted an interpretative approach with a constructivist perspective in investigating the use of DDTS in a school environment as a case study. The case study research strategy will be created using a concurrent mixed methods approach, a mixture of quantitative and qualitative research methods used simultaneously. I intend to capture the perceptions and experiences of five groups of educators and learners each immersed in a two-week DDTS during the academic session 2018-19. My overarching RQ is, ‘What do learners and educators perceive as the benefits and barriers of implementing a digital design thinking studio?’ Table 9 captures the overview of this study’s research design.

Table 9 - Overview of research design

<table>
<tr><th>Epistemology</th><td colspan="6">Constructivist - individual constructions of reality</td></tr>
<tr><th>Ontology</th><td colspan="6">Subjective - individual consciousness and multiple meanings</td></tr>
<tr><th>Theoretical perspective</th><td colspan="6">Social constructivism</td></tr>
<tr><th>Research approach</th><td colspan="6">Inductive</td></tr>
<tr><th>Methodology</th><td colspan="6">Interpretivist/Constructivist</td></tr>
<tr><th>Methodological design</th><td colspan="6">Interpretive perspective - single case study design using both qualitative and quantitative data (mixed-methods)</td></tr>
<tr><th>Research methods</th><td colspan="3">Case study</td><td colspan="3">Document review</td></tr>
<tr><th>Research tools</th><td>Semi-structured interviews</td><td>MIA questionnaire</td><td>Meta-competencies survey</td><td>Artefacts photographs video</td><td>Self-reflecting eportfolio</td><td>Observations</td></tr>
<tr><th>Underpinning constructs</th><td colspan="6">Social constructivism (Vygotsky, 1978)
Design Thinking Process
Curriculum for Excellence – four capacities
Meta-competencies framework</td></tr>
</table>

Adapted from Crotty, 1998, p.4 and Passey, 2020, p.103

3.3 Ontology and epistemology

Methodological approaches should correlate to ontological and epistemological positions. Gillham (2000) highlights that good quality research comes from the researcher’s ability to be cognisant of how they relate to different theoretical approaches.

“in our profession, our epistemological views dictate our pedagogic views.” (Hein, 1991, p.2)

The RQ should guide the methodological approach and research design; the main RQ raised in this study explores participants’ attitudes, experiences, and perceptions in delivering DT in a school setting. This RQ required me to explore these perspectives in the context of teaching and learning. Traditional objective methods used by an experimental researcher would not provide the insight needed to understand ”real-life phenomena” and the “real-world” values of study participants (Lincoln & Guba, 2013).

Kivunja and Kuyini (2017), in their paper ‘*Understanding and Applying Research Paradigms in Educational Contexts’* are concerned with individual constructions of reality and that all “behaviour and data are socially situated” (cited in Cohen et al., 2018, p.288); therefore, the entire context surrounding the phenomenon being studied needs to be considered. My epistemological belief is constructivist, and the overall research approach is underpinned by constructivist epistemology, which relies on “participants views of the situation being studied” (Creswell, 2014, p.37). In this paradigm, there is no single truth but multiple realities that are socially situated and interpreted by the participants, sometimes involving contradictory interpretations (Cohen et al., 2018).

The ontological stance of this research is interpretive (Lukenchuk, 2013, p.66), often related to a subjectivist position, concerned with the interpretation that individual consciousness brings, where the world exists, but people construe it in different ways. Participants are “anticipatory, meaning-making beings who actively construct their meanings of situations” (Cohen et al., 2018, p.288). This research aims to make sense of others’ meanings of the phenomenon being studied. Therefore, it is crucial to discover how the participants interpret the phenomenon in question.

3.4 Mixed-methods

Using multiple methods to collect and analyse data is encouraged and found to be mutually informative in case study research, providing a more synergistic and comprehensive view of the phenomenon (Yin, 2014). Having a clear RQ when using a case study helps guide the research on two fronts (Yin, 2014). Firstly, it helps define the boundaries of the case and ensure that the case study stays focused and feasible (Creswell, 2014; Jack & Baxter, 2008; Yin, 2014). Secondly, a straightforward RQ also helps guide the researcher to the most suitable sources of evidence and the appropriate methods to collect this evidence (Yin, 2014). The RQ guided the selection of more than one source of evidence, leading to various methods to generate and analyse data. MMR research is defined by Creswell (2014) as an approach to research "in which the investigator gathers both quantitative and qualitative data, integrates the two, and then draws interpretations based on the combined strengths of both sets of data to understand research problems" (p.2). I felt that mixed-method research would be the most useful in addressing my RQ fully.

According to Creswell (2014), the use of MMR provides breadth and depth of understanding, which can be challenging to achieve if only one method is used in isolation. Although the breadth of evidence may be achieved with quantitative methods, qualitative methods enable researchers to gain richer insights into individuals' perspectives (Coolican, 2009). Therefore, one source of evidence can be used to reinforce, verify, and add validity to the other (Stake, 1995; Yin, 2014). This study employs quantitative and qualitative methods to strengthen the data generated from each method and provide 'an array of evidence' (Yin, 2014). In keeping with the interpretive and constructivist methodological approach taken in this study, it enabled multiple lenses to be used to gain insight into the use of DDTS in education.

The research questions informed the methodology, drawing from a constructivist (interpretative) approach. Although qualitative research methods have conventionally been affiliated with interpretivism, quantitative methods and the ability to use multiple lenses to investigate phenomena have become valued (Gillham, 2000). Therefore, to meet the objectives of this study, multiple methods were required to enable experiences and perceptions to be objectively measured, analyse the thoughts and attitudes towards DDTS, and understand learners' and educators' perspectives on DDTS. A mixed-methods case study approach enabled me to investigate attitudes and perspectives using multiple lenses and understand the insights concerning participation in a DDTS.

Although interpretative, data analysis uses qualitative and quantitative data (mixed-methods), e.g., semi-structured interviews, MIA pre- and post-questionnaires, surveys, artefacts, and observation. The use of mixed-methods research (MMR) and the collection of quantitative data (survey) could be seen, by some, to be out of alignment with the underlying theoretical perspective of this study. However, the survey seeks to collect data unique to each participant and their personal views. It would have proved challenging to elicit these data through purely qualitative means. Therefore, it adopts a convergent parallel MMR (Creswell, 2014), which collects and merges the quantitative and qualitative data at the same time to '*provide a comprehensive analysis of the research problem'* (Creswell, 2014, p.44).

3.5 Characteristics of a case study

A case study is the methodological approach employed to study this phenomenon, aligning with an interpretive and SC stance. Case studies orientate toward an interpretive epistemological stance (Yin, 2014) and remain ‘true to the moral imperatives of constructivism’ (Lincoln & Guba, 2013, p.80) as it facilitates thick descriptions of the phenomenon and participants in a natural, real-world context (Geertz & Geertz, 1973) with “real people in real situations” (Robson, 2002, p.178). Case study rejects the idea of a single reality; instead, there are multiple realities, including the researcher’s views (Yin, 2014). By carrying out an in-depth investigation of a specific, real-life ‘project, policy, institution, program or system’ (Simons, 2009, p.9) from multiple perspectives, it allows you to catch its “complexity and uniqueness” (Simons, 2009, p.21). Yin (2014) observes that the case study facilitates ‘direct observation and interviews with participants.

Utilising a case study facilitates MMR of data collection to probe the phenomenon and explain, describe, illustrate, and enlighten it fully (Yin, 2014). This allows the gathering of multiple forms of evidence while expanding on knowledge and theory (Bassey, 1999; Cohen et al., 2018; Jack & Baxter, 2008; Tellis, 1997; Yin, 2014) and provides detailed and in-depth analysis to “inform decision making by policymakers, practitioners and theorists” (Bassey, 1999, p.20). The use of MMR aligns with a case study as it allows the creation of robust evidence within a bounded study (Yin, 2014, Creswell, 2014) with a detailed examination of a small sample (Blaxter et al., 2010) to allow for a more productive, more profound analysis of the phenomenon.

Alternatives to adopting a case study approach were considered. Firstly, action research was decided against because although it is practice-based and its main aim is to improve practice (Elliott, 1991), it involved self-reflexive and collaborative participants who were not the focus of this study. Another discounted approach was using an experiment, as the study was neither looking to address the idea of causality nor requiring scientific credibility or precision (Denscombe, 2014). Choosing a controlled trial did not resonate with the epistemological and ontological stance of the research.

Yin argues that a single case study is often used where time and resources must be considered, such as when a researcher is undertaking a study independently, such as this one. With other case studies, instrumental and intrinsic case studies are described (Stake, 1995); the intrinsic case study is considered when there is not a specific question but an intrinsic interest in a particular case. In contrast, the instrumental case study is guided by a specific question. Swanborn (2010) distinguishes a comprehensive and intensive approach, with the former referring to the study of many instances or a large population. Alternatively, an intensive approach focuses on an in-depth study of one instance within its context.

Since this research is a specific inquiry into the use of DDTS within one single school environment, this case study relates to the case study definitions provided by Stake (1995), Swanborn (2010) and Yin (2014). Therefore, this case study can be defined as a single, intensive, instrumental case study of a group of learners and educators working within one school. It focuses only on those learners and educators who have experience with DDTS.

General issues with case studies

Case studies have been acknowledged as contributing to knowledge within the social sciences, but, in the past, it has been suggested they are surviving ‘in a curious methodological limbo’. They do not correlate with the conventional rules of scientific inquiry (Gerring, 2007, p.7). Case studies have been regarded as ‘*soft*’ research. It has been claimed that there are limitations to the transferability of case study findings and the ability to generalise from a single case study (Yin, 2014). However, their use within the study of education is particularly suited to this complex environment (Yin, 2014). Single case studies can be valued and appreciated for their uniqueness and rich contribution to knowledge (Lincoln & Guba, 2013).

With this study, it is anticipated that readers, in the form of other educators, will identify with participants’ attitudes to DDTS and their ability to effectively implement it within their practice. Even though this study used a single case study approach instead of multiple cases, the robust methods used to create and analyse evidence could be replicated within another educational environment. From this case study, it is expected that the insights provided from this case might be transferable to other education environments. In keeping with research supported by a constructivist framework, transferability replaces generalisability (Lincoln & Guba, 2013).

3.6 Context of the study

With computing uptake dwindling in my 3-18-year-age school and the early realisation of the critical need for learners to have the digital computing competencies required for the future, I came up with a ‘*digital vision*’ in 2012 to enhance learners’ digital attributes. There were three main aspirations:

1) facilitate the use of a personal digital device for every learner and educator (Bring Your Own Device – BYOD - 1-2-1)

2) create a virtual learning environment accessible 24/7 to the school community

3) develop all educators with effective digital pedagogy to embed digital tools in all areas of the CfE curriculum

The school was the first in Scotland to achieve BYOD - 1-2-1 in the primary and secondary sectors in 2013. As '*Head of eLearning and Professional Development',* I was asked to speak at various national events, shaping the digital journey of learning establishments, nationally and internationally. The school received various accolades culminating in being the first primary school in Scotland to win the Digital Schools Award. The Secondary School was the first in the UK and Ireland to win a prestigious national award (see Figure 29).

Figure 29 - The first secondary school in the UK and Ireland to be named a 'digital school'

Source: FutureScot[32]

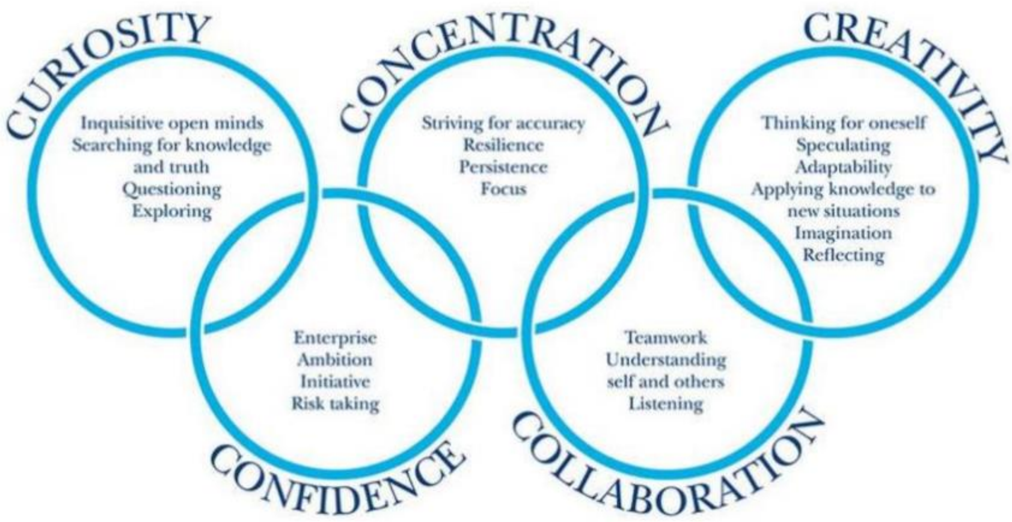
Various quality assurance and key performance indicators were studied during the '*digital projects'* three-year implementation phase (2013-2016). During that time, there were some highlights; however, despite the prominence and daily use of digital devices, computing uptake was still low. The digital impact on learners very much depends on individual educators' self-efficacy. The use of personal devices did not facilitate the development of MC and the examination

[32] FutureScot - https://futurescot.com/kelvinside-first-digital-secondary/

years in senior school were reticent to any form of digital adoption due to their focus on examination results.

Realising that digital computing was not the only critical MC essential for learners, I started the delivery of a new project called '*The 5C's*' (5 competencies), which was another whole school initiative focussing on the development of Creativity, Curiosity, Collaboration, Communication and Concentration (see Figure 30); a collection of competencies collating various attributes required by learners in the future.

Figure 30 – Five competencies - 5C's



As well as continual research, I also enrolled in a course from Harvard University entitled '*Leaders of Learning'*, which provided insight into the future of education and introduced me to DT*.* Following this, I enrolled in a '*DT*' course for educators at MIT and visited Boston and spoke with Michael Resnick, associate director of the Media Lab at MIT. The opportunities that DT could provide learners were exciting. This led to the establishment of the first DT summer school in 2017, where learners could join a DT studio on the themes of 'Bio fashion' or 'Swarm Robotics'. Throughout 2017 and 2018, I ran an extra-curricular '*Makers Club'* for learners in a DTS format. This DTS programme was extended in the summer of 2018 to two weeks on the themes of 'Mixed Reality Gaming' and 'Battlebotics'.

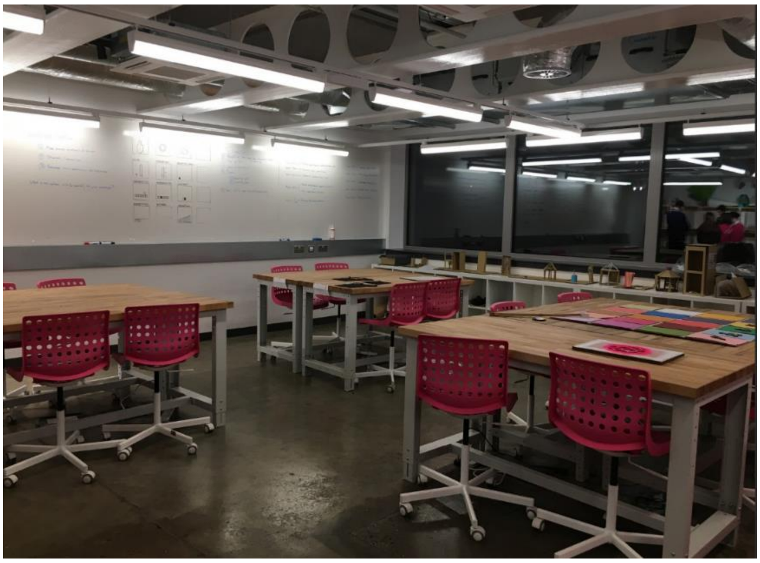
These ventures excited me about the potential of DTS as a model for future pedagogical and curriculum development. The potential for developing digital skills and other MC in an authentic, exciting way resulted in integrating DDTS into the normal school curriculum in the 2018-2019 school session instead of another summer extra-curricular venture. Reflection of the summer school initiative led to several iterations and identification of models to implement during term-time to incorporate digital computing into real-world scenarios while developing MC using a structured DT approach that educators could follow and adopt. This resulted in creating a '*new*' DT studio[33] that would house groups of learners for two weeks at a time while they immersed themselves in a DT project underpinned using digital tools. This would involve learners having two weeks out of their '*normal curriculum'* to immerse themselves in a digital DT immersion studioSo, in the session 2018-2019, learners were invited to attend a two-week DDTS instead of regular timetabled classes in a make-shift innovation laboratory (Figure 31). This is where the data were collected for the study. However, a purpose-built facility housing the UK's first *'School of Innovation'* was completed by August 2019.In 2018, while I was in phase one of my PhD studies at Lancaster University, I recognised the gap in research linked to the current project. I thought it prudent to directly capture participants' thoughts, perceptions, and experiences following their immersion studio. Therefore, I

[33] This was a previously under-utilised space in the school that was redesigned and reconfigured with all new equipment to house a temporary DTS.

asked and received ethical permission from Lancaster University to carry out the research.

The work underpinning this research intended to capture the experiences and perceptions of five groups of learners and educators immersed throughout the academic year in a senior secondary school in a two-week DDTS (Figure 31). Each scenario followed a DT approach described in Section 2.4, which provided consistency in the underlying pedagogical principles. However, there was difficulty in ensuring absolute comparability as not only did each scenario focus on a different theme or wicked question, but there were different participants, including coaches, educators and learners.

Figure 31 - Temporary Digital Design Thinking Studio



The DDTS consisted of a large open space with ten waist-height desks and twenty bar stools, all with wheels for easy mobility (Figure 31), providing learners with the option of sitting or standing. The room had a sink area, a photo-booth area, a whiteboard area and a resources area. The resources area consisted of twenty MS Windows laptops and chargers with various CAD software installed, e.g. Rhino and Fusion 360. It also housed three 3D printers, a laser cutter, various hand tools, and electronic equipment, including wires, connectors, LED (light emitting diodes) and programmable Arduinos. There was also a variety of cardboard, paper, cards, plasticine, pipe cleaners, glue guns, etc. for students to choose to use as needed.

Using SC as a lens to examine the benefits and barriers of such an approach, five groups of learners and educators were removed from their normal classroom setting and immersed in a two-week DDTS (Table 10). Each group was given a different real-world ’wicked problem’ designed to encourage empathy, debate, and discussion (Appendix 10), which would provide an open-ended challenge.

This research was a unique opportunistic phenomenon and intended to capture learners’ and educators’ experiences using this novel approach for learning and critically analyse the advantages and difficulties of adopting such an approach.

3.7 Study site and population

As discussed previously, a case study approach was adopted to investigate participants’ attitudes and perspectives concerning the use of DDTS in a school setting. Yin (2014) argues that the case should be clearly defined from the onset of a study to avoid ambiguity and ensure correlation. Defining the study site adds to its rigour by enabling others to relate to the context and determine if the study could be replicated in their context (Lincoln & Guba, 2013). The school will remain anonymous to protect the identity of the educators and learners.

This study was carried out in an all-through school in Scotland, UK. At the time of data collection, the school had 598 learners from age three through to eighteen years and seventy-six educators. The school followed the Scottish CfE[34] curriculum and the Scottish Qualifications Authority[35] (SQA) examination diet. The school developed all curriculum areas until Senior 3, when learners choose the eight subjects they wish to focus on for the National 5 examinations the following year (Senior 4). This is followed by selecting up to five subjects at the Higher level (Senior 5). If learners stay on for Senior 6, they choose a combination of two or three Advanced Highers and Highers.

The curriculum is taught in a traditional 8-period day:

Period 1:	09:00 – 09:45
Period 2:	09:45 – 10:25
Period 3:	10:25 – 11:05
Break	11:05 – 11:25
Period 4:	11:25 – 12:05
Period 5:	12:05 – 12:45
Lunch	12:45 – 13:45
Period 6:	13:45 – 14:25
Period 7:	14:25 – 15:05
Period 8:	15:05 - 15:45

3.8 Study sample

The target sample for this study was educators and learners who had participated in the inaugural first year of DDTS (2018-2019). During this first trial year, the DDTS would be populated by learners from Senior 1 (age twelve or

[34] Scottish Curriculum for excellence - https://education.gov.scot/education-scotland/scottish-education-system/policy-for-scottish-education/policy-drivers/cfe-building-from-the-statement-appendix-incl-btc1-5/what-is-curriculum-for-excellence

[35] Scottish Qualifications Authority - https://www.sqa.org.uk/sqa/70972.html

thirteen years) and Senior 2 (age thirteen or fourteen years). These age groups were deemed the most appropriate because the older years were focused on the examination curriculum. Each cohort was split into four groups of approximately sixteen learners. There were four DDTS sessions with Senior 1 learners and four sessions with Senior 2; details of these sessions are shown in Table 10.

Table 10 - Overview of DDTS sessions and participant numbers

DDTS Session	Year group	Number of learners	Number of groups	Lead Coach	Number of unique rotating educators
#1 Oct 2018 observed	Senior 1	17	7	Coach A	9
#2 Nov 2018 observed	Senior 1	16	6	Coach A	6
#3 Nov 2018 observed	Senior 1	15	7	Coach B	3
#4 Dec 2018	Senior 1	16	5	Coach B	4
#5 Jan 2019 observed	Senior 2	16	6	Coach C	2
#6 Feb 2019 MAI survey	Senior 2	13	5	Coach D	1
#7 Mar 2019 observed	Senior 2	17	7	Coach D	0
#8 Mar 2019	Senior 2	17	6	Coach D	0
Total Participants		131	49		25
Included in MAI		13 (17%)			
Included in the MC survey		113 (86%)			21 (84%)
Interviewed		88 (67%)	32 (one excluded)		7 (28%)

**Green highlighted rows indicated the sesions that were observed and captured.*

The educators involved were the subject specialists that the learners would have been with, for example, a mathematics teacher or a geography teacher. The educator would assist the externally-employed DT coach for two reasons: firstly, to ensure a suitable class ratio, and secondly, to cascade the DT principles and concepts to educators. During the DDTS, educators were referred to as coaches. The inclusion criteria for the study population were limited to any educators and learners who had experienced the DDTS, and in total, there were:

Quantitative:	MC survey: learners (*n* =115)	
	MAI: learners (*n* =13)	
Qualitative:	educators (*n* =7)	learners (*n* =32 groups – 88 individuals)

The educators and learners had no experience of the DTS before the intervention.

In line with SC, learners were interviewed in their collaborative grouping to elicit more co-constructed knowledge and encourage conversation and discussion around their experiences. One learner declined consent, and his group interview was removed from the data analysis. This left thirty-two groups for interview.

3.9 Sample profile

A total of 115 learners and 21 educators responded to the online survey, of which eighty-eight learners and seven educators agreed to participate in the semi-structured interviews (

Table 11). From this sample, one studio session was captured for the Metacognitive Awareness Inventory (MAI) questionnaire and analysis of their SRE.

Table 11 - Sample demographic profile of the survey participants

Independent Variable		MAI learners *n* =13	MC survey learners *n* = 115	Interviews learners *n* = 88	Interviews educators *n* =7
Gender	Female	6	54	42	4
	Male	7	61	46	3
	Other				
	Total	**13**	**115**	**88**	**7**
Age (years)	12-13		67	49	
	14-15	13	48	39	
	20-40				5
	40-65				2
	Total	**13**	**115**	**88**	**7**
Previous experience of DDTS	Yes				
	No	13	115	88	7
	Unsure				
	Total	**13**	**115**	**88**	**7**

3.10 Recruitment

The recruitment of survey participants took place over nine months between September 2018 and May 2019.

Educators

Educators were aware of the studio through whole educators' meetings and discussions on its development and internal logistics. Once educators were timetabled into a DDTS two-week block, an email asked them to participate in the research study. It included an information sheet (see Appendix 3) and a consent form (see Appendix 4). They were to return the consent form signed and dated if they were interested in participating.

Learners

An overview of the research was shared with the learners during their class time prior to the DDTS. The RQs were discussed, and learners were given an information sheet (see Appendix 6) and a consent form (see Appendix 7) to take away and share with their parents/guardians. If they were interested in participating, they would return the form to me signed and dated.

No incentives were offered for participation, and a maximum of three reminders were given. After this time, if the form was not completed, it was assumed that the participant had decided not to partake in the study.

3.11 Ethical considerations

The advice was sought from Lancaster University Research Ethics Committee regarding the conditions for ethics approval for this study. Since the research took place in a school during participants' working days, it was necessary to gain approval from the school's Rector as the main gatekeeper. The Rector understood the rationale for the study and fully supported the research; he was happy for all educators and learners who wanted to participate to do so; he was keen to have empirical research to ascertain the benefits and barriers to this phenomenon.

Given the age of the participants, careful consideration was given to ensure that ethical principles were applied at all stages of the research, from the planning and design of the study to the implementation and onward dissemination of the results (Oliver, 2010; Punch & Oancea, 2014). In early secondary school, the learners are young; therefore, parental consent was obtained in line with General Data Protection Regulations (GDPR, 2018). The learners were interviewed in their collaborative DDTS teams of approximately three to reduce anxiety or concerns and elicit group thoughts and feedback. I needed to have the confidence, trust and respect of learners and educators. Therefore, participants were informed that it was purely optional; I also shared a clear statement of my research intentions and allowed questions before obtaining consent.

3.11.1 Informed consent - Educators

Educator participants were fully briefed before participating in the interviews using departmental meeting time to initially share the purpose of the research study. Those educators interested in taking part took a participation information sheet (see Appendix 3) and a consent form (see Appendix 4) away to read in advance, which consisted of a series of statements against which participants were asked to agree with each statement. These statements were based on critical information from the participant information sheet, including how confidentiality would be maintained and data stored. A statement to check that participants agreed to the interview to be audio recorded was also included. Participants were asked to read the consent form before the interview day. This ensured that they had the opportunity to read the information, contact the researcher to ask any further questions and decide whether they wanted to proceed with their participation in the interview. On the day of the interview, the participants were given another copy of the interview participant information sheet and the consent form and allowed time to re-read this, if required, or ask any questions related to the study. They were asked for their approval to record the session on my mobile telephone, and the safeguards in place were explained.

At the end of the interview, the researcher invited participants to ask any questions about the study. A copy of the participant information sheet (see Appendix 3) was given away to participants to remind them of the purpose of the study, how their data would be stored, and whom to contact if there were any questions or concerns about the study. This information was also reiterated verbally.

3.11.2 Informed consent – Learners

Learners followed a similar format to educators; however, they were asked to take the information home and share it with their parent/guardian. Although, according to GDPR, they were at the legal age of consent, it was deemed prudent to have this safeguard in place.

3.11.3 Confidentiality

The University Research Ethics Committee approved all the software programs used for collecting and storing data. Access to these programs was two-factor-authentication password-protected. All associated electronic files were securely stored in a designated location to store research data within a system hosted by Lancaster University. Access to this storage area was also two-factor-authentication password-protected. As stipulated by the University's research ethics protocol, all data associated with this study will be destroyed ten years after completing this PhD thesis.

As recruitment for this study was internal, a password-protected university email account was used for this correspondence, and all correspondence was treated as confidential. The participant information sheet was used to explain and reassure participants that this confidentiality would be ensured (British Educational Research Association (BERA), 2019).

Once the interviews and survey were complete, the data were transferred to NVivo12 (2018) software program as an approved qualitative data management program. All data were anonymised using a participant identification number. Where participants were later involved in interviews, the same identification number was used to link participants' interview transcripts, survey data, artefacts and any evidence or notes associated with these data. Throughout the reporting of results from the survey data, no data could be identified as belonging to a participant.

Inviting the participants to identify a time and location for the interview ensured that the interview was convenient for the participant. At a time, they would be able to negotiate away from their class/work responsibilities. Participants requested for the interviews to take place within the school campus. For the few interviews in delegated areas, I ensured the space was booked for the meeting. However, most interviews were carried out in my office space. I ensured a '*do not disturb'* sign was on the door to avoid unnecessary interruptions.

The data collected from the interviews were only accessible to me, the research supervisors, and research monitoring authorities, who may have required access to the data. Strategies to ensure anonymity are vital in any piece of research to ensure that participants cannot be identified or traced (Cohen et al., 2018). Where educators worked in the same or nearby departments, their involvement in the study was not shared with other participants. Learners were asked not to discuss the interview or each other's answers following the interview. In transcribing, the interviewee's anonymity was maintained.

All data were anonymised using an identification number linking the participants' interview transcript to their survey data and any field notes associated with these data. After completing an interview, the researcher uploaded the audio file to a password-protected file computer and deleted the original audio recording from the audio recording device. All data were securely stored online with Lancaster University.

3.12 Quantitative data analysis

The quantitative data generated in this study were analysed using the Statistical Package for the Social Sciences software (SPSS, version 26) and Microsoft (MS) Excel. Before exporting the survey data, unique identification numbers were allocated to the responses. This enabled missing data, errors, and outlying scores to be checked before statistical analysis. An SPSS data file was prepared by creating abbreviated labels for each dependent and independent variable. The dependent variables in this study included attitudes to normal school and DDTS.

Two principal quantitative analyses were from the MC survey (n = 115) and the MAI questionnaire (n = 13). Both were administered to participants through Microsoft Forms accessed through a QR (Quick Response) code. The use of mixed factorial analysis of variance (ANOVA) was identified as the most appropriate statistical analysis method for the quantitative data in this study.

3.12.1 The MC Survey

The MC survey data were collected using a Microsoft Form (a copy of the digital form can be found in Appendix 13). Each of the MC was represented, and learners had an option of Normal School or DDTS with a 1-5 Likert scale asking how often they felt they used a particular MC (1 = Never, 2 = Sometimes, 3 = Often, 4 = A Lot, 5 = Always). There has been much debate around the most appropriate statistical methods used with Likert scale data. The main point of contention relates to classifying Likert scale data as ordinal or interval. According to Coolican (2018), the assumption that should be satisfied for using parametric tests are data at the interval level, normally distributed data, independence of measurements, and homogeneity of variance. However, Norman (2010) argues that parametric statistics can be used without normally distributed data. Data generated from a Likert scale can be classified as interval data and robustly analysed with parametric statistics. The responses were given verbal labels centred around a neutral item and were arranged horizontally and coded with consecutive integers that connote more or less evenly spaced graduations (Harpe, 2015). To this end, the data were coded for analysis and the scales were analysed as a group (Harpe, 2015) using a 1-5 Likert scale data: 1 = Never, 2 = Sometimes, 3 = Often, 4 = A Lot, 5 = Always. The outcomes of the two subjects (DDTS versus normal school) were compared using the Wilcoxon–Mann–Whitney two-sample rank-sum test, a nonparametric test designed to evaluate if two measurements from a single group were used are significantly different from each other. The test is a non-parametric alternative to a paired samples t-test and is used to evaluate the influence of intervention. It is suitable for evaluating the data from a repeated-measures design where the prerequisites for a dependent samples t-test are not met. The two-tailed hypothesis results calculated the mean and standard deviation (SD), the *p*-value, the *z*-value, and the effect size (*r*) with a 0.5 significance level.

3.12.2 MAI Questionnaire

The MAI questionnaire (Schraw & Dennison, 1994) is a widely used instrument that consists of fifty-two '*True*' or '*False*' questions (see Appendix 11) categorised by one of the six aspects of MR, for example, planning. The results of surveys were analysed using MS Excel to establish the mean SD and were used to run a pairwise one-tailed t-test, and from this, Cohen's d effect sizes were reported.

3.13 Qualitative data analysis

Face-to-face semi-structured interviews were used immediately following participants' two-week DDTS. In addressing the research objectives associated with this study, it was highlighted that using a survey alone would not have provided the opportunity to gain insight into the benefits and barriers of DDTS, the meanings attached to their attitudes, or their perspectives. Therefore, semi-structured interviews provided a window into participants' perspectives and enabled me to gain greater insight into the phenomenon. In the design of this study, it was felt that it would give rich insight and therefore be more productive to interview learners in their 'teams'. It was felt that this would encourage debate and discussion and ensure no learner felt awkward in a 1-to-1 with an educator.

The audio-recorded interviews were transcribed, and the content was analysed. The selected excerpts were minimally edited, including grammatical mistakes, to balance maintaining the authenticity of the participants' voices and enhancing the reader's understanding of the excerpts (Oliver et al., 2005). Numbers were used that aligned to the collection of other data to protect participants' identities.

3.13.1 Format of the semi-structured interviews

The semi-structured interviews immediately followed the two-week DDTS to capture fresh thoughts, ideas, and perceptions. These took place over nine months throughout the school session 2018-2019. I ensured the physical environment in which interviews would take place was considered to ensure participants felt comfortable discussing their personal experiences (McGrath et al., 2019). Participants were offered a choice of venues within the school campus and in the nearby botanical gardens. King et al. (2018) suggest that a public area can often be a more neutral space for an interview and can help encourage a relaxed and informal atmosphere. However, all participants choose various spaces around the school campus. Most educators preferred the interview conducted within a neutral office space, while the learners preferred to be interviewed in my base or the DT studio. Participants needed to identify a setting where they felt comfortable discussing their own experiences to help establish trust and rapport (Davies & Dwyer, 2007).

Before starting the interview, participants were asked if they had read and understood the participant information sheet (see Appendix 3, Appendix 6) and were invited to ask any questions for clarification. Participants completed a written consent form (see Appendix 4, Appendix 7), and I requested permission to audio record the interview with my iPhone. An interview structure (see Appendix 5, Appendix 8) was utilised to allow a focused yet open approach to data generation whilst ensuring that the discussion aligned with the study objectives. Ryan et al. (2009) suggest that the interview commences with a question that participants would feel happy answering. As participants opened with their experiences, opportunities were taken by the researcher to ask more probing questions to encourage participants to elaborate on their responses. These probing questions included: “Can you tell me some more about that?” or “Can you give me an example?” These probing questions demonstrated active listening and helped gain more in-depth insight into perceptions and experiences (King et al., 2018). A maximum of thirty minutes was allocated to each interview, mindful of participants' class/work priorities.

3.13.2 Thematic Analysis

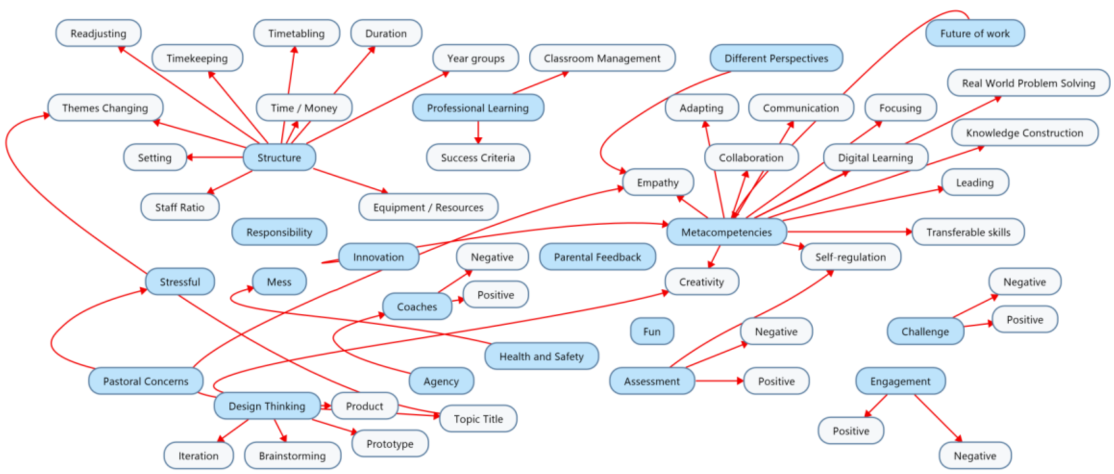
Braun & Clarke (2006) promote the use of thematic analysis, particularly with the use of constructionist paradigms within the social sciences and argue it is a useful method for 'identifying, analysing and reporting patterns (themes) within the data' (2006, p.6) and that a thematic approach that is rigorous can yield an 'insightful analysis that answers particular research questions' (Braun & Clarke, 2006, p.28). To ensure a rigorous thematic approach, this research adopted Braun and Clarke's (2006) six phases of thematic analysis (p.35) and the correlating fifteen-point checklist of criteria for good thematic analysis (p.36).

I added reflective comments to help analyse the interview data following the interview. In addition to providing a rich insight into participants' perspectives, the interviews presented opportunities to check and verify information from the observations. I transcribed the audio recordings, read and re-read, which enabled me to become immersed in the data and facilitate thematic analysis. This highlighted patterns within the interview data and the start of patterns emerging.

Transcripts of the interviews were entered into NVivo12 and were manually coded, starting with an iterative and inductive data immersion and interpretation (Liamputtong & Ezzy, 2005). There was substantial interview data to manage, with thirty-nine interviews in total (educator n = 7, learner groups n = 32). This process was efficient and helped code the material, select relevant extracts into themes and then collate these together. Braun and Clarke (2006) assert that using the interview or research questions as the 'themes' are the 'worst examples of thematic analysis' (p.15) because they fail to take account of emergent themes based on a process of induction.

On NVivo, I started the analysis of interview data to begin to generate codes. At the start, the coding process was guided by the study's conceptual framework, ensuring these were aligned with the research questions. More nodes and sub-nodes were established by working through the interview data, giving further insight into the participants' perceptions. The next stage was the theme development which involved reading and rereading coded nodes on NVivo to identify meaningful larger patterns of meaning (possible themes). This was an iterative process that organically evolved. These themes were reviewed, categorised, and labelled until data saturation and no new themes surfaced. The preliminary analysis came up with nineteen original nodes with their sub-nodes. For example, the node 'Structure' had eight sub-nodes, as illustrated in Figure 32 and Table 12.

Figure 32 - Preliminary nodes and sub-nodes



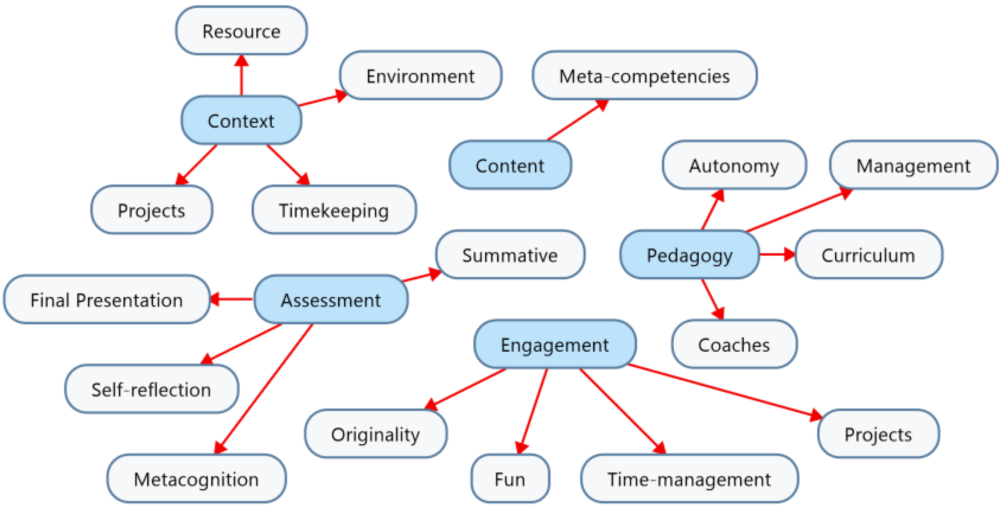
For ease of reference, Figure 32 is displayed in table format (Table 12) with the nodes in alphabetical order in the first column and the sub-nodes in column two.

Table 12 – Table representing the preliminary nodes and sub-nodes depicted in Figure 32

Nodes	Sub Nodes
Agency	
Assessment	self-regulation, negative, positive
Challenge	positive, negative
Coaches	positive, negative
Design Thinking	product, prototype, brainstorming, iteration, topic title
Different perspectives	empathy
Engagement	positive, negative
Fun	
Future of work	
Health and safety	
Innovation	
Mess	
Meta-competencies	empathy, adapting, collaboration, communication, self-regulation, leading, focusing, digital learning, knowledge construction, real-world problem-solving
Parental feedback	
Pastoral concerns	
Professional learning	classroom management, success criteria
Responsibility	
Stressful	
Structure	staff ratio, setting, themes changing, readjusting, timekeeping, timetabling, duration, time/money, year group, equipment/resources

NVivo12 automatically counts the number of times sources refer to each node and sub-node. For example, the nodes most referred to were 'innovation' (62 times) and ‘digital learning’ (65 times), and the least referred to were ‘pastoral concerns’ (2 times) and ‘success criteria’ (2 times). These nineteen nodes were recalibrated, selecting the most referenced, relevant, and aggregated where overlap occurred. Ongoing analysis facilitated renaming and refining each theme's specifics, which helped generate clear definitions and names for each theme. This created seventeen themes categorised using the SC theoretical framework underpinning the study: Context, Content, Pedagogy, Engagement, and Assessment (Figure 33).

Figure 33 - Final thematic analysis structure



The themes were checked and double-checked manually by selecting samples and blind recoding to improve the findings' credibility, trustworthiness, and validity. The process was repeated if there was cause for concern with a sample. My familiarity with the content of the transcripts meant the manual re-coding check was quicker than it might otherwise have been.

3.14 Reflexivity

Reflexivity as a researcher is essential; Berger (2015) describes reflexivity as "turning off the researcher lens back onto oneself to recognize and take responsibility for one's own situatedness within the research and the effect that it may have on the setting and people being studied, questions being asked, data being collected and its interpretation" (p.220). This requires me to reflect on my positioning in the study and the possible effect on the research process and outcomes (Yin, 2014). As this study was carried out within a setting where I knew all the participants, I was aware of the need to be reflexive, minimise bias, and ensure rigour.

During the interviews, it was evident that some learners were mindful of my position. They were conscious of how they spoke about others and seemed worried about offending. To promote trust within the interview, I was open and honest with participants, reassuring them that I was impartial and that the interviews would not be shared with anyone, including senior management.

I kept a reflexive diary throughout the study; according to Gillham (2010), the researcher should remain open-minded and move beyond their assumptions, particularly when the context of the study and the topic area are well known. Although reflexive diaries are not usually associated with quantitative research, due to the emphasis on the objective role of the researcher, they can be used in mixed-methods research to document the researcher's thoughts and feelings and decisions made during the research process.

3.15 Overview of methods

The data collected allowed me to investigate and analyse educators' perceptions and learners' experiences. Throughout the study, there were videos, photographs and observations, informal discussions with participants, and the opportunity to share their thoughts through semi-structured interviews. The survey of the MC helped identify which competencies educators and learners perceived to be developed during the sessions. Learners also participated in a pre-and post-MAI questionnaire (see Appendix 11) to identify if they perceived any changes in their MR.

This research examined the overarching question: '**What do learners and educators perceive as the benefits and barriers of implementing a digital design thinking studio?'**

This was captured through the following RQs highlighted in

Table 13, alongside the instruments used to capture the evidence.

Table 13 - Alignment of evidence with research questions

	Metacognitive Awareness Inventory Questionnaire	Semi-structured Interviews	Meta-competencies Survey	Observation & artefacts photography images & video	Self-reflection eportfolios
RQ.1 – to what extent are meta-competencies utilised during a digital design thinking studio compared with normal schooling?		x	x	x	
RQ.2 – to what extent do learners think digital design thinking studios develop digital computing competencies?		X		x	
RQ.3 – do learners feel challenged and motivated by this type of learning?		X			x
RQ.4 – how do participants perceive formative assessment practices?		X			x
RQ.5 – to what extent do learners think a digital design thinking studio develops learners' metacognition?	x			x	x

3.16 Project description

Each DTS had a DT specialist with experience in technical, digital, computing, electric, and engineering fields led each two-week session. They were the '*lead coach'* and drove the DT process from beginning to end. The lead coach was not a *'General Teaching Council for Scotland'* (GTCS) qualified educator. This meant that there always needed to be a qualified educator in the room for legal reasons. As learners were removed from their normal curriculum for two weeks, this was managed by having the educators attend the DDTS during the period they should have them. In the DDTS, they were known as coaches (support).

The DDTS, although underpinned by the same messy, iterative process, had a different topic for each group of learners. This was deliberate, so learners would not know what they were doing ahead of time. Each session introduced learners to the DT process and their ‘wicked’ problem. The coaches used a variety of strategies, including class, group, and individual work, to navigate their way through the DT process.

3.17 Chapter summary

This chapter has identified that this study drew from constructivism and interpretivism as underpinning theoretical frameworks. This methodology was guided by the study’s main RQ, which aspired to gain insight into research participants’ perspectives and attitudes toward using a DDTS within a real-life educational context.

This chapter established some additional aspects of the research design by examining the rationale for an MMR case study approach. The study was identified as a single, intensive, instrumental case study of participants working within one school and sought an in-depth understanding of their attitudes and perspectives concerning the use of DDTS. Furthermore, MMR would enable the researcher to meet the study’s objectives and gather a robust array of evidence.

This chapter focused on the collection methods employed in this study to generate qualitative and quantitative data. Focusing on each method used in this study was not to segregate or diminish the strengths and value of each method but instead to demonstrate the rigour applied in the use of each method. Semi-structured interviews were used to generate qualitative data and explore participants' perspectives on using DDTS. This chapter identified that the sample of interview participants drew from those who had participated in the two-week session and had given their agreement to take part in the semi-structured interviews.

An overview of the format of the semi-structured interviews was provided, and ethical considerations concerning informed consent, confidentiality, and ensuring the protection of interview participants were discussed.

Chapter 4. **Findings**

4.1 Chapter overview

This chapter focuses on the results of the MMR data collection and analysis. These results come from data obtained during the DDTS sessions and include observations, photographs, videos, artefacts, semi-structured interviews, MAI questionnaires, and MC surveys. The evidence is analysed, classified, and framed using the tenets from the theoretical framework of SC identified in Chapter 2 Section 2.2, namely: **context, content, pedagogy, engagement,** and **assessment** and are as follows.

4.2 Context

Four major themes emerged from the analysis of the semi-structured interviews:

- Environment
- Timetabling
- Projects
- Resources

4.2.1 Environment

Learners were initially excited by the novelty of using the designated classroom as DDTS which contrasted with their normal classroom environment, “the studio was really good. It was a bit different from what our normal classrooms were; they made it a bit more interesting a bit more exciting for us” (Group 24). Interestingly, they liked the environment, which kept them on task, “I liked that there was an open plan, so you didn’t get as distracted cause you could see what everyone else was doing" (Group 31).

However, as the days progressed, some learners started to feel claustrophobic and commented that they were in the same space with the same people for too long, "I didn't like the fact that you were in one room with the same people every day for two weeks as it got quite intense" (Group 6). This feedback resulted in regular 'walk & talk' breaks being implemented.

4.2.2 Timetabling

Timetabling was a challenging issue, predominately for educators, who felt some learners, between two-week holidays and the two-week studio, were out of class for four consecutive weeks resulting in significant gaps in their knowledge, "getting through your subject when you've missed them for two weeks… had a real impact" (Educator 4). This was felt to impact mathematics and English particularly hard as they "saw them seven periods (a week), they missed quite a lot" (Educator 7). There was a suggestion by several learners and educators to continue with daily mathematics and English classes as usual during the DDTS as this would allow some breaks from the studio and time to reflect but also ensure they did not fall behind.

Some learners were worried about missing lessons and 'falling behind' in their course work resulting in being unprepared for examinations, "it's kind of stressful because we did two weeks of no like maths or English, but there's a maths exam coming up it's hard to get back into maths after two weeks off" (Group 8).

Interestingly, learners did not seem to perceive themselves 'learning' in the DDTS, "In here [DDTS], you don't get any lessons, it's hard to go back right into school after two weeks of no learning, especially because we got tests coming up in December” (Group 8).

4.2.3 Projects

All the sessions had a different ‘*wicked problem*’, direction and coach, which significantly varied learners’ experiences. Some groups did not like the focus of the project they were working on, “(the topic was) something I wouldn’t pick. I would’ve preferred a different topic” (Group 15). One of the largest grievances was the feeling that they had missed a ‘*better’* session that another group had. Most commented on wanting to participate in the AR-focused DDTS.

4.2.4 Resources

The DDTS was well equipped, “everything was on hand; all the tools for whatever was needed was available” (Educator 7), and the equipment was of high specification. Learners were surprised by the number of resources freely available for them to use at any time, “we enjoyed being given the responsibility of getting to use the tools and getting to actually use the stuff. In normal class, you’re limited with what you can use” (Group 27) as the DDTS had everything they could want. Although learners did not always have the time to utilise what they wanted, “unfortunately, we didn’t get to use the 3D printer because of shortage of time” (Group 24).

4.3 Content

In many ways, the DDTS is less concerned with content per se and more interested in optimising and extending learners’ prior competencies through authentic, personalised learning. Therefore, this section examines learners’ perceptions of MC development during the DDTS.

4.3.1 Meta-competencies developed

This section examines how learners perceived crucial MC were developed in a DDTS compared with normal class lessons. This framework is categorised by the new proposed MC framework in Chapter 2 (see Figure 17) and in full in Appendix 2.

In each of the sections that follow, learners (*n* =115) were asked to complete a digital Microsoft Form listing each of the MC and, using a 1-5 Likert scale identify their perception of how often they felt they used that MC in DDTS compared with their normal school setting (described fully in section 3.12.1).

4.3.1.1 Successful Learner

The MC for the Successful Learner are:

- Creativity
- Adapting
- Planning and organising
- Strategy and management
- Critical thinking and problem-solving
- Curiosity

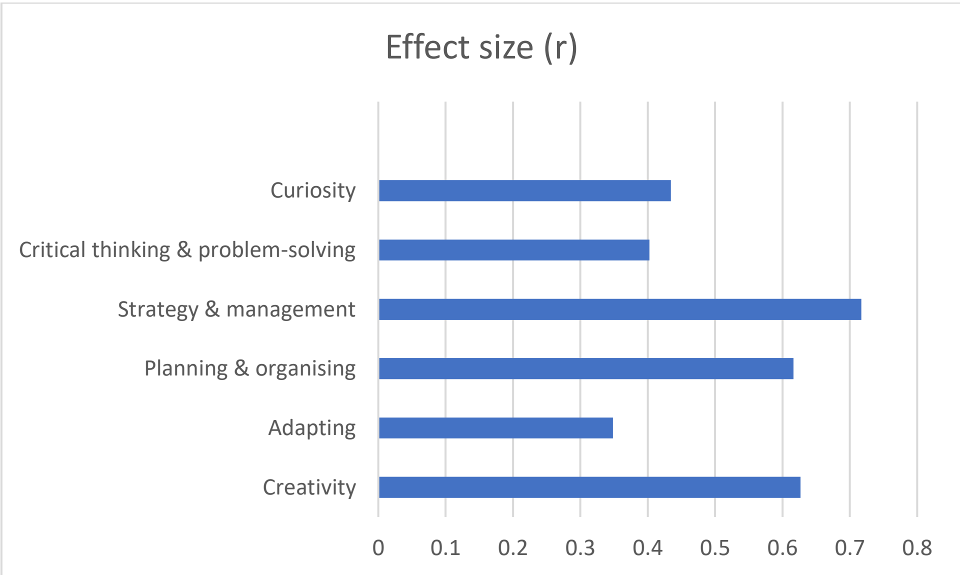
Table 14 captures each MC's mean and standard deviation and then uses a Wilcoxon Signed-rank Test to compare and generate an effect size (r) (see Figure 34).

Table 14 - Successful learners - competency development - normal school versus DDTS

Successful learner	normal school		DDTS		Wilcoxon Signed-rank Test *Two-tailed*				
n=115	mean	SD	mean	SD	mean	SD	z	p	Effect size (r)
Creativity	3.37	1.08	4.46	0.86	1785	224.23	-6.72	<.00001	.6266
Adapting	3.32	0.93	3.83	0.92	1914	236.27	-3.733	.0002	.3481
Planning & organising	2.77	0.67	3.7	0.82	1785	224.23	-6.61	<.00001	.6164
Strategy & management	2.2	0.8	3.45	0.88	2525	290.84	-7.69	<.00001	.7171
Critical thinking & problem-solving	3.14	0.94	3.77	1.06	1540	200.77	-4.3158	<.00001	.4025
Curiosity	3.22	0.85	3.87	1.02	1785	224.23	-4.656	<.00001	.4342

Using criteria of Cohen (1988) for effect size: *.1 = small effect, .3 = medium effect, .5 = large effect*

Figure 34 - Successful Learner - graph of effect size



4.3.1.1.1 Creativity

The Wilcoxon Signed Rank Test (Table 14) revealed a statistically significant positive change in the development of **creativity** in the DDTS compared with the normal class, z = -6.72, p = <.00001, with a large effect size (r = .6266). These results correlated with learners' experiences in the DDTS. Most groups commented on the excitement of having their ideas and thoughts materialise, “We liked how you could express your creativity and use your imagination to make it into something in real life” (Group 11). Learners enjoyed the hands-on approach to bringing their innovative ideas to life, “the thing I love about the studio is because you can get hands-on… I just find you have a lot of freedom; you explore and find your own ideas” (Group 9). Learners felt they could come up with their ideas and then investigate the potential of their ideas, “I liked that we could just let our imagination go and be creative” (Group 4), learning what works and what does not from the process.

Several groups commented on the lack of creativity in their normal classes, “you can be more creative than you can normally be in school because when you’re in normal lessons, you get told what to do, but when you’re here, you can do what you want, you can create stuff” (Group 26). One of the educators highlighted the open-ended creativity of allowing learners to think up ideas for themselves, “the projects get the pupils to think in a different way, you’re trying to look at a problem and think about it creatively, come up with lots of different solutions you could create” (Educator 5).

However, some learners raised concern about their inexperience and their need for guidance and support, so they did not embark on an impossible task, “There’re no wrong ideas, so that’s good, but we need to know when an idea was too big to solve because if it is, we get our hopes up and trying to do that one when actually it’s not possible” (Group 16).

4.3.1.1.2 Adapting

The Wilcoxon Signed Rank Test (see Table 14) revealed a significant change in learners' perceptions of **adaptability** in the DDTS compared with the normal class, z = -3.733, p = .0002, with a medium effect size (r = .3481).

Observations of learners throughout their DDTS highlighted that each session was underpinned by flexibility and adaptability. Learners had to respond and modify their approach in the face of unforeseen circumstances, challenges, and mistakes. Learners felt the studio session involved them overcoming, changing, and modifying their strategies and ideas, "If we did something and it didn't work, then we have to try and backtrack to figure out what wasn't working and then change that… We didn't see mistakes as failures" (Group 27). Learners identified a trial and error approach for much of the session, "We learned to expand on an idea, and if it doesn't work, adapt and try again" (Group 32).

4.3.1.1.3 Planning and organising

The Wilcoxon Signed Rank Test (see Table 14) revealed a statistically significant positive change in the development of **planning and organising** in the DDTS compared with the normal class, z = -6.61, p = <.00001, with a large effect size (r = .6164).

Learners identified the importance of planning and organising their learning, "we had to keep changing our plans ourselves, which was different from normal" (Group 16), and they had to plan their next steps, "It helped us think about what we were doing and what to do next" (Group 30).

While most learners embraced this autonomy, some struggled to think and organise their learning, "I think we should have made a plan… I think it teaches you like planning skills" (Group 8).

4.3.1.1.4 Strategy and management

The Wilcoxon Signed Rank Test (see Table 14) revealed a statistically significant positive change in the development of **strategy and management** in the DDTS compared with the normal class, z = -7.69, p = <.00001, with a large effect size (r = .7171).

Learners commented on the need to manage their own time as well as the complexities that arose, something that they did not regularly encounter in normal classes, “you need to get this done by now… but you can’t do that with this, so you need to all be constantly organising what is happening” (Group 8). Managing their strategy constantly and next steps proved mentally exhausting for learners, “I was thinking about different things all day that kind of took the energy out of you… because we are used to like working, and everything is in front of you, but then here there’s no instructions there’s like create a design, and you can literally do anything with that… So that’s where your brain had to work really hard like thinking, is that a good idea? And you have to decide whether that’s going to work or not and then work out how to make it happen as a team” (Group 5).

4.3.1.1.5 Critical thinking and problem solving

The Wilcoxon Signed Rank Test (see Table 14) revealed a statistically significant change in the development of **critical thinking and problem-solving** in the DDTS compared with the normal class, z = -4.3158, p = <.00001, with a medium effect size (r = .4025).

Learners acknowledged that the session involved continual open-ended problem-solving with no correct answer; nevertheless, they were not afraid to make mistakes, "we did lots of problem-solving and we weren't afraid to fail" (Group 3). Learners recognised the need to analyse what they were doing so they could clarify to others, "we learnt kind how to properly look at stuff and think, oh that could work, that could work better, and that doesn't work. Like, analyse it and understand it and then explain it" (Group 30). There were challenges getting help from peers to solve problems as every group was working on different projects, "some tasks were more difficult to work out and solve, and there was no one to help you as everyone was working on different things" (Group 12).

Although they were working on very different projects, learners still highlighted their problem-solving processes to help each other, "most of them were problem-solving… they were working through trial and error… and it was incredibly beneficial. They're actually showing me how to do it, which was really nice to swap that role a wee bit as well… they could show me and their peers how to work through this process" (Educator 4). Educators enjoyed seeing the organic problem-solving process in action, "the design thinking studio's philosophy is very effective, of taking a step back, giving them the parameters, and letting them genuinely solve problems" (Educator 3).

4.3.1.1.6 Curiosity

The Wilcoxon Signed Rank Test (see Table 14) revealed a statistically significant positive change in the development of **curiosity** in the DDTS compared with the normal class, z = -4.656, p = <.00001, with a medium effect size (r = .4342).

Many learners were excited by the '*wicked problem'* and threw themselves into trying to find solutions, “we were excited to start to get to think about our project, and we started doing some brainstorming in our work which just raised more questions” (Group 1). Finding one answer just led to more questions which involved learners having to think outside their usual parameters, “we were interested in finding answers, but each answer gave us more things to think about. You had to jump out of your comfort zone of what you would like normally think” (Group 13). Some learners were uncomfortable with being curious because it led to more questions, “I think we did work quite hard once we got the correct idea; it could be a bit frustrating when you’re going through idea after idea because you just keep coming up with more ideas” (Group 25).

4.3.1.2 Confident Individual

The MCs for the Confident Individual are:

- Self-awareness
- Self-regulation
- Self-mastery

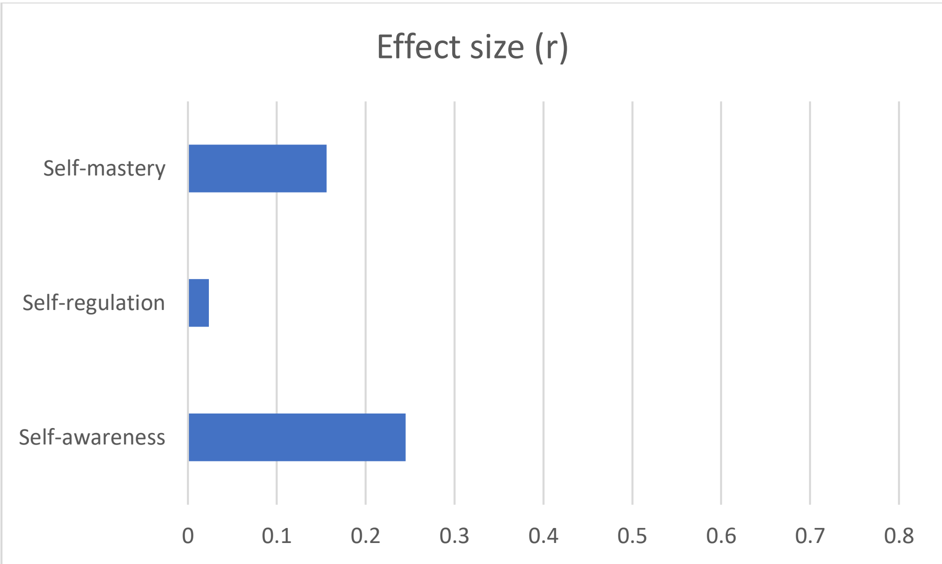
Table 15 captures each MC’s mean and standard deviation and then uses a Wilcoxon Signed-rank Test to compare and generate an effect size (*r*) (see Figure 35). There was a small to medium effect size recorded in this area.

Table 15 - Confident Individual - competency development - normal school versus DDTS

Confident Individual	normal school		DDTS		Wilcoxon Signed-rank Test *Two-tailed*				
n=115	mean	SD	mean	SD	mean	SD	z	p	Effect size (r)
Self-awareness	3.5	1.23	3.41	0.95	1743	220.26	-2.6265	.00854	.2449
Self-regulation	3.41	0.95	3.43	1.04	1540.5	200.77	-.254	.80258	.0237
Self-mastery	3.2	0.79	3.44	1.09	1870.5	232.23	-1.6729	.09492	.1559

Using criteria of Cohen (1988) for effect size: *.1 = small effect, .3 = medium effect, .5 = large effect*

Figure 35 - Confident Individual - graph of effect size



4.3.1.2.1 Self-awareness

The Wilcoxon Signed Rank Test (see Table 15) revealed a statistically significant positive change in the development of **self-awareness** in the DDTS compared with the normal class, z = -2.6265, p = <.00854, with a small effect size (r = .2449).

Learners seemed mindful of their DDTS learning and could self-reflect on their experiences. Some learners commented that they found it difficult to concentrate in the DDTS, as they would “get distracted sometimes when people are running around” (Group 27). Others found that “focus was quite hard because when you’re doing it for hours on end and people are trying to talk to you” (Group 2). Some learners acknowledged it was sometimes challenging to stay on task because of all the fun things around, “there are so many things to do there… it's challenging to stay focused on one thing when there are so many cool things around you” (Group 9).

However, some learners commented on the fact that they felt so focused that they needed a timeout from the intensity, “it’s nice to be able to relax for a few minutes and have little breaks and then get back on to it because you have to think quite a lot when you are in it” (Group 4). Several groups commented on the mental exhaustion and the fact that the project was always on their mind, even when they went home, “I worked harder and was exhausted. I think when we went home, it was kind of relaxing because even although we weren’t in the studio, there was still a lot of thinking about what to do and stuff” (Group 24). One group suggested this was because they had autonomy over their learning and had to continually self-reflect on what they were doing, “you use a lot more brainpower, you’re concentrating for the whole two weeks, it is because you have to answer questions to make good questions and answer them and then improve them, then make them even better” (Group 1). Most groups believed they were working harder in the studio setting, “Like think I was thinking a lot more, I don’t know, I was a lot more switched on” (Group 22).

4.3.1.2.2 Self-regulation

The Wilcoxon Signed Rank Test (see Table 15) revealed a statistically insignificant change in the development of **self-regulation** in the DDTS compared with the normal class, $z = -.254$, $p = .80258$, with a large effect size ($r = .0237$).

Learners remarked on the need for self-regulation throughout the project, “You don’t really get told what to do at all. It’s really like you do what you think is right” (Group 23). Learners accepted that initiative was required, “I think there were aspects in it that were hard, but I think you knew what you had to do, and you could just go up and do it” (Group 15). Self-management was evident in all of the DDTS sessions, where learners took responsibility for their behaviour and learning goals, “it gives you an… intense feel because you are your own task manager… it just lets you take a lot of responsibility” (Group 9). Learners commented that they had the autonomy to “tackle anything you wanted and do it in your own order instead of following a book” (Group 9).

However, some learners found this responsibility and self-discipline challenging, “I disliked that there was not one certain way to do things, and there were no wrong answers as sometimes I work better with a specific method and goal” (Group 12) and would therfore have preferred to be given structure and guidance.

4.3.1.2.3 Self-mastery

The Wilcoxon Signed Rank Test (see Table 15) revealed a statistically significant positive change in the development of **self-mastery** in the DDTS compared with the normal class, $z = -1.6729$, $p = .09492$, with a small effect size ($r = .1559$).

Learners were aware of the need to develop persistence and grit during the

DDTS, “We learnt a lot of perseverance. I think if one thing doesn’t work, you keep working until it does work” (Group 29). This developed a ‘can-do’ attitude in learners where they would keep looking for solutions, “sometimes we encountered some problems, which kind of set us back and to work around them was kind of challenging but it was good fun and teaches you resilience” (Group 20). Many groups acknowledged the challenges they encountered but were pleased to keep trying until they found a way, “I felt very challenged by this and relied on working through it and not giving up” (Group 16).

Self-reflecting on problems and solutions was not restricted to studio time. Many groups commented on the fact that they thought about it at home and on the way to and from school, “I think it made you think more… you would think about it quite a lot, and you would think about it while going to school, what can I do to make it better? and stuff like that” (Group 29). This continual self-reflecting and looking for improvements highlighted a growth mindset in learners, “We learned to expand on an idea, and if it doesn’t work, try again” (Group 32), “you had the one idea, then your first ideas not going to be perfect, so you shouldn’t just give up; you should constantly try and improve that” (Group 31).

4.3.1.3 Responsible Citizen

The MCs for the Responsible Citizen are:

- Ethical and sustainable thinking
- Responsible decision making
- Global consciousness

Table 16 captures each MC’s mean and standard deviation and then uses a Wilcoxon Signed-rank Test to compare and generate an effect size (*r*) (see

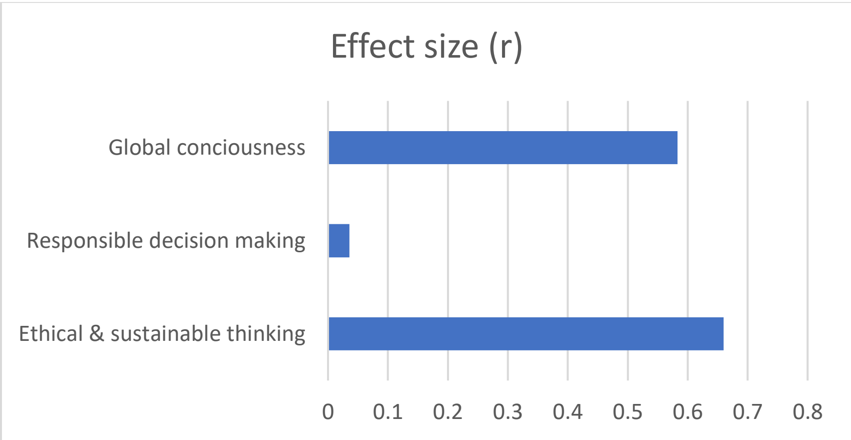
Figure 36).

Table 16 - Responsible citizen - competency development - normal school versus DDTS

Responsible Citizen	**normal school**		**DDTS**		**Wilcoxon Signed-rank Test** *Two-tailed*				
***n*=115**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**z**	**p**	**Effect size (r)**
Ethical & sustainable thinking	1.39	0.49	2.17	0.62	1540	200.77	-7.07	<.00001	.6598
Responsible decision making	2.98	0.82	3.04	1.10	1785	224.23	-.383	.70394	.0358
Global consciousness	1.86	0.56	2	0.65	1008	146.07	-6.25	<.00001	.5829

Using criteria of Cohen (1988) for effect size: *.1 = small effect, .3 = medium effect, .5 = large effect*

Figure 36 - Responsible Citizen - graph of effect size



4.3.1.3.1 Ethical and sustainable thinking

The Wilcoxon Signed Rank Test (see Table 16) revealed a statistically significant positive change in the development of **ethical and sustainable thinking** in the DDTS compared with the normal class, z = -7.07, p = <.00001, with a large effect size (r = .6598).

The quantitative results correlated with observations and feedback where group discussions acknowledged the consequences and impact of their ideas and actions, “there was an element of sort of social justice, doing things for the good of other people that eventually would help other people” (Educator 3). Learners enjoyed seeing the big picture and how their work encapsulated in larger global issues, “what we were working on is part of a much bigger problem worldwide, so perhaps our idea could help lots of people” (Group 1). I observed several conversations between groups that concerned learners involving moral and ethical decisions, what was right, what was wrong, and what would they do about it.

4.3.1.3.2 Responsible decision making

The Wilcoxon Signed Rank Test (see Table 16) revealed a statistically insignificant positive change in the development of **responsible decision making** in the DDTS compared with the normal class, z = -.383, p = .70394, with a minimal effect size (r = .0358).

As learners were given autonomy to make their own decisions, most stepped up to the mark while some tested the boundaries. The majority appreciated the freedom, “I liked the relaxed environment in the classroom and that you were trusted to use the tools and machinery” (Group 12). A handful of learners chose to make some irresponsible decisions, particularly concerning health and safety, which involved a trip to the nurse’s room on three separate occasions. One learner was caught trying to steal a Stanley knife from the DDTS; thankfully, it was found before it was removed from the school grounds. A few other pieces of equipment were taken from the DDTS, including a few Arduinos and a battery charger. There were some behavioural issues with the autonomous learning environment with a couple of disinterested learners; however, most learners were fully engrossed in their projects and ideas.

4.3.1.3.3 Global consciousness

The Wilcoxon Signed Rank Test (see Table 16) revealed a statistically significant positive change in the development of **global consciousness** in the DDTS compared with the normal class, $z = -6.25$, $p = <.00001$, with a large effect size ($r = .5829$).

Most of the DDTS sessions had a global perspective to allow learners to understand, act and find a local solution to an issue of global significance, "ours was aimed at infirm people, like elderly people, and there are elderly people all around the world, so we could be helping so many people with our idea" (Group 24). The tasks aimed to raise learners' awareness of their world, their role in it and the positive part they can play to make it better for others.

4.3.1.4 Effective Contributor

The MCs for the Effective Contributor are:

- Social awareness
- Collaborating
- Leadership
- Communicating

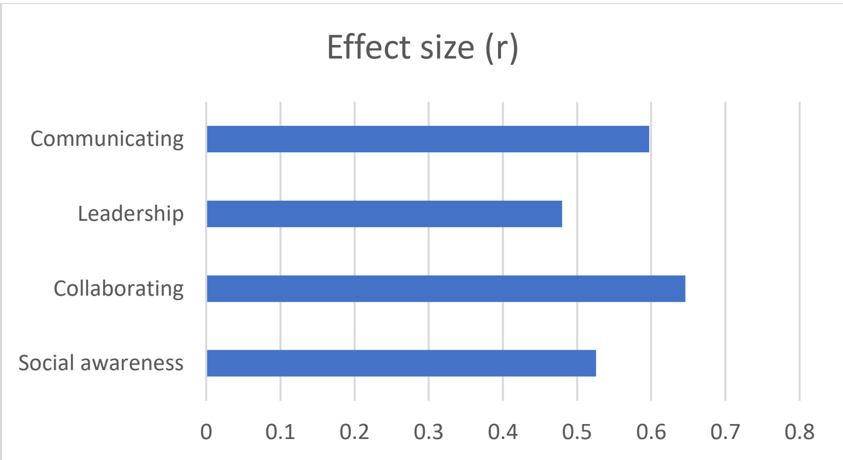
Table 17 captures each MC's mean and standard deviation and then uses a Wilcoxon Signed-rank Test to compare and generate an effect size (r) (see Figure 37).

Table 17 - Effective contributor - competency development - normal school versus DDTS

Effective contributor	normal school		DDTS		Wilcoxon Signed-rank Test *Two-tailed*				
n=115	mean	SD	mean	SD	mean	SD	z	p	Effect size (r)
Social awareness	3.32	0.93	4.10	0.76	1786	224.2	-5.634	<.00001	.5255
Collaborating	3.18	0.91	4.19	0.69	2139	256.8	-6.925	<.00001	.6458
Leadership	3.10	0.94	3.88	1.04	1701.	216.3	-5.147	<.00001	.4800
Communicating	3.30	0.89	4.32	0.91	1958	240.3	-6.405	<.00001	.5973

Using criteria of Cohen (1988) for effect size: *.1 = small effect, .3 = medium effect, .5 = large effect*

Figure 37 - Effective Contributor - graph of effect size



4.3.1.4.1 Social awareness

The Wilcoxon Signed Rank Test (see Table 17) revealed a statistically significant positive change in the development of **social awareness** in the DDTS compared with the normal class, *z* = -5.634, *p* = <.00001, with a large effect size (*r* = .5255).

There were many examples of learners emotionally understanding the feelings and thoughts of others during the DDTS, whether this was within and between groups or with those they were trying to help. The group who visited the old people's home found the experience particularly empathetic, "I kind of liked that we were helping them do something that's purposeful, and you're kind of helping somebodies' life. It means so much to them" (Group 2). Some of the learners found this visit a challenging social scenario as it took them out of their usual comfort zone, "I cried a little when we left, and I almost cried when we spoke to them" (Group 6).

4.3.1.4.2 Collaborating

The Wilcoxon Signed Rank Test (see Table 17) revealed a statistically significant positive change in the development of **collaboration** in the DDTS compared with the normal class, z = -6.925, p = <.00001, with a large effect size (r = .6458).

The DDTS saw groups working together for two weeks on their project, "there was much more group work and collaboration that sort of peer-to-peer learning was incredibly strong" (Educator 4). All groups commented on the use of teamwork and collaboration during the DDTS, "I think we just really learnt to work as a team" (Group 32) since "it's more like you're in a group, and you have to get to this end place together" (Group 27). Many learners "enjoyed learning from other people" (Group 9) and found ways to make their ideas work by interaction, "both of us shared each other's ideas and were stuck on something we'd find a way to make it work together" (Group 17). They appreciated the benefits of teamwork, "individually we wouldn't have been able to make it but putting our skill together worked" (Group 8), and would have found the task impossible individually, "I think you definitely need to be in a group; it would be a lot harder to do it by yourself" (Group 28).

Learners seemed to brainstorm and solve problems together much more than in normal class and relied less on help from educators, “they were working together in small groups, they’re turning to one another to get through the problems, rather than to the teacher” (Educator 4). Learners also found that collaborating with others opens your mind to new ideas, “that was good because it wasn’t just you, sometimes your opinion just sticks, but if you have other people’s input, it got better” (Group 28). This helped generate better ideas together, “some people’s ideas didn’t work, whereas some people had different ideas, and then when we combined them it created something very good” (Group 29).

Group work also facilitated learners identifying and utilising their strengths and passions, “some of us in the group are better at researching stuff up and making 3D printing and laser cutting, and other people are better at making like more like practical, like actually making the thing” (Group 29). Although they were working on different tasks, they were joined in a shared learning journey, “we were on task doing different stuff, so it kind of worked well on collaboration skills” (Group 31). Learners identified the benefits of this approach and felt it should be utilised in their normal classes more often, “I’d like to see teamwork more in classes because we just have to do it ourselves if we got to do partners or group work then we learn more” (Group 23).

The groups were chosen based on interests and passions, “he [the lead coach] chooses groups of what people were interested in so you wouldn’t be in a group where you didn’t want to do” (Group 31) which also meant working with peers they would not usually work with, “Some of them went for the idea that they liked and ended up working with people that they hadn't worked with before”

(Educator 6).

However, some learners did not like that their team was chosen for them, “I didn’t like the fact we didn’t get to pick our partners, but I do feel it was beneficial for me to have to work with people who weren’t my friends, or I didn’t know” (Group 5). A few groups resonated with this and mentioned disagreements and frustrations with other members, “I ended up doing all the work, and we fell out one big-time” (Group 6). However, the art of compromise and negotiation was also evident through teamwork, as learners were “listening to ideas and seeing what other people wanted to do” (Group 15) and felt they “learnt how to collaborate because we were bickering with each other constantly and we learned to compromise a lot as well so we could get what we wanted” (Group 23).

Another opinion was that not all learners fully engaged in the group work, and some found themselves on the periphery, “A couple of pupils… were just on the fringes rather than fully participating. I guess that is the downside of group work, in some ways, is that other pupils can end up carrying a lot of the development” (Educator 4).

4.3.1.4.3 Leadership

The Wilcoxon Signed Rank Test (see Table 17) revealed a statistically significant positive change in the development of **leadership** in the DDTS compared with the normal class, z = -5.147, p = <.00001, with a medium effect size (r = .4800).

The DDTS “was quite ideas based; I saw them so involved and developing their skills so effectively, and also showing great leadership amongst their group as well and talking to each other and working through problems very independently, in a way that that sort of small group work allows" (Educator 4). Learners commented on the fact that the DDTS was not lead by educators and that the leadership came from within their groups, "sometimes if one of us had an idea and the other two had an idea, we had to choose one because we didn't have enough time to do both, it definitely taught us leadership" (Group 32). Some learners proved to be natural leaders and empowered others, "I felt challenged and motivated because some of the work I did was really hard, but I was working with a girl, and she loved motivating people, which lifted me up" (Group 20).

4.3.1.4.4 Communicating

The Wilcoxon Signed Rank Test (see Table 17) revealed a statistically significant positive change in the development of **communication** in the DDTS compared with the normal class, z = -6.405, p = <.00001, with a large effect size (r = .5973).

Learners commented positively on their ability to communicate throughout the DDTS, "I enjoyed the teamwork and discussion aspect" (Group 11) as it allowed them "to talk to other people you don't usually talk to" (Group 25). This facilitated deeper discussion, "I think I worked harder because you're more free to talk, but you're encouraged to communicate and collaborate more" (Group 22). The ability to communicate allowed learners to share their ideas aloud during discussions and presentations, "I liked that we could discuss things together and get the best idea as a group" (Group 4). Learners acknowledged the benefits of sharing and discussing their written reflections with the group for feedback, "I was shy at first when I had to talk to the whole class about what I was doing, but after a couple of times I started to enjoy it, and some of the ideas that other groups gave us really helped” (Group 13).

4.3.1.5 Digitally Astute

"Oh, my goodness, it was amazing what they’re doing on the computers" (Educator 4).

The MCs for the Digitally Astute are:

- Digital literacy
- Computing literacy
- Digital design
- Computational thinking

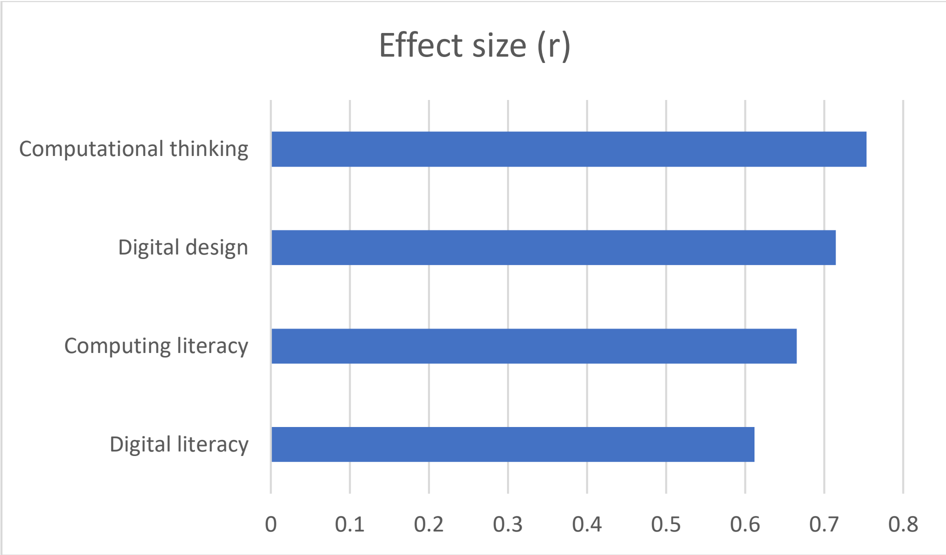
Table 18 captures each MC’s mean and standard deviation and then uses a Wilcoxon Signed-rank Test to compare and generate an effect size (*r*) (Figure 38).

Table 18 - Digitally astute - competency development - normal school versus DDTS

Digitally Astute	**normal school**		**DDTS**		**Wilcoxon Signed-rank Test** *Two-tailed*				
***n*=115**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**z**	**p**	**Effect size (r)**
Digital literacy	1.91	0.76	2.77	0.78	1540.5	200.77	-6.5597	<.00001	.6117
Computing literacy	1.82	0.52	2.87	1.08	1743	220.26	-7.1348	<.00001	.6653
Digital design	1.86	0.58	3.17	1.01	2185.5	260.99	-7.6632	<.00001	.7146
Computational thinking	1.90	0.59	3.24	0.92	2376.5	277.91	-8.0834	<.00001	.7538

Using criteria of Cohen (1988) for effect size: *.1 = small effect, .3 = medium effect, .5 = large effect*

Figure 38 - Digitally Astute - graph of effect size



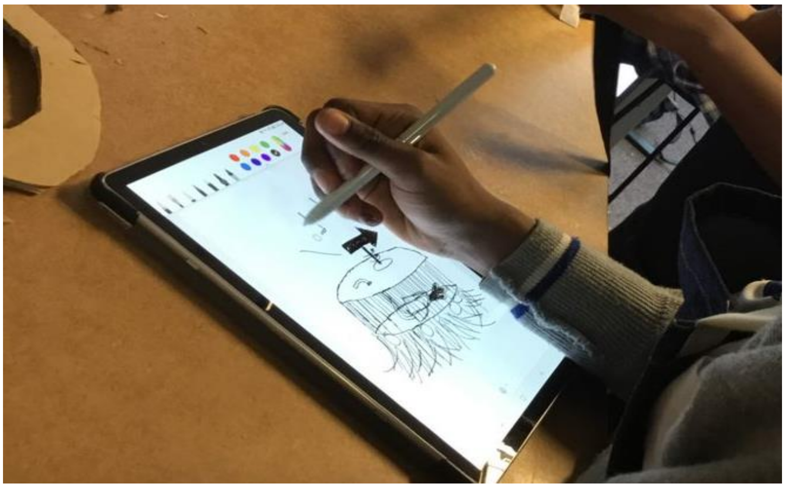
4.3.1.5.1 Digital literacy

The Wilcoxon Signed Rank Test (see Table 18) revealed a statistically significant positive change in the development of **digital literacy** in the DDTS compared with the normal class, z = -6.5597, p = <.00001, with a large effect size (r = .6117).

Learners liked that technology was embedded into the process, “I liked that we got to use lots of new technology that we wouldn’t use in the classroom” (Group 2). They were encouraged to stay safe and use technology responsibly daily in the DDTS; this included handling ‘with discretion all personal information shared online to protect their privacy’ (see Appendix 2 - T1.1.2) and an awareness of their ’digital footprints and their real-life consequences and manage them responsibly’ (see Appendix 2 - T1.1.3).

Effectively using digital tools was apparent in learners' searching, processing, and managing of information. They could ‘find, organise, analyse, and evaluate media and information with critical reasoning and justify my selection in terms of validity, reliability, and awareness of plagiarism’ (see Appendix 2 - T1.4.2). As part of their daily digital self-reflecting journal entries, learners used digital tools (see Figure 39) to capture, create and modify text, images, sound, and video to present and collaborate. This allowed them to ‘use digital tools to design and develop significant digital artefacts (e.g., multi-page website, online portfolio, simulation) to achieve a purposeful outcome’ (see Appendix - T1.4.3).

Figure 39 - Using digital tools to create and modify images



Learners gathered and combined data and information from various sources to create a final presentation to their peers. Learners also handled files, shared digital resources using permissions, and uploaded and downloaded resources daily. As part of their brainstorming stage and determining precedents, learners demonstrated efficient searching techniques, for example, using ‘and’ or ‘not’. They would ‘select and use digital technologies to access, select relevant information and solve real-world problems’ (see Appendix 2 - T1.4.1). As well as communicating digitally within the DDTS, learners were regularly in communication with external agencies, ensuring they ‘communicate with an online audience effectively to exchange messages, ideas, and opinions’ (see Appendix 2 - T1.5.4).

4.3.1.5.2 Computing literacy

The Wilcoxon Signed Rank Test (see Table 18) revealed a statistically significant positive change in the development of **computing literacy** in the DDTS compared with the normal class, $z = -7.1348$, $p = <.00001$, with a large effect size ($r = .6653$).

Despite learners' quantitative results indicating they felt they used computing literacy, this area was not as evident as other digital aspects; however, they did "enjoy problem-solving and having freedom to explore ideas and independence to use the different technologies in the studio" (Group 2). A couple of groups discussed technological trends, the advantages and disadvantages of using technology in our everyday life and mentioned ethical issues around product development; however, this was very dependent on the individuals' interests within the group and the nature of the artefact in development.

There were several discussions around network functionality, and the impact on the devices learners were using, as this was often erratic and caused some frustrations for learners. This involved learners routinely using 'troubleshooting strategies to solve routine hardware and software problems' (see Appendix 2 - T2.4.2), which helped them 'identify, define and analyse computing problems and requirements appropriate for solution' (see Appendix 2 - T2.5.6). Learners were also encouraged to share how digital devices and software were assisting them with their artefact, highlighting how 'specialised computing devices can be used for problem-solving, decision-making and creativity in all subject areas' (see Appendix 2 - T2.4.3).

4.3.1.5.3 Digital design

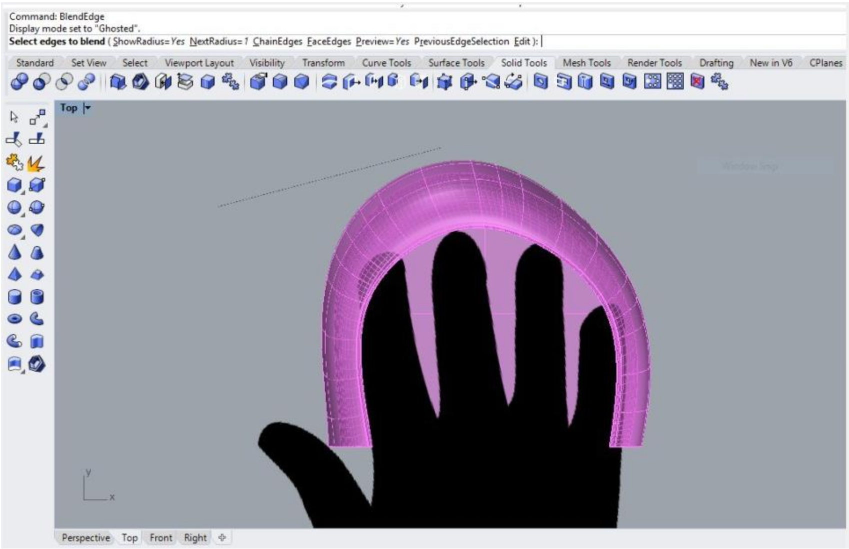
The Wilcoxon Signed Rank Test (see Table 18) revealed a statistically significant positive change in the development of **digital design** in the DDTS compared with the normal class, $z = -7.6632$, $p = <.00001$, with a large effect size ($r = .7146$).

Learners were using a range of strategies to investigate a design brief and create a specification in creative and innovative ways using a variety of practical skills to create a personalised item, which enabled them to 'synthesise, create, and produce information, media, and technology innovatively and creatively selecting and using the 'best' digital tools or resources to create an artefact or solve a problem' (see Appendix 2 - T3.1.3).

They investigated the materials and resources available to them while designing and making a new product while continually evaluating it through the iteration process and continuously looking for improvement, allowing them to 'select appropriate development tools to design, build, evaluate and refine computing solutions to process and present information whilst making reasoned arguments to justify my decisions' (see Appendix 2 - T3.1).

Learners were encouraged to create solutions in 3D and 2D and justify the construction/graphic methods and the design features. They used tools, e.g., Autodesk's Fusion 360 and Rhino 3D, to create 2D and 3D models in digital CAD format while using the 3D printer and laser cutter to output their CAD drawings to manufacture their components/prototypes. Some learners commented that although they had previously used a CAD program called Autodesk and Tinker CAD, they found using Fusion 360 and Rhino 6 (see Figure 40) challenging to learn due to their intricate and complex nature.

Figure 40 - Working with Rhino 6 – creating a 3D Design



Although introductory ‘training’ lessons on using Rhino 6, e.g. cutting, mirroring, sizing, covered most of the learner requirements, they were not enough when they needed to go off-piste. Additionally, some learners forgot what they needed to do when it came time to use it and needed constant support. The learners had access to a collection of Rhino training videos, but they preferred to seek direct help rather than independently locate it.

One group found real frustration because they needed to use another product, Fusion, but did not have the knowledge or skills to use it for what they needed: “it was difficult to use Fusion; it took us like three days to a week to make it. It could have taken us 2 hours if we know how to use it” (Group 2). They suggested that learning how to use Fusion at the beginning of the studio, like the Rhino session, would have saved them time. However, they recognised that because they were the only group using it, that time could not be dedicated to that, as “there was only one group it wasn’t enough to dedicate part of the day to a lesson” (Group 2).

Other learners felt they did not use some of the tools because they were not given enough instruction on using the software and hardware during their time in the studio, “I think a lot more groups would have used the 3D printer if they were actually taught how to” (Group 2). Some felt they lacked independence using these new tools and constantly needed support and help.

Some learners commented on the fact that they found this aspect of the studio boring because they had limited skills, and the coach took over and did it for them, “I think a lot of people found Rhino a bit boring because it was like taking away from us, like actually making stuff and going on the computer” (Group 25). This was compounded by the fact that the assisting educators did not have the level of expertise to be of assistance, which meant the specialist coach was the only one who could help; “I didn’t have the technical knowledge of what they were doing, or what they were trying to achieve. So that was a hindrance because you didn’t know how to guide them or what they can do next” (Educator 5).

As part of their ongoing self-reflection, learners used digital means to capture and share their learning journey with others, helping develop ‘effective media and communications skills’ (see Appendix 2 - T3.2.5). They also had to ensure they had ‘relevant design methods and techniques, appropriate communication methods to present information’ (see Appendix 2 - T3.2.4).

4.3.1.5.4 Computational thinking

The Wilcoxon Signed Rank Test (see Table 18) revealed a statistically significant positive change in the development of **computational thinking** in the DDTS compared with the normal class, z = -8.0834, p = <.00001, with a large effect size (r = .7538).

Although most groups were not necessarily designing, manipulating, or building code, they were encouraged to examine their problem-solving strategies and break them down into a series of small, more manageable problems allowing them to ‘sort through big data and driving insight from it’ (see Appendix 2 - T4.3), then develop skills in logically organising and analysing their data to ‘generate, process, analyse, present meaningful information from data’ (see Appendix 2 - T4.2.2).

Facilitating their ability to ‘create, evaluate, and revise data visualisation for communication and knowledge’ (see Appendix 2 - T4.3.2) thus ensured they could ‘analyse complex data set to answer a question or test a hypothesis’ (see Appendix 2 - T4.3.3). Learners were also encouraged to ‘create models and simulations to help formulate, test, and refine hypotheses’ (see Appendix 2 - T4.1.1).

Several groups used Arduinos[36], which focussed on identifying processes to create a physical solution and correcting errors in program logic as part of their design brief, allowing learners to ‘engage in systematic testing and debugging methods to ensure program correctness’ (see Appendix 2 - T4.4.3). Another DDTS involved developing virtual reality (VR) solutions. This was the only studio that focussed on allowing learners to design and build a software program using visual language combining constructs using multiple variables, which facilitated using ‘an iterative design process, including learning from making mistakes, to gain a better understanding of the problem domain’ (Appendix 2 - T4.4.2).

[36] Arduino - https://www.arduino.cc/

Many groups commented that they would have chosen the VR studio rather than the one they got, “there’s was a group after us that did some digital coding, and I would’ve preferred that” (Group 15). Indeed a few groups commented that they would have liked to focus on engineering and technology, “I would just change what we were doing to something maybe like engineering or more technology-based” (Group 18).

4.4 Pedagogy

Four major themes emerged from the analysis of the semi-structured interviews:

- Autonomy
- Curriculum
- Coaches
- Management

4.4.1 Autonomy

Learners enjoyed having autonomy over their actions, “I liked having to take full responsibility of the project as opposed to a teacher telling us exactly what we should do” (Group 15). They appreciated the support if they needed it, “so, it was like you could think of your own ideas, and they would help us sometimes” (Group 17). However, sometimes, learners felt there was not enough support which forced them to use initiative, “I think because the teachers didn’t always help if you needed help… if it didn’t work, you couldn’t be like no, you had to rethink it all and do it again” (Group 28).

Having many options was very different from normal school as they found there “are so many different ways of doing it because usually in school there’s only one way to do it, but when we were doing the studio, there were many different ways of doing it" (Group 15). Having the choice to take the design in any direction they wanted was difficult but appealing for learners, "I think this is challenging but in a good way. The teachers didn't really tell you what to do...[he] would give you an idea for a good direction to take it, but he wouldn't tell you. He left it to you to try and work out" (Group 31).

Many groups commented that their autonomy made them work harder and think more about what they were working on, "I was working hard, like trying to get all the stuff to work so a lot of problem-solving and trial and error" (Group 31). Most groups positively acknowledged the independence they were given in the DDTS, "in normal school you're assigned work, you do it, you're assigned more, you do it, but with the studio, you create your own work" (Group 9).

4.4.2 Curriculum

The curriculum was vastly different from normal school, which one educator summed up, "the main difference is that you've got rid of all the subjects, and it's just you're doing a lot of different things at the same time…The fact that it is almost entirely active… in a normal school day, they would have sat down and worked quietly in class" (Educator 3). Another educator commented on the attractive prospect of having time to spend developing a project rather than in and out of 40-minute classes, "there's more opportunity for group learning… it's quite nice to have that intense time working on one thing and bringing it to a conclusion" (Educator 5).

Some learners liked this holistic learning process "we like trying new stuff as well cause in subjects it is like do what the teachers says… but here it is, just like try it, and if that doesn't work, try something else, and if that doesn't work, then it doesn't matter; at least you've tried, it's about the process" (Group 5). While some liked their eight-period structured day, "I already like the school curriculum" (Group 25), the perception by those learners was that they were not 'learning' anything because it was enjoyable. Not having facts to learn for an examination was common, "we learnt a lot of creativity, and we collaborated a lot, but in terms of the learning aspect, we don't think we really learnt anything new" (Group 24).

One of the difficulties for educators was the personalised development depending on the learner's ZPD, the group, tasks and projects. One educator commented that "everyone is off in different directions doing their own thing, for a teacher its chaos" (Educator 4). Another educator commented on the underlying pedagogical process, "well, I thought that the concept of it was absolutely excellent. I think it amalgamates so many different positive pedagogical principles and delivers them all at once because of how active it is, how collaborative it is, how creative it is. It is about problem-solving; it's inventive. There's sort of no right and wrong, but some things are better than others, and the kids have got to try and figure that out themselves. Not really teacher lead: it's just more teacher-guided. So, in terms of like, the basic principles of how it works, and that the core idea for it was fantastic" (Educator 3).

Learners liked having the studio as part of their regular curriculum, "I mean, it would be cool if they made it part of the normal curriculum as it's more productive" (Group 26). Having a balance between academia and the DDTS also appealed to some, "if you were doing academic stuff like science and maths, you could also do a studio as well, and kind of do something a lot different" (Group 31).

Others thought the concept of the DDTS should be integrated into regular classes, "I think with some projects like modern studies, it would be quite interesting if they were as open-ended as the studio because you could take it in your own direction. So, I think implementing that into other classes would be good" (Group 31).

4.4.3 Coaches

The role of the educator was significantly different from regular classes, which proved to be both exciting and frustrating for learners. In the DDTS, learners were encouraged to refer to educators or the MKO as '*coaches*', "the coach is really nice; if you need help, then he will help you. It's much more casual than a normal teacher" (Group 13). Each studio session had a lead coach that stayed with the learners for the entire two weeks; they were a specialised DT coach with specialised computing, engineering, and electronic competencies. They were assisted by a timetabled rotation of two different classroom educators (support coaches) throughout the day. This meant at least three coaches were with sixteen learners at any one time.

Overall, learners felt inspired and motivated by the coach's approach and thoroughly enjoyed their 'light-touch' in terms of supervision and direct teaching, "I wish my other classes were more like free in a sense… where the teachers aren't as strict with you" (Group 21). Coaches were found to be knowledgeable, supportive, and fun, "he's an absolute legend and actually lets us do our ideas, and he's funny" (Group 2) and "Coach C has been really good because he obviously knows what he’s talking about” (Group 9).

Some learners felt that they needed support, but they were left waiting while other groups received attention, “it was boring because when you were stuck, and you had to sit there, and you can’t really do anything for half an hour before because the coach is helping another group” (Group 2).

Learners felt that waiting for help hindered their progress because sometimes they did not have anything else to get on with, “sometimes you have to wait for quite a while for help before the coaches come over and help you… we can’t really do something else unless we have help” (Group 2). Therefore, despite the low coach to learner ratio, the support coaches acknowledged they often did not have the competencies to assist learners with their more advanced questions, “I couldn’t really do an awful lot for him. I think having another pair of specialised hands would have been a good idea for that” (Educator 6).

Some coaches took over, which annoyed learners, “the people who were helping us basically did it for us, and we wanted to do what we wanted” (Group 27). Some educators acknowledged themselves that they were giving too much guidance, “the instruction is to help them and don’t do it for them because you just see straight away what they’re doing wrong. I mean, but the trick is not to tell them, so they learn for themselves” (Educator 3).

4.4.4 Management

The difference in this learning style brought around some challenges, “I think it was easy for some characters to get distracted by the lack of structure” (Educator 7). Some learners were concerned by the difference in classroom management, “the coaches are a lot more chill than our teachers, but I think they should have the same strictness as normal teachers because the children were not really under control" (Group 8).

Some of the support coaches, who are the 'normal' classroom educators, struggled with the lack of essential classroom management, "it lacked the nitty-gritty basics of teaching, to make sure that when you're given instructions like nobody's talking" (Educator 3) and felt there should be more control, "I think some pupils need more direct supervision than maybe the lead coach had any experience of" (Educator 7) and at times were tempted to take control, "there was a couple of occasions when I wanted to intervene in a classroom control level" (Educator 7).

4.5 Engagement

Four major themes emerged from the analysis of the semi-structured interviews:

- Fun
- Projects
- Time management
- Originality

4.5.1 Fun

The dynamic, hands-on, playful nature of the project was appealing to learners, "It is more active. It's a lot more fun. When something's fun, you're definitely going to be more excited going to class and be happy like I can't wait to do this" (Group 28). Learners found, "it wasn't like normal school, it was so much fun" (Group 10) which inspired them as "it was quite motivational. It was quite fun as well like the fun made us motivated to work" (Group 11). Several groups commented that they were excited and intrinsically motivated to come to school because of the enjoyment they were deriving, “on Sunday night, I wasn’t dreading school. I was quite excited for it because we got to learn something, we definitely worked harder, and it made us more creative” (Group 23).

However, not all learners found the whole process engaging, “not that I didn’t enjoy it, but it is just not for me. Some bits were fun like the creating bits I enjoyed, and you get to see other people’s creations and how you can improve on your own” (Group 9).

4.5.2 Projects

Several learners commented on their passion for the projects they were working on and how this helped motivate them, “I felt kind of challenged with the project. I felt motivated with the type of learning, as it is more interesting and exciting than just being in the classroom” (Group 2). Learners commented on the fact they were motivated by ownership and oversaw their own decision, timescales and creativity, “I liked that the studio was different and a new challenge that enabled me to do cool things that I could make my own. This was better than just doing the same thing as everyone else” (Group 6). They enjoyed creating their projects, thinking, and doing it for themselves. Some felt this helped raise self-esteem, “it makes me a bit more confident, like try it and if it doesn’t work, then it’s not bad” (Group 5).

Each project’s real-world, problem-solving nature motivated learners who enjoyed the open-ended, unstructured nature, “then there is a lot more brainpower and concentrating for the whole two weeks” (Group 1). All the learners commented on the freedom and trust they enjoyed while working on the project. This might have been the trust to use the tools, “It was quite exciting to have all the tools… we were trusted to use them, and I think most of us did use them well, and it was fun” (Group 11). It could also be the accountability they had with regards to how they used their time, “In normal class, you need to be quiet, and you can’t talk. In the studio, you can just talk, stand up and have a walkabout, you get more responsibility” (Group 2). Educators and learners commented on developing competencies for the future, “it’s skills you can like use in your future life and skills you will actually have to be using” (Group 6).

4.5.3 Time management

Learners found having the responsibility to manage their own time empowering and motivating, “I think it forced you to work harder, work faster, like in a good way, so you make your deadlines, and you get more stuff done... A bit hard at first, but it got easier” (Group 26). Some embraced this unstructured approach, while others acknowledged the willpower and restraint required to stay on task, “I think at first it could be quite hard, but because there’s no real schedule or anything. I can see how people could get off or just not do much” (Group 25).

A lack of experience ensured that not all learners managed their time successfully, “you have to think and work at the same time, and you have deadlines” (Group 8). Some groups acknowledged that managing their time was difficult when they did not know what to do, “it’s quite stressful when you don’t know what to do” (Group 2), and when you feel overwhelmed, “we had to do so much stuff because you only have two weeks, and it’s quite stressful” (Group 1).

4.5.4 Originality

Learners were motivated by being active, “we were not stuck at a desk all day”

(Group 4) and having an exposed space to work in, “I liked that there was an open plan so you could constantly see what everyone else was doing” (Group 31). The uniqueness of the environment and learning process was inspiring, and many commented that they “liked how the days felt so short” (Group 2). Learners felt it was very different from anything they had experienced before, with one group commenting that “I liked the fact that we were not in the classroom and that we had a lot more freedom to do what we wanted to do, as opposed to just being told what to do” (Group 2).

Learners acknowledged that this process engaged parts of the brain not typically employed in class, “I felt that I used a different side of my brain that we don’t use in school” (Group 4). Most learners commented that they worked harder, “Yeah, worked harder because you have time limits to get everything done” (Group 27). Every day is different, “In the studio, every day, you tackle different challenges, so it’s never really the same. It isn’t repetitive” (Group 2). This novelty and autonomy was tiring and challenging for learners.

One educator identified that the DDTS could motivate learners who typically found classrooms challenging, “What did become clear that some children who struggle in a classroom environment excelled in that situation, and vice versa” (Educator 1).

4.6 Assessment

Four major themes emerged from the analysis of the semi-structured interviews:

- Self-reflecting eportfolios
- Final presentation
- Summative assessment

- Metacognition

4.6.1 Self-reflecting eportfolios

Assessment of learners during their time in the DDTS was captured through ongoing peer and self-reflection with a final presentation at the end.

Each learner used their school email account to log in to a digital online system that facilitated writing their daily reflections in a SRE. Although this was the first time that learners had used such a system, they all grasped the navigation and posting of comments quickly and easily. Indeed, several groups compared the system to using ‘social media’ and enjoyed having the ability to comment on each other’s posts and share photos of their progress which they felt generated more discussion, “as someone who uses social media quite a lot, I found commenting the same as Instagram” (Group 9).

4.6.1.1 SRE guided questions

Capturing learners’ self-reflections through blog posts was a daily occurrence, carried out at different intervals throughout the day. It required learners to write their thoughts and feelings, why they were doing what they were doing, how it was going, what they found challenging, and their next steps. Throughout each of the two-week DDTS, for approximately four days, learners were provided with ‘guided’ questions (see Figure 41 and Figure 42) for them to reflect on.

Figure 41 - Super-enabling devices - day 2 ‘guided’ self-reflection

DAY 2 REFLECTION

By[redacted] 10/02/18 AT 11:40 AM Privacy: School

I hope you all had a wonderful visit today to[redacted]House. Please post your first blog post in the "Projects" tab under your project (you should see your name beneath one of the boxes), and answer these questions:

- Describe the residents you spoke with, who had the greatest impact on you, and why.
- How was the visit different than what you'd expected?
- Discuss any project ideas that may have been sparked in your imagination.

Figure 42 - Super-enabling devices - day 6 'guided' self-reflection

DAY 6 REFLECTION

By[redacted] 10/08/18 AT 10:41 AM Privacy: School

Excellent progress today! In your blog post this evening please respond to the following:

1. What design decisions did you make today?
2. What do you think the next steps in your project are?
3. How has your project changed since you first began prototyping last week?

And... don't forget to post your pictures! If you do not have pictures in previous blog posts, please go back and add them.

Guided questions were used early in the studio to scaffold learners' writing. The eportfolios were visible to everyone in the studio and shared daily using the large presentation screen. This was to elicit feedback and encourage discussion, *"it was good to do because you got to tell the other people in your class what you've been doing, and I think it was nice to see other people's work; we got really useful feedback"* (Group 17). My observations found that learners genuinely listened and took on board and reflected on the feedback from peers; in fact, they almost seemed more interested and concerned with the opinions of their peers than those of the coach.

4.6.1.2 Honesty

Educators had conflicting opinions about how honest learners were with their posts and feedback. One educator commented that “they’re doing a washup of good points, bad points, taking feedback, and the kids were quite honest” (Educator 6). Another educator felt that some learners were not saying what they truly felt in their posts for fear of their reflections being shared with the rest of the class. Their comments, group posts and replies to the coach were shared on the big screen with everyone to see, “I’m not entirely sure the kids were honest because it ended up projected on the big TV screen at the front. I think if only the coach was reading it and not the whole class that they might be more honest” (Educator 1).

4.6.1.3 Reflection

Some educators and learners were not familiar with using learner-centred feedback from peers and self-reflecting as a tool for evaluation. Rather than developing metacognitive capacities, they saw it as keeping a log of your progress, “it helps it shows what you’ve done, so you have a record” (Group 11). This perception of simply recordkeeping meant that some groups felt taking time out of their studio experience to write up what they were doing was a waste of time: “I just feel like it was a bit of a time-waster; it’s something that you know anyway” (Group 6). One group commented that they should only write their self-reflecting blog post when they have something to write, which might be days apart (Group 18).

Several groups recognised that blogging about what worked and what did not work helped them alter their thinking when faced with a new problem or scenario. Reflecting on their own or other groups’ blog posts helped them think through issues and make informed decisions, “you forgot what you worked on but looking back, it helped you remember so you didn’t make the same mistake again; you learned from it” (Group 17).

4.6.1.4 Progress

Educators identified that sharing the feedback and blog posts collectively helped make them meaningful and helped learners learn from each other and think about what they are doing and why “it’s good to help them look critically at their projects” (Educator 5). Having a record of their thought processes visually helped see where they had come from; it captured their learning journey and allowed you to “see where they have gone with their thinking” (Educator 5). It also allowed them to capture each stage and process, “it helps formalise what they’ve done and what they’ve learned" (Educator 5).

Formalising each stage in their learning journey helped learners who identified that, at times, they felt they had not achieved anything, but reflecting on their blog helped them acknowledge their progress, “I think it was good to think back on what you’ve done that day because if you didn’t then you wouldn’t have considered in your head what you’ve actually accomplished that day” (Group 32).

Figure 43 - Group 2 - reflection blog - day 8 – example of a collaborative post highlighting the next steps

Today we worked on Rhino and finalising our ideas. Before break we worked on Rhino, making a house using different commands, such as copy, mirror, join and trim.

After break we looked at our design ideas and though that we could use a hook on one hand and a device that had the ‘fingers’ on the other hand. We also thought that there could be little hooks at the bottom of that device that would make it easier to bring the yarn over the top of the ‘fingers’.

We made our first prototype of that design today and I feel we got quite a lot done. I think our next steps are to make a working prototype and work out what materials and how we are going to actually make our final design.

Several groups identified that it made them think about what they were doing and their next steps (see Figure 43). They felt that what they were writing was genuine and meaningful comments that they would implement," it made us think about what we were doing next because when you were doing your project, you would look back at your old one. You'd see what you said you wanted to improve on, and you actually do that… it felt like you were really trying to improve" (Group 31). This was a common theme for learners; what they were writing was beneficial and meaningful. Several groups said that keeping a self-reflecting blog helped with their next steps because it "helped us think about what we were doing, what to change, and we were really thinking about it" (Group 28).

Several educators commented on the usefulness of self-reflecting as a means of formative assessment; "I think that's really important that they understand where they are in their process, and they can self-assess as they go; I think it's a key part of the process in any learning" (Educator 4). They saw the value in the learner at the centre of the process, explaining and talking through their thought processes and reflecting on what went right and wrong. They felt the process was very inclusive and effective because they were all learning from each other. It removed the focus from the teacher grading, marking, and giving feedback, "It emphasised the learner, rather than the teacher having to mark all their presentations, which again, I don’t think is effective. Give this grade, It doesn’t really mean anything to them, but it does mean something for them to think about it and reflect” (Educator 3). However, one educator felt self-reflection was a waste of time and that it “didn't fit into that model very well” (Educator 5) and felt they would learn more from the coach’s feedback.

Several groups highlighted that they enjoyed sharing their learning at home: “I went home and showed my mum what we had done, and she got to see it as if she was there for like the final presentation” (Group 23).

Learners also commented on their pride when they looked at their final product and then looked back on the process that got them there: “it was good seeing how your projects evolved in the two weeks. It was fun because we can now look back at the little cardboard box we made a week ago, and now we are having our project 3D printed and laser cut out of wood” (Group 28).

4.6.2 Final presentation

The final presentation was delivered on the very last day to the rest of the class, including any available educators. This allowed learners to showcase their learning and was created collaboratively by each group online. My observations highlighted the respectful nature of this session; they asked interesting questions and gave sensitive feedback, except for one learner, who repeatedly asked the same inappropriate question to every group, resulting in frustrating his peers.

4.6.2.1 Easy

All the groups highlighted that keeping their daily SRE made their final presentations straightforward; this was in part due to the fact they already had a log of everything they had done, “it was a lot easier to make the final presentation at the end because we had all the photos and blog comments there” (Group 11). It was also more accessible because they had ‘lived’ the experience and could talk through the intricacies and details of their learning journey, which made it less daunting. Only one group mentioned that they did not like the final presentation, and this was because they felt “their final product was a failure” (Group 24).

4.6.2.2 Proud

Overall, learners felt the final presentation was a good idea “because everyone can see your final product and get comments, which is good” (Group 19). Most groups mentioned they enjoyed displaying what they had been working on and enjoyed seeing what the other groups had achieved. Most groups said they enjoyed talking with each other and giving and receiving feedback; it “was good to do because you got to tell the other people in your class what you’ve been doing, and it was nice to see other people’s. We got useful feedback” (Group 17).

However, all of the educators who watched the final presentations commented on the professionalism, passion, and knowledge, “I saw a second-year class doing their presentations, and I thought that was excellent. They explained how their thing worked, their thought process, you know, reflected on what went right and wrong and then questions, and I feel it was very inclusive, and everybody was learning from everybody else’s reflections. So, I felt that was a very effective way of doing it. It also puts the emphasis on the learner, rather than the teacher” (Educator 3).

4.6.3 Summative assessment

Learners made many comparisons between the formative and summative assessment processes. Many remarked that the formative assessment used in the DDTS was more straightforward, “I did like using self-reflection instead of an exam as there was less pressure, and it taught you how to be honest with yourself” (Group 12). Learners enjoyed that formative assessment provided feedback from others, “the comments of others really helped me, I thought it was valuable” (Group 30), and they liked the fact that there was no wrong answer, “I liked the self-reflection as it was one of the first times, I actually looked back at the work I have done and evaluated it. I liked the fact that there were no “wrong answers”, and that any idea could be possible” (Group 2).

4.6.3.1 Strengths

Some groups commented that formative assessment helped identify areas of strengths, “I think it helps you find what you are strongest in” (Group 8) as well as areas for improvement, “I reflect back and know what I could improve on but can also focus on what I did well” (Group 6) which some felt was more valuable than summative assessments, “I think it can help you understand where to improve on more than an exam” (Group 4). One group highlighted the ability of formative assessment as a means to think deeply: “it lets people express their opinions more and encourages critical thinking” (Group 9).

One group acknowledged that formative assessment facilitated personalised progress that could accumulate over time, “I feel self-reflection is better because then the teacher can see what you know and what you’re like over the year” (Group 5), which would create a cumulative personalised learning journey, “I prefer it a lot because you can see where you need to improve, and the result is based on a build-up of your work rather than just one test" (Group 7). However, another group were concerned that summative assessments are more accurate indicators of content coverage, "self-reflection is good, but I don't know if it shows teachers if the pupils have learned 100% of the curriculum, while tests can be more precise" (Group 15).

4.6.3.2 Summative stress

Every group commented on the topic of formative assessment being less stressful than summative assessment, "I feel if I do self-reflection, I won't be as stressed" (Group 20); without worrying about summative scores, "it meant I could express how I feel about my learning rather than stressing about getting a perfect score in a test" (Group 6). Groups highlighted that formative assessment allowed them to examine their work and areas for development without stress, "as you got to analyse what you had done in the unit and reflect on what you'd learned without the pressure and anxiety a test causes" (Group 5) which helps you in the future, "it's less stressful as it doesn't require studying, and it also forces you to think about what went well/wrong, which will make future projects better" (Group 3).

4.6.3.3 Examination work

One group preferred summative assessment and to be told what to work on, "I'm not a fan of self-evaluation; I'd rather be evaluated so I know what to do next time. When I make decisions, why would I then go back on that and say I could've done better?" (Group 8). Another group liked using formative and summative assessments depending on the subject, "for certain subjects, exams and tests are more effective, but for this type of activity, self-reflection is better" (Group 5).

4.6.4 Metacognition

This section provides a summary of the results of one group's MAI questionnaire (*n* =13) and an analysis of SRE (*n* =13). The results from the MAI were collated and analysed using the Microsoft Excel package (see Appendix 12).

The learners' SRE were analysed on NVivo 12 using the metacognitive regulation (MR) markers (see Figure 44). There were 94 instances of MR identified. All areas of MR were evident in the analysis, and Figure 44 shows the percentage of MR markers present. There were instances where some full and robust comments aligned with more than one MR marker; in these instances, they were linked to each marker present.

Figure 44 - Percentage of instances of MR in learners' SRE

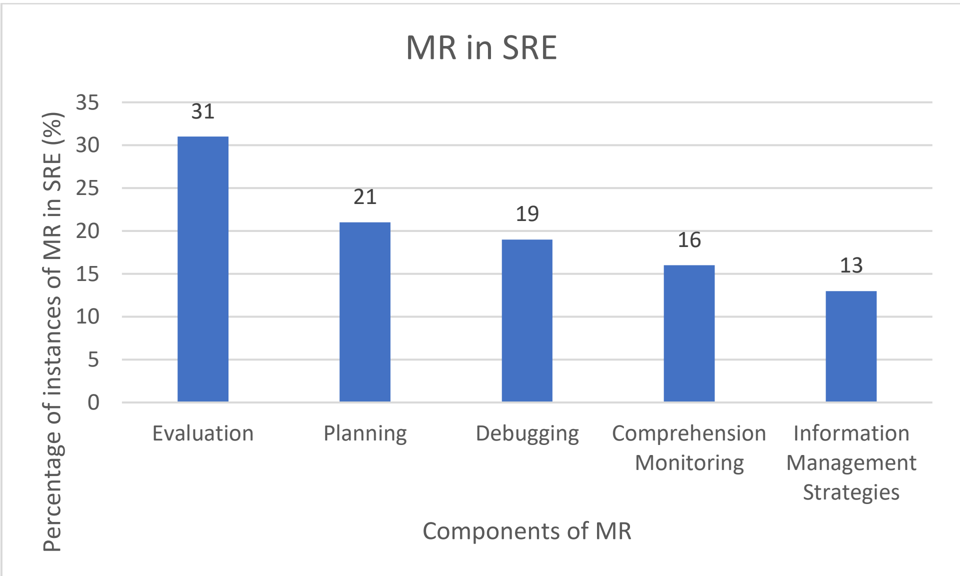
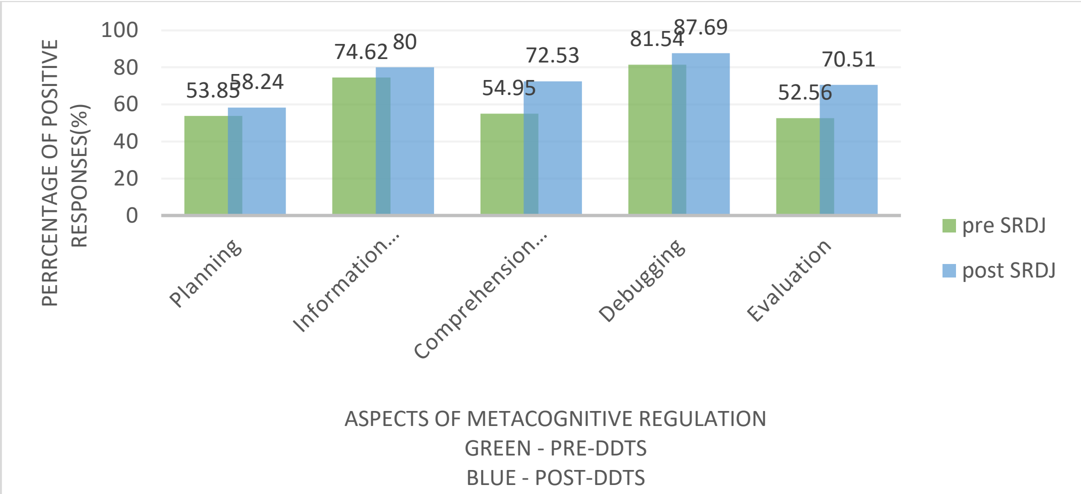


Figure 45 shows a graph of the results from the MAI questionnaire and highlights that every component of MR improved following two weeks in the DDTS (green=pre-DDTS, blue=post-DDTS). Interestingly, learners' perceptions of their information management skills (IMS) (75%) and debugging (D) (82%) skills started from a position of strength.

Figure 45 - Percentage of positive responses pre and post DDTS from the MIA questionnaire



Detailed statistical analysis (see Table 19) of the MAI highlight a positive effect in all areas. Planning (P) (d=0.22) had a ‘small’ effect size, whereas Information Management Strategies (IMS) (d=0.41) and Debugging (D) (d=0.38) had a ‘medium’ effect size with Comprehension Monitoring (CM) (d=0.83) and Evaluation (E) (d=0.68) showing a ‘large’ effect size. Although CM and E started lower than the other MR components, it is interesting to note the significant increase in learners’ perceptions of CM and E following the use of the DDTS.

Table 19 - Descriptive statistics, outcomes of paired-sample t-tests and effect sizes of

metacognition before and after their use of SRE in the immersion studio

Metacognitive Regulation (MR) Markers	**Mean**	**SD**	**Mean**	**SD**	**t-test**	**Cohen's d**
Metacognitive Regulation (MR)	Pre DDTS		Post DDTS			
Planning (P)	3.77	1.19	4.08	1.78	0.236	**0.22**
Information Management Strategies (IMS)	7.46	1.51	8	0.97	0.066	**0.41**
Comprehension Monitoring (CM)	3.85	1.54	5.08	1.42	0.009	**0.83**
Debugging (D)	4.08	0.67	4.38	0.98	0.183	**0.38**
Evaluation (E)	3.15	1.38	4.23	1.93	0.016	**0.68**

*Notes: SD = standard deviation, degrees of freedom = 13, *p<0.05, 1-tailed, paired,*

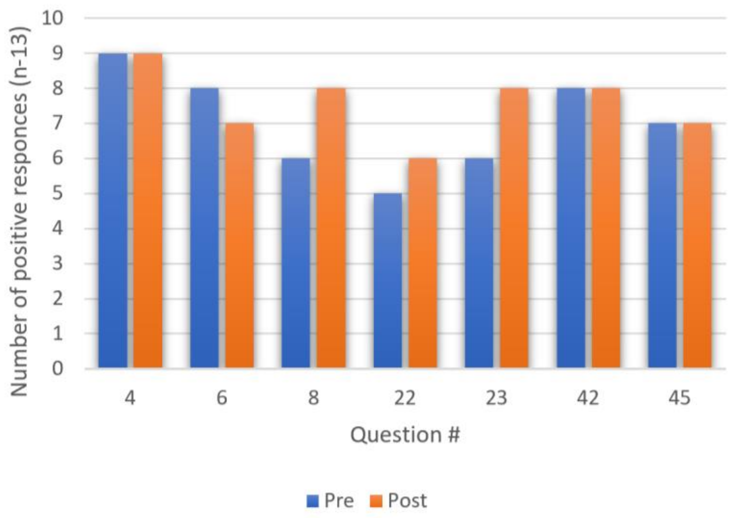
$p - value \quad H_0 : M_1 = M_2 \quad H_a : M_1 < M_2$

The following sub-sections offer a summary of each of the six MR markers.

4.6.4.1 Planning

Planning is the process of goal setting and allocating resources before learning and was demonstrated in 20 instances (see Figure 44 - 21%) in the learners' SRE. Brainstorming and determining objectives is the first and foremost part of the planning process. This was illustrated in the MAI (see Appendix 11 – Q#8) that both brainstorming and solving-problems (see Appendix 11 – Q#23) had improved during their time in DDTS. An example from an SRE highlights this continual brainstorming process: “Our initial idea was to just make a normal riot vest. Then we decided to make it more interesting by looking at self-defence for animals, and we saw porcupines, and how they use spikes as a self-defence mechanism, so we decided to combine them" (Group 13).

Figure 46 - Graph of positive 'planning' responses pre-and-post-DDTS



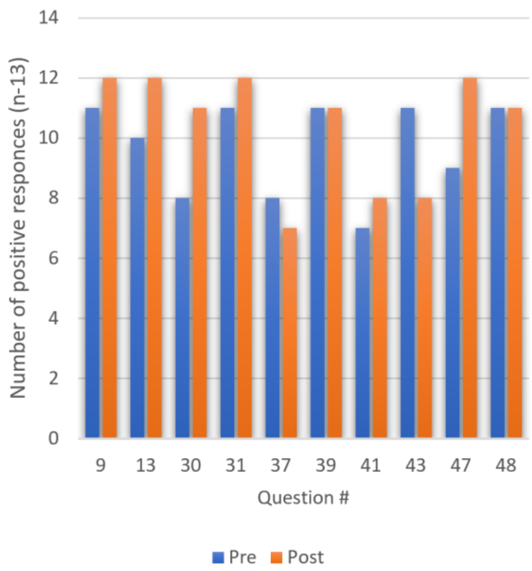
During interviews, all the learners commented that using the SRE helped them plan their next steps and having the ability to read over what they had written previously helped them identify their course of action the following day, "It was great to have a look at what you had written before because you'd be thinking about what to do next and then from reading what had already worked and not worked for you helped you decide what to do next" (Group 28). Entries supported this in the SRE of planning their next steps, choosing the best solution to their problem, and identifying resources required: "we thought about different ways of making it work and have decided in our next steps" (Group 4).

However, the results from the MAI highlighted a decrease in the number of learners that thought about what they needed to learn before they started the task (see Appendix 11 – Q#6 – 54%). This correlates with the small number of learners pre- and post-MAI that felt they did not ask themselves questions about what materials they needed before they began a task (see Appendix 11 – Q#22 – 46%), illustrated by this SRE entry, "we didn't really think about what to use before we started” (Group 19).

4.6.4.2 Information Management Strategies

IMS highlight learners’ abilities to sift, interpret, analyse, and elicit meaning from the information they encounter, and to identify strategies to use their newly acquired knowledge effectively; for example, organising, elaborating, summarising, and selective focusing.

Figure 47 - Graph of positive ‘information management strategies” responses pre-and-post-DDTS



Although IMS had the lowest number of entries in the learners’ SRE (see Figure 44 - 13%), there were still aspects of it appearing; for example, there were references to learners’ monitoring goals, “our goals for next week is to make a working ventilation system and try and make the glove comfier to wear” (Group 25) which was reinforced by the MAI which saw a 23% increase (see Appendix 11 – Q#47 – 92%).

Overall, the learners’ perceptions of their IMS were strong. The majority felt that they slowed down (see Figure 47 – Q# 9 – 92%) and consciously focused (see Appendix 11 – Q#13 – 92%) when they encountered essential new information. There was also a significant increase in learners feeling that they concentrated on the significance of new information (see Appendix 11 – Q#30 – plus 23%).

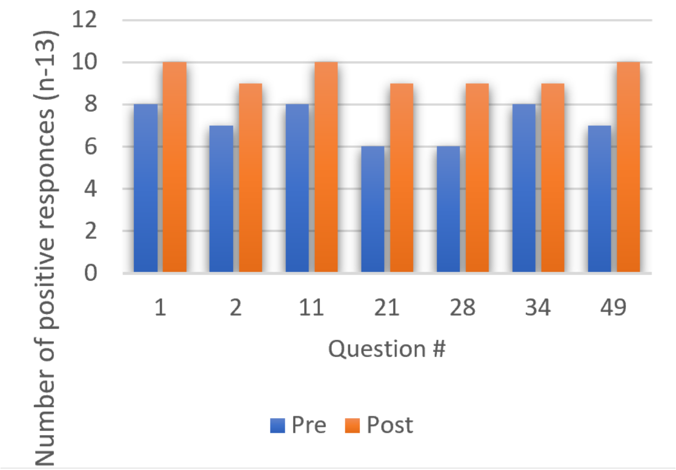
Learners did not feel that they used pictures or diagrams to help them in the learning process (see Appendix 11 – Q#37 – 54%); however, every SRE mentioned the use of sketching/pictures/photographs to help them with the process, “while making our first prototype, we made it the exact same as the sketch that we drew” (Group 23), and this was an area that they all identified as motivating when interviewed, “taking the photos was really fun” (Group 1).

Q#43 highlighted that following the SRE, more learners did not feel that they were asking if what they were learning was relevant to what they already knew (see Appendix 11 – Q#43 – minus 23). They did not know they were making the connection between previously learned and new information.

4.6.4.3 Comprehension Monitoring

CM is the process that allows learners to assess their learning or strategy use; how well they understand the information they are receiving, and how they are using it. All the SRE highlighted aspects of CM where learners consider several alternatives to a problem before starting off and continually question themselves and their strategies as they are learning, “the initial brainstorming idea we came up with lots of ideas… We talked about our ideas and how we could develop them, and we chose the one we felt we could create… We had to go back to the drawing board and rethink all the issues that we had and how we could solve them” (Group 14).

Figure 48 - Graph of positive 'comprehension monitoring" responses pre-and-post-DDTS



Overall, the number of CMs identified in the SRE was low (see Figure 44 - 16%); however, although the MAI pre-scores for CM were low (see Figure 45), there was an increase in every single one of the CM questions when the post-MAI was carried out, the only MR component to achieve this. Learners felt they reflected on how well they were doing when learning new information (see Appendix 11 – Q#49 – plus 23%), analysing the usefulness of strategies while they studied (see Appendix 11 – Q#28 – plus 23%), and taking time to understand meaningful relationships (see Appendix 11 – Q#21 – plus 23%). During the interview, the learners certainly reinforced the idea that they took time to think about their ideas and were keen to highlight that working and collaborating with peers helped their thought processes.

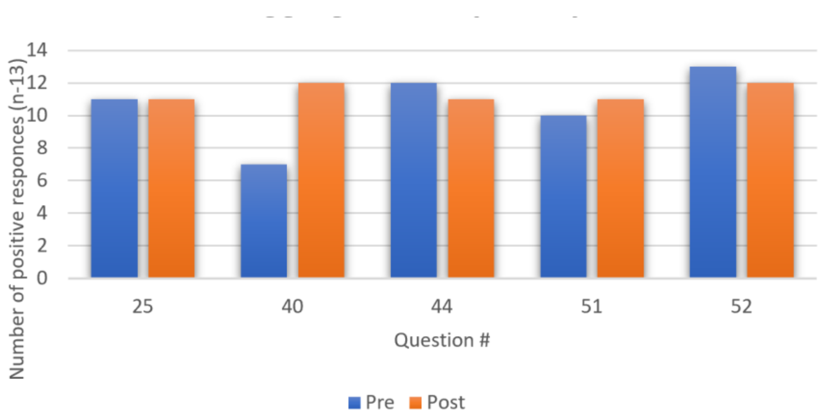
During interviews, most of the learners (85%) felt the SRE was beneficial in making you think and reflect and brought all your thoughts together like a giant picture board, "when you're trying to improve something, it makes you think that methodically like what I've done so far, what do I want to do next? And then like, what can I do after that? And it's pretty useful, because before when you're just thinking how to improve something you might like, there'll be a bunch of disconnected thoughts, and this pulls them together, it's a good strategy" (Group 20).

4.6.4.4 Debugging

Debugging is acknowledging and using strategies to correct comprehension and performance errors. Working together with others and receiving feedback was important to all the learners and deemed easier than working on your own, "Yeah, it was good to be in a group and would be a lot harder if you had to do it by yourself" (Group 31). Learners enjoyed this method of teamwork and collaboration and could identify that some of their best ideas came from sharing with others, "I learned a lot from listening to other groups talking about their problems and how they solved them, it really helped us take a different view on our problems, and we also realised everyone was in the same boat" (Group 22).

There were several debugging strategies (see Figure 44 - 19%) identified in the learners' SRE, with learners acknowledging and appreciating feedback from others, "The first prototype was a mask. It wasn't very good, but our classmates gave us some good ideas which we liked" (Group 11).

Figure 49 - Graph of positive 'debugging' responses pre-and-post-DDTS



The MAI questions highlighted a significant increase in one of the debugging questions. Learners felt more confident in changing strategies when they did not understand what they were doing (see Appendix 11 – Q#40 – plus 38%), “When we presented our idea to the class, most of the feedback was positive but commented on how big it was made us think about changing and improving our next prototype” (Group 14).

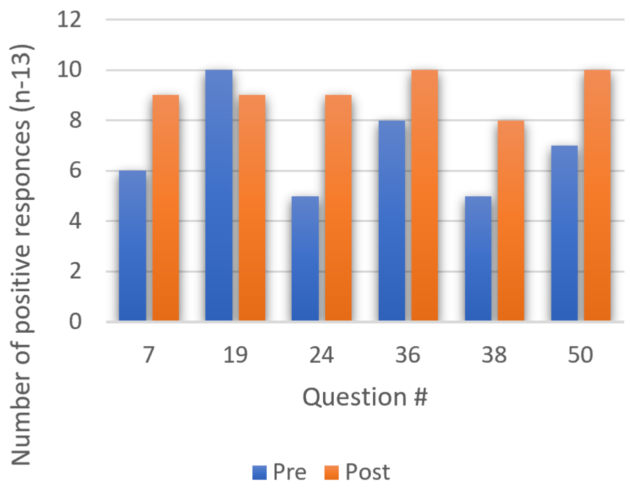
4.6.4.5 Evaluation

Evaluation is the analysis of performance and strategy effectiveness after a learning episode. Of all the markers tallied in the SRE, the highest frequency of all MR components was for evaluation (see Figure 44 – 31%).

This was replicated in the MAI results (see Figure 50 – 71%) and during interviews. Students seemed confident in their ability to evaluate what they were doing. This might be due to the iterative nature of the task. All the SRE had several evaluation markers where students discussed how well they did, “I enjoyed working on the project but realised that when I finished that I could have thought about it more before I started, I would like to have been a bit neater and a bit more realistic” (Group 17).

The MAI results highlighted a 23% improvement in three evaluation questions. Students felt confident in their knowledge that they had learned as much as they could during a task (see Figure 50 – Q#50 – plus 23%) and believed they had considered all the options after solving a problem (see Figure 50 – Q#38 – plus 23%). Learners also felt they were aware of their performance following a test (see Figure 50 – Q# 7 – plus 23%).

Figure 50 - Graph of positive 'evaluation' responses pre-and-post-DDTS



One interviewee felt that SRE was more meaningful because he had ownership and would implement and use the adaptations, "I liked that I could look back on my own thoughts about what to improve and change; a few times I changed what I did because I remembered what I'd done before" (Group 15).

4.7 Chapter summary

This chapter presented the findings of the research and collated them using the tenets of social constructivism: context, content, pedagogy, engagement, and assessment. The next chapter will discuss the findings related to the RQ that drove the study.

Chapter 5. **Discussion**

5.1 Chapter overview

This chapter reiterates the background issues driving the study and addresses the RQ, highlighting the key findings from Chapter 4. It identifies the influence this could have on education. It recognises the contribution to the theoretical framework and fills a research gap. This is followed by highlighting the limitations of the research and suggests areas for researching the challenges and complexity surrounding the use of DDTS in an education setting. It concludes with the chapter summary drawing the research to a close.

5.2 Summarising the background issues and driving the study

As 4IR grasps the world, it has brought unprecedented change compounded by the recent COVID-19 global pandemic. To thrive in this new technologically advanced society, learners must develop the much-needed MC required to thrive in the world they are to inhabit. To this end, many education systems globally are moving towards a more personalised CBE approach underpinned by the tenets of SC.

Scotland adopted its curriculum, CfE, towards such an approach in 2004 to develop: successful learners, confident individuals, responsible citizens, and effective contributors. However, despite some global accolades of curriculum innovation, the reality of the new curriculum has failed to engage learners in developing their digital technology acumen. It also failed to identify components and provide guidance or structure for educators to develop essential MC.

Combined with a diet of traditional national examinations focussed on content rather than MC, it has ensured crucial MC for the future has failed to materialise for many learners.

This research was driven by questions around the use of an immersive design thinking studio focusing on digital content to identify the benefits and barriers of such an approach.

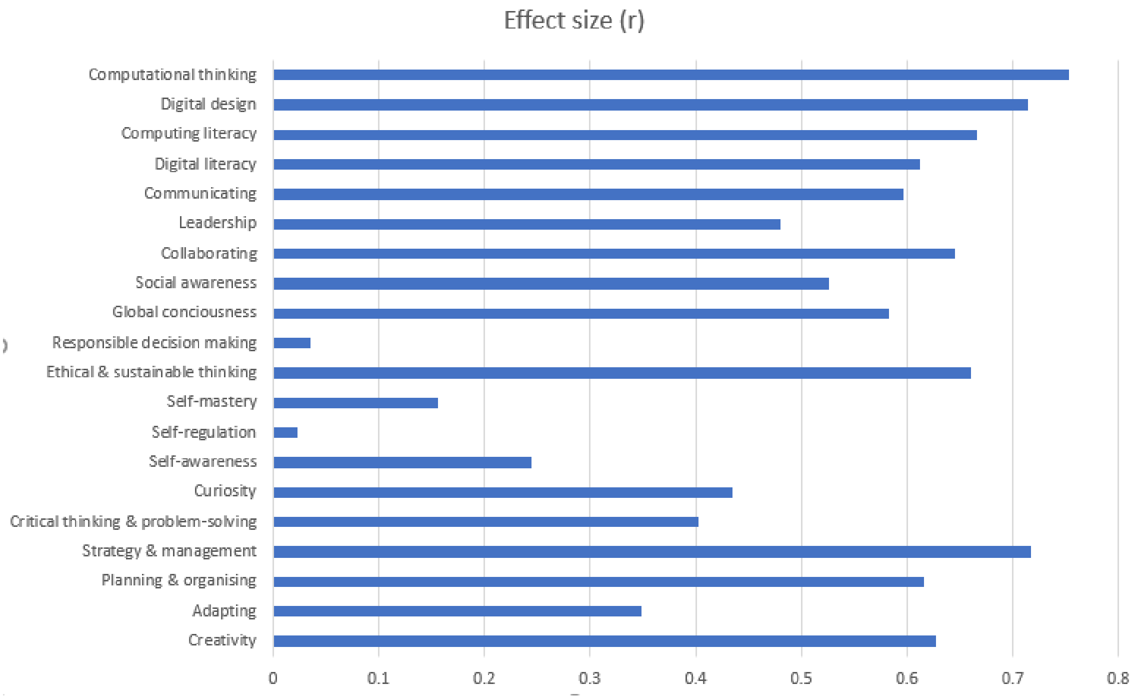
5.3 Addressing the research questions

This study's overarching question was: **'What do learners and educators perceive as the benefits and barriers of implementing a digital design thinking studio?**' This primary question was captured through five secondary RQs, which will be addressed in the following sections.

5.3.1 RQ.1 - to what extent do learners think meta-competencies are utilised during a digital design thinking studio compared with normal schooling?

Figure 51 highlights the collective MC and the corresponding effect size from this research. This illustration highlights learners' perceptions of the use of MC during the DDTS compared with normal classes. Surprisingly, twelve of the twenty (60%) MC saw a significantly large effect, highlighting that learners perceived using more MC in the DDTS than in their everyday classroom experience.

Figure 51 - All MC effect size



Successful Learner

Most of the MCs associated with the Successful Learner had a large effect. This was not surprising because the components underpin the whole DT process and are usually not aspects of normal classroom lessons. Learners were asked to be continually curious and creative while critically problem-solving and using this information to re-evaluate and adapt their next steps. All the groups expressed enjoyment at being given the freedom to come up with creative ideas and having the freedom to bring them to life. However, during the DT process, particularly when challenges presented themselves, a few learners wanted to be told what to do. They did not want to manage themselves as they found it exhausting and tiring.

Confident Individual

The components of the Confident Individual saw the least amount of effect size of all the capacities. Learners acknowledged their ability to reflect, self-regulate and readjust their purpose continually; they also discussed their perseverance, grit, persistence, as well as their ‘can-do’ growth mindset approach; areas they suggested they were not necessarily accustomed to developing in normal class; however, this did not correlate with the quantitative data. This was an interesting anomaly, and I questioned the learners’ understanding of the vocabulary used in the MC questionnaire, for example, self-mastery.

Responsible Citizen

Two of the three aspects of the Responsible Citizen saw a large effect size, with ‘Ethical and sustainable thinking’ (r=.6598) and ‘Global consciousness’ (r=.5829) having a large effect size and ‘Responsible decision making’ (r=.0358) having a nominal effect size. This might suggest that learners felt their experience of making responsible decisions was comparable to their normal class experience. Learners commented that they liked having the big picture presented to them and could see where they were going and that they were taking positive affirmative action towards it. They also acknowledged their excitement in participating in something bigger.

Effective Contributor

The components of the Effective Contributor all had a large effect size. This was not surprising as the premise of the DT process is centred around developing empathy, social perceptiveness, working in teams, empowering others, and communicating. Learners particularly enjoyed having the autonomy to converse and collaborate, which led to deeper learning; every group highlighted this positively. However, some learners felt there were times that they needed quiet time to think, and in the DDTS, they never quite got that.

Digitally Astute

All the Digitally Astute components saw a large effect even though only one group was specifically involved in writing programming code. Using CAD software, digital eportfolios, online researching and communication, digital photography, laser cutting, and 3D printing ensured learners felt they were using digital tools in a real-life scenario. Learners were asked to compare the DDTS with normal classes, for example, mathematics or geography, which might explain the large effect size; this might not have been the case if they were directly comparing DDTS with a digital computing class.

It was interesting that several groups mentioned they were not learning anything during their time in the DDTS. They perceived learning as obtaining knowledge and being tested on what they understood. Developing MC was deemed irrelevant because there is not a test or a system tracking and monitoring their progress. Therefore, although the approach provided opportunities for the development of MC, the focus of their concern is on examination performance and test scores rather than on the holistic development of learners.

5.3.2 RQ.2 – to what extent do learners think digital design thinking studios develop digital computing competencies?

The analysis highlights learners perceive themselves to be using digital computing daily in a more enjoyable and integrated way. They saw it as part of the learning process and used the digital tools and instruments required to accomplish their goals as a means to an end. Observations of DDTS sessions highlighted that the learners that had more technical competency and confidence were keen to help their peers in a mentoring capacity.

Each two-week session had a different focus. Interestingly, most of the groups interviewed wanted to be in the session that was fully digitally focused, building AR avatars as part of designing a game for helping others.

One of the difficulties that became known was the need for training on digital tools for both support coaches and learners. As this was the first-time learners had used, for example, Rhino, Arduino, Fusion 360, laser cutter, and a 3D printer, they needed to know how to use them. This was problematic as each group was at different stages with different requirements. This resulted in the lead coach trying to work his way around groups and help them with their next steps, which saw some groups waiting for help as the support coaches did not have the technical expertise to help. This could have been avoided if there were two experienced coaches; however, as this was not the case, asynchronous videos were created for learners to navigate if they could not act further. This resolved some '*wait-time'* issues, particularly if it was a training issue.

A few learners commented on their future career aspirations, being excited by the engineering, digital and computing options they saw in DDTS (Nikoomanesh et al., 2014).

One of the difficulties of the DDTS was the different directions that learners took, which created a time and resource issue. Everyone was at a different stage with different needs. It made it difficult to track who had application experience of which aspects of digital technology. It would be crucial to have some system to track and monitor learners' uses of digital technologies over time to ascertain gaps and next steps.

5.3.3 RQ.3 – do learners feel challenged and motivated by this type of

learning?

Learners consistently acknowledged that they were engaged and challenged in the DDTS often more than in normal class. However, it was also apparent they did not consider themselves to be '*learning*' as there was no '*examination*', and it was fun. The importance of identifying explicitly the MCs that are being developed and have some tracking and monitoring system would highlight the advantages of the DDTS to learners.

Learners commented positively on their autonomy and felt challenged by the real-world, hands-on, original, active learning approach. However, some compared their experience with others' groups and sessions and were disappointed.

Most groups were engaged in what Stables (2013) would term a '*successful project',* where it is challenging enough to create excitement and enthusiasm but was still attainable. Three scenarios were identified that led to an '*unsuccessful project'* and thus demotivated learners (Bond et al., 2020). Firstly, learners quickly became frustrated and annoyed if they took on a task too big or too hard for them. Secondly, if they were not in agreement with the rest of the group regarding the direction of travel, some learners isolated themselves, and it took a lot of coaching to get their mindset back on track. Lastly, one of the biggest demotivators for learners was being *'stuck'* with nothing to get on with as they waited for help. This is certainly an area that needs thoughtful consideration. I feel that having two dedicated DT coaches with learners for the whole session, with support coaches popping into cascade the DT approach to them, would have been ideal.

Having ownership of the project was both exciting and frustrating for learners.

They would persevere in overcoming challenges and think about it constantly; however, this was tiring for some who felt they were working their brain '*harder*'. There was also stress when things were not developing as they hoped, as they felt the full responsibility for delivering their project. Hence, the desperation from some groups when they realised the deadline was looming for sharing with an audience.

Despite awareness of DT as a process, it was clear that some of the support coaches were not familiar with the practical applications of DT. They struggled with the lack of structure and found themselves '*telling*' learners what to do rather than guiding and supporting them. This correlated with Carroll et al. (2010), who acknowledged the importance of having coaches that were familiar with the process involved. Learners commented that after having autonomy, they did not like being '*told*' what to do by some support coaches.

Learners were motivated by the creative process and having their conceptions materialise, reinforcing the study outcomes by Haller-Seeber et al. (2020) that learners were motivated by hands-on learning. This was particularly true of learners who typically struggle with normal classroom environments. They loved the freedom to move about and talk whenever they wanted. They would often discuss ideas with other groups, and some were motivated and took charge of their group in the studio environment. Many educators commented on the *'difficult'* learners from their classroom who seemed to be excited and thriving in this learning environment, which correlated with Riedinger and McGinnis's (2017) and Doppelt's (2008) findings. However, other learners were easily distracted in the busy environment.

Some learners loved the immersion side of the studio experience and found that they could get *'their teeth into it',* which aligns with Wright's (2018) immersion studio research in Australia, which found it was an effective way to engage and educate learners. However, some learners disliked being in the same room with the same people all day and would have preferred it was just a couple of half days a week. A unanimous change implemented in the first few days of running the DDTS was that regular breaks needed to be incorporated throughout the day, including outdoor walks to 'clear the head'.

Many educators and learners commented positively on the coaches' role, preferring it to the direct instruction given in normal class. The DDTS reframes the relationship between the learners and the educator, which correlates with Wright et al.'s (2018) findings.

Learners seemed motivated to research and discuss global issues and topics not discussed at school (Haller-Seeber et al., 2020, p.7); however, some learners found the independent inquiry and research activity frustrating and challenging (Reynolds, 2016).

Learners were very motivated by the studio's collaboration, teamwork, and social environment. They were co-constructing knowledge, discussing perspectives, opinions and views while actively developing crucial interpersonal skills. It was clear that learners had differing social and emotional competencies; some empowered others, effectively negotiating and convincing them; equally, they dealt with set-back better and reframed their mindset quicker. It was clear these were not competencies developed in normal classes or some households, and it was interesting to observe learners to see how others effectively handled situations.

5.3.4 RQ.4 – how do participants perceive formative assessment practices?

Learners perceived their self-and peer-assessment to be straightforward, particularly because it was online and built into their daily process. Overall, learners felt this was meaningful and helpful and highlighted their learning journey much better than a test score and were certainly much less stressful. However, a couple of learners stated they would prefer to sit a test and could not see the value in acknowledging strategies and processes.

Most learners enjoyed using the SRE, and every other day, learners were given self-reflection prompts (see Figure 41 and Figure 42) to help guide them through the process. It was evident that some learners saw this as an inconvenience and felt that they were just logging what they had achieved that day and not necessarily their reflections about it. Interestingly, the two learners who were reticent about their use were both absent during the explanation of the purpose of the SRE, highlighting the crucial importance of explaining to learners *'why'* they are doing it, which potentially reinforces Pink's (2011) theory that purpose is core to motivation. This is key for educators too, who need to understand the bigger picture of why learners are self-reflecting and setting their own goals and how this has an impact on improving a learner's ability to think about what they are doing, how they can do it better, and what they should do next.

Many of the interactions were at a metacognitive level (Savery et al., 2001), and learners and educators were continually challenging each other's thinking with probing questions. Learners genuinely seemed to cherish receiving feedback from each other and other groups; they enjoyed the interaction and sharing of ideas and problems. It created an environment where no one felt they had all the answers, where everyone was trying to do their best and readily accepted help from others. It encouraged a growth mindset and can-do attitude, where no project or task was too big to attempt. Their only limitation was their imagination.

There were concerns that some learners held back from being honest in their writing because the self-reflections were shared with the whole class. This could be circumnavigated by just the lead coach looking over their reflections in private.

It was interesting that several of the educators acknowledged formative assessment as more beneficial for the learner as it fully involved them in their decision making and next steps and that feedback was more beneficial than a test score; it also gave them a better insight into learners' thoughts and understanding. However, a few educators commented that it was difficult to track and monitor the '*learning*' of competencies and that it is '*easier*' to do a test or examination and record results. This resonates with Tam (2000) and Dick (1991), who highlight how difficult it is for educators to evaluate using constructivist methods; learners constructing their meaning and going off on their personal learning journey makes it notoriously difficult to make the learning *'visible'* (van Hover & Hicks, 2017).

Some educators and learners quickly identified that DDTS is not about the finished product; it is about the learning journey and sharing ideas, thoughts, perspectives and co-constructing knowledge through discussions, informal conversations and showcasing their work. The lead coach effectively supported teamwork and dialogue and encouraged learners to express new ideas and ask questions.

Most learners quickly adapted to the ambiguity and embraced the pursuit of *'correct'* answers. There were often multiple ideas, and learners had to justify their thought processes to others, combine ideas, and feed off each other. Many learners acknowledged that they worked as a team and had better ideas together, and they were not afraid to say they did not know something.

5.3.5 RQ.5 – to what extent do learners think a digital design thinking studio develops learners' metacognition?

The development of MR was apparent in all the data gathered. During interviews, all the learners mentioned that using the SRE helped them think 'better.' Clearly, making their thinking visible (Hattie, 2008) enabled them to discuss, reflect, and readjust their next steps. There were some anomalies in the results; for example, time management was positive in the MAI but negative in the interview and SRE entries. This could be explained by the fact that students associated MAI with learning in general and the other two methods with the specific DDTS task where time was an issue.

While learners' perceptions of their abilities to analyse (IMS – 75%) and correct errors (D – 82%) started from a position of strength, all the components of MR saw an increase following the two weeks of DDTS. Initially, students felt less confident in their P, CM and E skills; however, following the use of the DDTS, both CM and E improved significantly. E was also the heaviest coded marker on the learners' SRE, which directly contrasts with the results from Sapientiae and Wozniak's (2015) study into teachers' use of SRE, which found their E skills weak. This might suggest that the development of self-evaluation formative assessment strategies within schools are helping to improve evaluation skills (Carless & Boud, 2018). Learners' SRE highlighted many E and P entries (see

Figure 44), which the nature of their task could explain. DDTS, by their very nature, involves continual iteration; it would be interesting to use a control group and continue this research into other subject areas.

All the learners commented on how much the SRE made them think about what they were doing outside of class; they could access it 24/7, allowing them to share what they were doing with family and friends. Many learners commented on how proud they were to share their SRE at home. Hattie (2008) has identified the importance of connecting learning with the home and parents (Johannesen, 2013; Vasinda & McLeod, 2011). Peers were also identified as useful mentors (Hadley, 2007), and they learned a lot from each other; looking at classmates' posts/comments made them think more about what they were doing and why and how they could change it.

5.4 Contribution to education

This research study contributes to the discussion about current educational challenges. In the first instance, this study provides insight into our understanding of the benefits and barriers of an immersive DDTS in a secondary school setting. It provides a 'warts and all' approach for educators interested in knowing more about this approach or indeed looking to develop their own DT approach.

This research provides a significant opportunity for understanding a new DT-based education paradigm that focuses on abductive reasoning and cognitive skills like curiosity, innovation and critical thinking, and the development of social skills such as empathy, facilitation, and collaboration. To identify its potential, an analysis of several key global 21st-century learning perspectives, alongside current research, provided a MC framework critical for providing guidance and structure for a personalised competency progression in learners.

One goal of this paper was to present DT as a detailed instructional model and show how DT is consistent with the principles of instruction arising from SC. It also sought to provide a clear link between SC theory and practice.

"Constructivism can provide unique and exciting learning environments; it is the challenge for practitioners to engage the learners in authentic and meaningful tasks and evaluate learning using assessment methods that reflect the constructionist methods embedded in the learning environments" (Tam, 2000, p.58).

To this end, identifying the critical tenets underpinning SC were highlighted and explored, providing the key principles for educators looking to develop this pedagogical approach with learners. The correlation between SC and DT was presented along with an educational DT model suitable for novice educators to potentially adopt. DT provides a formalised process for creating learner-centred learning experiences through its meta-disciplinary methodology, which offers educators the support they need through its signature pedagogies, methods and processes which organically lend themselves to developing the much-needed MC in learners.

The research findings are significant in highlighting the potential of a DT approach to developing MC, particularly digital, in learners. This study highlights how a human-centric, empathy-focussed pedagogical approach, underpinned by SC, encourages many learners to become more motivated and actively engaged with their issues. It also highlights the potential of formative assessment processes, including SRE, to enhance learners' metacognitive processes; learners are encouraged and expected to think creatively and critically and monitor their learning journey.

"So, as we contemplate the very structure of schooling – divided by age and tested through exams – perhaps it is time to introduce new methods and new measurement?" (Leask, 2021, p.13)

DT provides a set of principles and strategies to create learning environments where learners are engaged in negotiating meaning and socially constructing reality. However, this should not be considered the only solution to developing SC principles in learning but merely a useful tool for educators. There are many obstacles and challenges with employing a DT approach identified in this thesis (management, curriculum). Therefore, it is not considered appropriate for all learners; instead, educators should reflect and adapt their methodology accordingly to their learning environment and needs. However, this alternative approach could be a powerful tool for educators to create new and original teaching methods and consider the potential benefits; it should make it a sincere consideration.

However, widespread adoption will require a systematic transformation of practice and recognition of the value of formal and informal connected DT learning environments and experiences. This will require a systematic change from those in charge of policy to familiarise themselves with the current challenges and potential solutions.

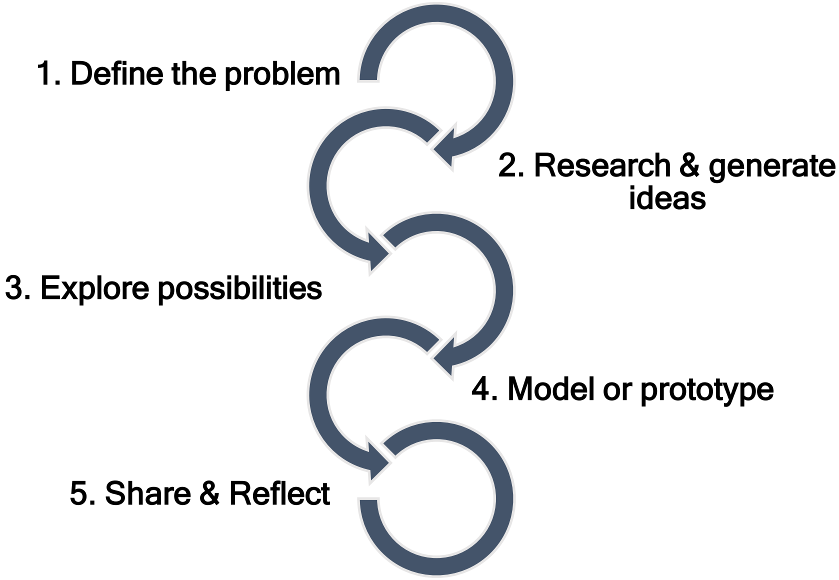
Supposing expertise using DT is cultivated in schools through innovative educational interventions coordinated, in that case, it is proposed that this experience may better prepare learners for concurrent and future participation and engagement in the world they are to inhabit.

5.5 Contribution to theory

This research makes several contributions to theory. Despite CfE's adoption of constructivism principles, many educators would struggle to identify these and the implication for classroom practices (Brophy, 2002). DT can be a missing link between theory and pedagogical science (Scheer et al., 2012). The difficulty for educators transitioning from awareness of the tenets of SC to then applying them in practice was felt to be made more difficult because SC is principally a theory of learning focusing on the nature of knowledge and knowledge construction (Brophy, 2002).

To address the challenges above, this research made five contributions to theory. Firstly, it identified, categorised and exemplified the tenets of SC for assimilation into educator's practice. Secondly, it identified the essential MC required of learners and created a framework of outcomes, experiences and exemplification. Thirdly, it proposed an educational DT model (see Figure 26) that encapsulates all fundamental tenets of SC in its process to help guide and build stronger theoretical and empirically grounded connections between research and classroom practices.

Figure 52 - Proposed Design Thinking Model for Schools - repeated from Figure 25 for clarity



Fourthly, it identified the benefits and barriers of adopting this approach in the classroom. Finally, it suggests a possible relationship between the underlying principles of SC through the formalised process of DT in developing essential MC in learners.

5.6 Filling a research gap

There is a shortage of empirical research to inform educators of the potential benefits and barriers of a DDTS and a dearth of literature on how they might develop their own DTS. This study addresses this gap in the literature by identifying the advantages and the challenges of implementing a DDTS (see Table 20).

Table 20 – Summary of the main barriers and benefits identified in this research

Barriers	Benefits
• Learners took various personalised learning paths, making it challenging for educators to track and assess their learning. • A couple of groups found it difficult to motivate themselves to work with the same people on the same project all day and would have prefered more direction. • Some educators found it difficult to adopt a more hands-off role and wanted to 'tell' learners what to do. • A few participants struggled with the lack of structure and classroom management. • Learners disliked extended 'waiting' for help to move forward. • Many learners disliked that each group had a different theme and would have preferred to have the same. • Some educators and learners found it stressful to 'lose' two weeks of class time, particularly mathematics and English, who 'lost' ten sessions each. Some felt this impacted their preparation for their stressful examinations. • Some learners struggled with self-regulation. • Some learners felt they didn't 'learn' anything during the DDTS because there was no examination and no 'focus' on the MC. • Some learners were not clear on the purpose of SRE.	• Learners enjoyed being active and hands-on and bringing their ideas to life. • All groups enjoyed choosing a real-world problem-solving project to work on and using 'real-world' data and primary research. • All groups enjoyed and were motivated by the social interaction, collaboration and co-construction of knowledge. • Most learners enjoyed the coach's role who facilitated and supported them. • Most learners loved autonomy, responsibility and accountability. • Twelve of the top twenty critical MC saw a 'large' increase in their use in the DDTS compared with normal school (see Figure 51). • Most learners enjoyed keeping a SRE and sharing continual updates of their plans and progress, culminating in a final presentation. Many deemed this fun with very little anxiety compared with stressful examinations. • Learners enjoyed the autonomy and freedom they were given to develop projects that they found motivating and engaging. • It was learner-centred with learners' past experiences optimised and extended; it was personalised to an individual's passions, interests and ZPD. • Learners felt they 'worked harder' as their own taskmaster. • Learners were proud of their accomplishments. • Learners felt they inhanced their metacognition

The research looks to analyse the experiences and perceptions of learners and educators involved, particularly pupil engagement, and the scope for developing a MC culture.

This research helped address a substantial gap in understanding the outcomes of using DDTS in a school setting. With no known current research examining the use of a DDTS in the development of MC, this study furthers the understanding of such an approach with young secondary school learners.

5.7 Limitations of the research

This study has several limitations. There was a dearth of empirical research on DDTS in schools. The study is limited to one secondary school setting, and the participants are educators and learners timetabled into the DDTS sessions. The DDTS sessions are mandatory and integrated into the timetable, unlike the DTS summer schools, which were voluntary. Therefore, this study recognises that some educators and learners might fundamentally dislike change or this learning style. It is recognised there was a small sample size due to the scale of the research and the time available. As an independent school with an average class size (n=16), it is recognised as an unrealistic *'normal'* class size for most schools, altering how the findings might be used.

The mixed-methods approach endeavours to provide a detailed, full description; however, it is recognised that this is unlikely to be replicated. It should be acknowledged that educators that volunteered for the interviews could have a strong opinion at either end of the spectrum. I was cognisant that learners needed to have terminology at a level they could understand and relate to, so they could respond appropriately; however, there are anomalies in the research that suggest learners' understanding of key terminology varied. Another limitation is that although a mixed-methods methodology was employed, the data collected were self-reported and dependent on the experiences and perceptions of the participants. Thus, the study was limited to the beliefs of the educators and learners and their willingness to express their feelings and insights. There was also no control group used for the MAI questionnaire to use as a comparison.

As an opportunistic exploratory case study, it has several associated limitations. As a case study, it allowed for a lot of detail to be collected from a real-life setting that would not typically be easily obtained. However, as with all case studies, it raises subjectivity, validity, and reliability questions. As the primary researcher collecting data, it was necessary to keep in mind the dangers and criticisms usually associated with case studies and take precautions and care to avoid them or minimise their consequences, particularly the subjectivity of data analysis. One of the most significant disadvantages is the small sample of participants from one school, limiting the ability to generalise these findings to larger populations. Case studies are synonymous with selection bias; however, this was outwith my control as everyone involved in the studio experience was included in the research. Therefore, the research results should be considered formative and viewed with caution as to the extent to which these results can be applied in other contexts and situations.

To do the research justice and provide pertinent findings, it attempts to capture the full DDTS experience. To facilitate the breadth of understanding of DDTS, some areas could not be captured as fully as I would have liked, for example, the MC framework, due to a limit on word count.

Furthermore, although several international educational research databases were searched, only literature published in English was included in this review. Another limitation is that only DT research published within the 2008–2021 period was investigated. Whilst I am cognisant of this restriction, it is the period that DT started appearing in educational discourse and relates more meaningfully to the current situation. The inclusion criteria (see Appendix 9) are included to ensure a level of rigour and validity to the study, although it is acknowledged that the literature captured differs in empirical quality.

Finally, whilst the previous studies were diligently read, analysed, and coded, and differences discussed and resolved, the human shortcoming of having omitted or misinterpreted information provided in the individual articles cannot fully be excluded.

5.8 Suggestions for further research

Despite the limitations identified above, this opportunistic case study captured the potential of a DDTS to develop the essential MC in learners in an engaging and challenging way. The need for further research in this area, in particular the implementation and evaluation of the DT model identified in this thesis, is recommended to understand the impact the process has on learner motivation and the development of MC in learners. It would be prudent to examine practical applications of the six-step '*DDTS educational model'* with collaborated refinements to help identify a working model for novice educationalists wishing to embark on DDTS.

Further data are needed to provide a more nuanced understanding of how we can effectively engage and challenge learners. Indeed, a larger sample would provide more comprehensive data on how this might be adopted with various age groups. A longitudinal study examining the development of digital competencies through such an approach would be useful.

An examination of using SRE and a personalised MC framework for entry into an apprenticeship, further education and the workplace instead of high-stake examinations is of critical importance if we have any chance of reshaping the principles of the current education system.

Further longitudinal studies into the development of MR using DDTS and SRE would be valuable, as would studies where DT and SRE were integrated into 'normal' class settings. Examining (Pink, 2011) aspects of motivation using DDTS and SRE would be a valuable addition to research in this field, particularly as Ibabe and Jauregizar (2010) found that the use of SRE resulted in better academic performance, particularly in low motivation students.

5.9 Chapter summary

This chapter summarises the research and discusses the RQs in depth. It pulls the research together to summarise the findings while identifying the contribution to theory, education, and its success in filling a research gap. Limitations of the research are presented, as are suggestions for further research.

Chapter 6. Conclusion

The current education system in Scotland requires a radical overhaul to embrace the MC required by 21st-century citizens, particularly digital computing competencies. Having established challenges with the current education system, it was crucial to look for potential solutions to this phenomenon. To this end, I devised a framework of MC to lend structure and guidance to CfE's aspirations of Successful Learner, Confident Individual, Responsible Citizen and Effective Contributor. In addition to these areas, an additional category of Digitally Astute was attached to acknowledge the critical importance of this area in the lives of learners. Identifying a MC framework was the first step (the what), followed by highlighting the tenets of SC, which is considered a good 21st-century pedagogical process to underpin the learning process and this research (the why). This was followed by adapting a DT approach, considered an innovative pedagogical framework (the how), to focus on digital competencies in an immersive studio setting, resulting in creating a DDTS. An educational DDTS model was designed and recommended for ease of use in an educational setting with design thinking novices.

This research aimed to critically analyse the benefits and barriers of using a DDTS in a school environment, examining the development of MC and learners' perceptions of motivation, challenge, and formative assessment practices – all concerns of our current education system. There is a need for education systems, schools, and educators to move from providing curriculum and traditional education processes to co-creating curriculum, employing engaging pedagogy and navigating learning networks (McWilliam & Haukka, 2008). To support the development of MC, education will need to reinvent itself as knowledge creation (Bereiter & Scardamalia, 2006), facilitating a systematic transition from traditional epistemology of direct instruction and regurgitation for examinations to enhancing learning through a design epistemology (Lim et al., 2013) and creating a transition from the transfer of knowledge to the development of individual potential.

Challenges from 4IR, low digital technologies uptake, disengaged learners, as evidenced by the increase in unauthorised absences and truancy rates[37], growing poverty-related attainment gap, increasing digital skills gap (Meechan, 2021), global (PISA, 2018) and national (The Scottish Government, 2018), evidence of a declining education system and weak economic growth (BBC, 2018) suggest a need for a radical rethink of Scotland's CfE system is long overdue.

Scotland's response has been to create a '*National Improvement Framework'*[38] (NIF) focusing on six aspects of education: school leadership, teacher professionalism, parental engagement, assessment, school improvement and performance information. Although these drivers of improvement are commendable and worthwhile, they do not address the fundamental issues. Barnett (2014) argues that educators need 'to give serious attention to the potential for radical educational innovation, concerned with learners who have to make their way in a challenging world' (p.9). The failure to recognise this and investigate a radical overhaul to education will only be compounded by the

[37] Scotland's Education Attendance Statistics - https://www.gov.scot/Publications/2017/12/3099/348579

[38] Scotland's National Improvement Framework - https://beta.gov.scot/policies/schools/nationalimprovement-framework/

exponential changes during the 4IR (Ford, 2016) and the challenges that automation, robotics, big data, and AI will inevitably bring.

Barnett (2014) argues that curricula that develop graduates that are “inflexible, unable to respond to strangeness, to the challenges and new experiences that the world presents – is short-changing its students”. The DDTS model of SC education develops all of the key MC; however, little research on its potential impact in schools is evident from my literature review. To adopt DDTS into schools would require radical changes to our current system and a complete redefinition of educator training. Nevertheless, it is hard to imagine such a *‘disruptive’* change to our current system. Cranmer and Lewin (2017) highlight that ‘*incremental innovation’* (p.411) is a more effective and permanent solution when introducing new pedagogy; however, as a nation, we are already falling behind, and therefore we do not have the luxury of time as countries around the world focus on disruptive pedagogical changes to their education system.

Finland has made a radical change by implementing its ‘Phenomenon’ approach, encouraging interdisciplinary, real-world learning. However, it could be argued that a DDTS model enhances even more MC through its unique approach.

However, it would be unrealistic to think that DDTS can facilitate every type of learning situation; in theory, a combination of ‘Phenomenon’ and DDTS could provide an excellent 21st-century constructivist education system. Both systems encourage learner-centred activities, enhancing engagement in a real-world setting and developing many of the same MC. Both encourage metacognition, brainstorming, problem-solving, goal setting, exploring topics, knowledge construction, and self-reflection, with the teacher giving appropriate guidance and feedback. Meeting the needs of every learner and providing a personalised learning journey has its challenges.

This study's findings highlight that learners perceive all twenty MCs to be cultivated more during DDTS; indeed, 60% of them have a significantly larger effect size than their experience arising from normal schooling. However, despite this finding, most learners perceived themselves not to have learned anything of *'value'* during their time in DDTS, emphasising the crucial need for education systems and educators to identify, scaffold and promote the development of MC.

This research also highlights that learners in the DDTS environment are actively engaged in working on projects, tasks and activities which are authentic and relevant. The focus is on learners as constructors of their own knowledge in a real-world context. It puts ownership of learning in learners' hands and provides multiple lenses and viewpoints. They can develop a host of MC in agency, responsibility, confidence, creativity and engage in processes that provide opportunities to take risks and celebrate successes.

This study emphasised that the DT approach is a potentially adaptable tool that may be integrated into reflection models to transform learners into reflexive learners and transform SC learning into action by providing educators with a formalised process to engage learners. The more that learners operate on the edge of their capability and are supported by peers and educators, the more they learn and the better they engage with the material in higher orders of thinking (Skills Development Scotland, 2017). This study is relevant in this context because it highlights how a human-centric, empathy-focused pedagogical approach encourages learners to become more actively engaged with issues around them, giving learners “time, access to materials, and people to connect with, creates opportunities for invention and creation” (Becker, 2016, p.195). This new learning culture draws on socially embedded, authentic, interest-driven, and technologically rich learning opportunities, actively supporting individuals to engage with formal and informal learning that fosters personally meaningful life-long learning encouraging curiosity, collaboration, passion, and play.

More importantly, the MC imparted through DT, such as creativity, problem-solving, innovation, curiosity and critical thinking, social skills of empathy, as well as collaboration and leadership, go beyond specific knowledge-focused fields and lays a sound base for any career, demonstrates how DT-based education programmes could be a beneficial paradigm to be adopted.

The use of DDTS in schools could help engage and motivate those currently disengaged learners, in turn improving truancy and dropout rates in school and could begin as young as primary school (Freimane, 2015). Engaging learners in real-world, authentic, problem-solving scenarios underpinned by digital technologies could prove to be a catalyst for improving digital computing uptake in learners. Having digitally-skilled DT coaches that qualified educators assist could also address the critical educator shortfall while promoting STEAM careers (Noel & Liu, 2016; Tschimmel, 2019).

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Appendix 1 – Chart analysis of 21CC

	EU	OECD 2030	ATC215	P21	SS	WEF	NRC	CfE
Foundational Literacies	Literacy competence Languages competence	Disciplinary, Interdisciplinary, Epistemic, Procedural		English, reading or language arts World languages	Effective oral and written communication	Literacy	Oral and written communication active listening	Literacy
	Science, technological, engineering and mathematical competence			Mathematics Economics Science		Numeracy Scientific literacy		Mathematics & Numeracy Science
	Civic competence Cultural awareness and expression competence		Citizenship (local & global)	Arts Geography History Government & Civics Civic literacy Environmental literacy Social & cross-cultural skills		Civic literacy Cultural literacy	Artistic and cultural appreciation	Expressive Arts Religious & Moral Social Subjects Citizenship Heritage Community Learning
	Entrepreneurship competence		Life and career skills	Health literacy Financial, economic, business and entrepreneurial literacy		Financial literacy	Physical and psychological health	Health & Wellbeing Enterprise Sustainability Financial Career
			Information literacy	Information Literacy Media Literacy			Information literacy	
	Digital competence		ICT literacy	ICT literacy		ICT literacy	ICT literacy	Technologies
Competencies		Cognitive & meta-cognitive	Learning to learn, meta-cognition		Accessing and analysing information		Cognitive processes and strategies	
			Creativity and innovation	Creativity and Innovation		Creativity	Creativity and innovation	Creativity
			Communication	Communication		Communication	Communication	Communicate in different ways and in different settings
			Collaboration, teamwork	Collaboration	Collaboration	Collaboration	Teamwork and collaboration	Work in partnership and teams
			Critical thinking, problem-solving, decision-making	Critical Thinking and Problem Solving	Critical Thinking & Problem Solving	Critical thinking/problem solving	Problem-solving Critical thinking	Problem-solving
								Critical thinking in new contexts
								Create & develop

	EU	OECD 2030	ATC215	P21	SS	WEF	NRC	CfE
Character Qualities – Soft Skills	Personal, social and learning competence	Social & emotional	Personal and social responsibility	Global Awareness		Social and cultural awareness	Personal and social responsibility	Commitment to participate responsibly in political, economic, social and cultural life
				Leadership and responsibility		Leadership	Leadership	
				Flexibility & adaptability	Agility and adaptability	Adaptability	Adaptability Flexibility	
				Initiative and self-direction	Initiative and entrepreneurs	Initiative	Initiative	Take initiative & lead
					Curiosity and imagination	Curiosity	Intellectual interest and curiosity	
						Persistence/grit	Perseverance, grit	
		Physical & practical Attitudes & Values: • *Personal,* • *Local,* • *Societal,* • *Global*		Productivity and accountability			Continuous learning Adaptive learning Interpretation Integrity Cooperation Decision-making Responsibility Ethics Self-direction Self-presentation Social influence with others Intellectual openness Citizenship Career orientation Appreciation for Diversity Self monitoring Self evaluation Self reinforcement Analysis Reasoning and argumentation	Enthusiasm Motivation Determination Openness to new thinking and ideas Independent Respect for others Ethics Relate to others and manage themselves Be self-aware Ambition Enterprising attitude Resilience Self-reliance

Appendix 2 – Proposed meta-competencies framework: Successful Learner:

Successful Learner	Sub-competence	Description	Experiences & outcomes	Tasks & Activities	Cognitive outcomes
Overarching competence				*Tasks & activities the learner would actually 'do'*	*The skills, strategies and concepts that are being developed*
SL1 - Creative intelligence	SL1.1 - Observing	Generate business ideas by observing the world	SL1.1.1 - I have a continuous flow of new business ideas that comes through observing the world. SL1.1.2 - I scrutinize common phenomena and everyday experience to get new business ideas. SL1.1.3 - I observe the activities of customers, suppliers, and other companies in order to gain insights and new ideas. SL1.1.4 - I try different techniques to see the world in a different light.		
	SL1.2 - Associating	Come up with new ideas through associations	SL1.2.1 - I connect seemingly unrelated questions, problems or ideas from different fields. SL1.2.2 - I understand, categorize and store new knowledge in a way where I can consistently make, store and recombine associations.		
	SL1.3 - Questionning	Ask questons to develop new ideas	SL1.3.1 - I ask questions that challenge common wisdom and the status quo. SL1.3.2 - I ask others to justify themselves and challenge their assumptions. SL1.3.3 - I ask questions to understand why products and projects underperform.		
	SL1.4 - Conducting experiments	Generate new ideas through experimentation	SL1.4.1 - I conduct experiments to understand how things work and to create new ideas and new ways of doing things. SL1.4.2 - I seek diverse experiences and leverage those experiences to generate new ideas.		
	SL1.5 - Networking	Build a trusted network of diverse individuals to spark new ideas	SL1.5.1 - I go out of my way to meet people with different kinds of ideas and perspectives to extend my knowledge. SL1.5.2 - I have a large network of individuals with whom I frequently interact to get new perspectives and refine new ideas. SL1.5.3 - I attend many diverse professional and/or academic conferences outside my industry/profession. SL1.5.4 - I initiate meeting with people outside my industry to spark ideas of new products, services or customer bases.		
SL2 - Effectual reasoning	SL2.1 - Iterating and pivoting	Am flexible, adaptable and take advantage of opportunities	SL2.1.1 - I consider failed experiments or unintended outcomes opportunities to learn about what my startup could do better. SL2.1.2 - I try different approaches until I find business models that work.		
	SL2.2 - Acting resourcefully	Utilise existing resources	SL2.2.1 - When I seek to build a new venture, I start by considering what I know, what resources I have, and what I can do with those things. SL2.2.2 - I always adapt what we are doing to the resources we have.		
	SL2.3 - Forming partnerships	Build partnerships to support my ideas	SL2.3.1 - I focus on building partnerships, even if they might later become rivals, rather than beating competitors. SL2.3.2 - I reduce uncertainty in the early stages of creating an enterprise by obtaining pre-commitments from key stakeholders, suppliers or customers.		
	SL2.4 - Calculating affordable losses	Think in terms of affordable losses	SL2.4.1 - I think it terms of affordable loss rather than expected returns, deciding what I am willing to lose rather than what I expect to make. SL2.4.2 - Instead of calculating upfront how much money I need to launch my project, I estimate the investment of time, money and other resources that I am willing to lose.		
SL3 - Planning & Organisation	SL3.1 - Taking the initiative	Assess and initiate things independently	SL3.1.1 - I initiate processes that create value SL3.1.2 - I take up challenges SL3.1.3 - I act and work independently to achieve goals, stick to intentions and carry out planned tasks SL3.1.4 - I set priorities and focus on realistic goals		Synthesising knowledge,
	SL3.2 - Product management	Develop steps for a product's life cycle	SL3.2.1 - I create, define, classify and apply business models SL3.2.2 - I define product features SL3.2.3 - I oversee development of product, process, and business models SL3.2.4 - I orchestrate product launch/release	Creating processes, canvas business model, market types TAM & SAM, Agile project management, lean start-up	System thinking, business modelling, development of new products and services
	SL3.3 - Resource allocation	Gather and manage the resources you need	SL3.3.1 - I locate and manage the material, non-material and digital resources needed to turn ideas into action SL3.3.2 - I make the most of limited resources SL3.3.3 - I explore and manage the competences needed at any stage, including technical, legal, tax and digital competences	Navigation of resources, discernment of resources, organising, supervising, standardising	
SL4 - Strategy & Management	SL4.1 - Managing complexity	Make decisions dealing with uncertainty, ambiguity and risk	SL4.1.1 - I make decisions when the result of that decision is uncertain, when the information available is partial or ambiguous, or when there is a risk of unintended outcomes SL4.1.2 - I handle fast-moving situations promptly and flexibly SL4.1.3 - I cope with ambiguity, uncertainty & risk	Goal-setting, scoping, filtering, sorting	Decision making, synthesis, troubleshooting, prioritizing,
	SL4.2 - Performance & results	Creating effective processes and outcomes	SL4.2.1 - I evaluate a product's business performance SL4.2.2 - I assess and improve business processes SL4.2.3 - I am accountable SL4.2.4 - I formulate product strategy SL4.2.5 - I evaluate business ideas & opportunities	Identifying key performance indicators,	Business skills, understanding of complex data, Information sourcing, data organisation, synthesising critique
	SL4.3 - Professionalism	High standards in the work you do and the way you behave	SL4.3.1 - I take ownership and responsibility for my work and plan and prioritise work effectively SL4.3.2 - I honour all confidentiality, legal, safety or compliance obligations SL4.3.3 - I prioritise, take initiative and make decisive actions SL4.3.4 - I have a professional appearance appropriate for the environment SL4.3.5 - I am reliable and punctual and value integrity, honesty, and keeping promises	SLffective time-management, developing business relations,	
	SL4.4 - Financial & economic literacy	Financial and economic know-how	SL4.4.1 - I estimate the cost of turning an idea into a value-creating activity SL4.4.2 - I plan, put in place and evaluate financial decisions over time SL4.4.3 - I manage finance to make sure value-creating activity can last over the long term SL4.4.4 - I aspire to create public value through wielding influence, generating positive social impact and generating wealth	Business ethics, business trend awareness, research application, deal-making, macroeconomic analysis	Attraction of financing, legal aspects of establishing an enterprise, general principles of financial accounting
SL5 - Critical thinking & problem solving	SL5.1 - Data collection	Curating and managing data	SL5.1.1 - I select appropriate digital tools to assemble, evaluate and utilise information SL5.1.2 - I identify challenges in collecting the data and how to overcome them SL5.1.3 - I use formal and informal methods to gather the widest range of information possible SL5.1.4 - I carry out sustained, in-depth investigations, obtaining information that is difficult to get hold of	Image associated ideas, word association,	Identifying data sources, structuring data, data visualization
	SL5.2 - Analysis	Extracting meaning or solving a problem from relevant material	SL5.2.1 - I identify essential elements of the issue/object of analysis and select appropriate methods SL5.2.2 - I conduct analysis and identify key issues, opportunities, risks and challenges SL5.2.3 - I ensure my deductions are sound and valid and my inferences fit relevant evidence and are accurate SL5.2.4 - I analyse relevant information using strong logical reasoning SL5.2.5 - I question the credibility, accuracy and relevance of information and sources SL5.2.6 - I understand and articulate patterns, cause/effect relationships and critical indicators related to the current problem	P:O:A (Predict:Observe:Analyse), SWOT analysis	Logical thinking, analytical thinking, predict and anticipate, ask relevant questions, thought experiments, inverse reasoning,occam's razor, characterising problems, specifying problems, identifying critical gaps, deconstruction, lateral thinking, regression, distributions, descriptive statistics, correlation, confidence intervals, significance
	SL5.3 - Evaluating	Using criteria to make reasoned judgements	SL5.3.1 - I identify appropriate criteria and use this to judge the value of ideas and solutions SL5.3.2 - I judge the object of evaluation using appropriate evidence and/or valid criteria SL5.3.3 - I clearly articulate the connection between evidence and conclusion SL5.3.4 - I use evidence and reasoning to support thinking and follow logical procedures to draw conclusions SL5.3.5 - I frame questions, make predictions, and design data collection and analysis strategies SL5.3.6 - I identify and analyse patterns, trends, and relationships in the data or information		Information processing, sequence, compare & contrast, classify, sort, locate and collect, contextualisation, criticising, revising source quality, identifying logical fallacies, conceptualisation, cost-benefit analysis, weighing decisions, decision trees, purpose awareness, weighing intrapersonal drivers
	SL5.4 - Inferring	Deduce or conclude	SL5.4.1 - I generate and evaluate options prior to making decisions SL5.4.2 - I clearly identify/justify assumptions and provide evidence SL5.4.3 - I use strong persuasive support to present arguments and demonstrate conclusions SL5.4.4 - I develop and answer open-ended questions using higher order thinking skills SL5.4.5 - I apply critical thinking research methods and communication tools to create original work		Use precise language, reasons for options & actions, inductive reasoning, deductive reasoning, estimation techniques, interpretation, judge and decide from reasons or evidence
	SL5.5 - Perspective taking	Recognising and articulating the strengths and limitations of multiple perspectives on an issue	SL5.5.1 - I articulate the content and complexity of an issue from multiple perspectives SL5.5.2 - I analyse the strengths and weaknesses of multiple perspectives SL5.5.3 - I acknowledge appropriately my personal views or bias and identify the influences on that perspective SL5.5.4 - I consider context or incorporate different perspectives to evaluate thoughts or actions SL5.5.5 - I use an understanding of the history and culture of the organisation to create a realistic strategy		Identifying biases, mitigating biases
	SL5.6 - Interpreting	Identifying, compiling & integrating components ideas	SL5.6.1 - I identify logical connections, synergies or inconsistencies between various sources and data, supported by evidence SL5.6.2 - I make coherent integration that results in new understanding SL5.6.3 - I make inferences or predictions regarding situations or information SL5.6.4 - I bring together relevant information to inform thoughts, actions or beliefs SL5.6.5 - I synthesis the data or information, generate options and use evidence to build a case for the best response		Synthesising,
	SL5.7 - Framing scientifically	Concepts and theoretical perspectives	SL5.7.1 - I identify concepts and theoretical perspectives on how individuals, groups, and societies organise, perceive, and communicate about reality SL5.7.2 - I use multiple resources to plan, design, and execute real world problems SL5.7.3 - I use technology to collaborate and solve authentic problems SL5.7.4 - I draw on relevant thinking and best practice to inform strategy development SL5.7.5 - I demonstrate knowledge of the scientific principles, methods and processes used to conduct a systematic and objective inquiry		Identifying critical assumptions, defining variables, defining terms, modeling of the real world, academic mindset
	SL5.8 - Explaining & evaluating	'Best' solutions & why	SL5.8.1 - I evaluate answers based on concepts and presents findings and recommendations using evidence based solutions SL5.8.2 - I persist in solving challenging problems, adapting strategies and approaches as needed SL5.8.3 - I develop and answer open-ended questions using higher order thinking skills SL5.8.4 - I reflect on and learn from my own actions, prioritising, analysing situations, developing solutions		Test conclusions and improve ideas, judge value, evaluate information, develop criteria, metacognition, reflective judgement

Confident Individual:

Confident individual	Sub-competence	Description	Experiences & outcomes	Tasks & Activities	Cognitive outcomes
Overarching competence				*Tasks & activities the learner would actually 'do'*	*The skills, strategies and concepts that are being developed*
CI1 - Self-awareness	CI1.1 - Core values	Awareness of fundamental beliefs and principles	CI1.1.1 - I am consciously aware of my core values and can apply them in various situations CI1.1.2 - I reflect on how my own values and principles influence my behaviour and impact on others		Conscientiousness, extraversion, agreeableness
	CI1.2 - Personality awareness	Awareness of emotions, self, thoughts and mindfulness	CI1.2.1 - I identify and positively understand influences on my life and take responsibility for my own feelings, thoughts, wants, and actions CI1.2.2 - I accurately recognise my emotions and thoughts and their influence on my behavior CI1.2.3 - I accurately assess my strengths and limitations and possess a well-grounded sense of confidence and optimism CI1.2.4 - I am aware of my emotions and quickly and easily access and describe thoughts, wants, & feelings under stress		Self-acceptance, openness, observing
	CI1.3 - Motivators	Stimulus to do something	CI1.3.1 - I am aware of the motivators that drive me to achieve my goals CI1.3.2 - I use extrinsic and intrinsic motivators at different times for different tasks CI1.3.3 - I access and use my feelings in an appropriate manner in any context to facilitate learning and achieving goals	Clersonal user manual	Environmental mastery, passion, self-motivation
	CI1.4 - Self reflection & mindfulness	Reflect on actions to engage in process of continuous learning	CI1.4.1 - I explore my own beliefs and assumptions to find solutions to problems CI1.4.2 - I question and reflect, in a positive way, what I do, why I do it and whether there is a better, or more efficient way of doing it in the future CI1.4.3 - I practice noticing and naming my experiences focussing on what I want, not what I don't want CI1.4.4 - I create realistic and relevant goals based on self-reflection	Self-reflective journaling, personal user manual	Reporting, responding, reasoning, relating, reconstruction, comprehension awareness, self assessment, critical reflection, attentiveness
CI2 - Self-regulation	CI2.1 - Emotional self control	Manage and respond to an emotional experience effectively	CI2.1.1 - I manage my emotions and feelings appropriately and remain calm and focused under pressure CI2.1.2 - I learn from mistakes, understanding what works and what doesn't CI2.1.3 - I respond to challenges with logic and reason, avoiding emotional reactions CI2.1.4 - I take difficult news or negative feedback without blaming or defending		Taking criticism, comfort with discomfort, stress management
	CI2.2 - Flexibility	Adaptable, consciously using a variety of behaviours and tools	CI2.2.1 - I handle multiple demands, shifting priorities and rapid change CI2.2.2 - I demonstrate flexibility, including the ability to incorporate new ideas and revise previous decisions CI2.2.3 - I create alternative ideas and approaches to maintain progress when faced with difficulty CI2.2.4 - I adapt positively to changing circumstances or other constraints		Adaptiveness, tolerance of change & uncertainty, ambiguity tolerance
	CI2.3 - Conscientiousness	Desire to perform a task to a high standard	CI2.3.1 - I am organised, systematic, punctual, achievement oriented, and dependable CI2.3.2 - I meet commitments and hold myself accountable for meeting my objectives		Commitment,
	CI2.4 - Trustworthiness	Do what you say, when you say you'll do it	CI2.4.1 - I lead by acting in a positive and consistent manner with my words matching my deeds CI2.4.2 - I act ethically and build trust through reliability and authenticity CI2.4.3 - I admit my own mistakes and confront unethical actions in others CI2.4.4 - I take tough, principled stands even if they are unpopular		
	CI2.5 - Resilience	Adjust easily to misfortune or change	CI2.5.1 - I keep calm, considered and focussed whilst persisting in the face of challenge/difficulty CI2.5.2 - I recover rapidly from setbacks and persists in realising objectives, even in difficult or adverse circumstances CI2.5.3 - I am not discouraged by challenges and uncertainty CI2.5.4 - I pursue goals and opportunities despite obstacles and setbacks acting in congruence with my values CI2.5.5 - I have the ability to stay optimistic and see the bright side even when I encounter setbacks		Self-reliance
	CI2.6 - Self management	Organisation of yourself	CI2.6.2 - I acknowledge my emotional and professional limits and seek help when necessary CI2.6.3 - I foster open communication and stay receptive to bad news as well as good CI2.6.4 - I seek feedback from others on my strengths and limitations and modify my behaviour accordingly CI2.6.5 - I plan workload/goals and deliver on my commitments to consistently high standards		Setting evaluation processes, framing success and failure, work ethic, sense of control
	CI2.7 - Time management	Using time effectively	CI2.7.1 - I meet commitments effectively and efficiently and deliver on time CI2.7.2 - I manage personal time to recharge taking time for mentoring, personal growth and reflection CI2.7.3 - I prioritise in order to avoid constraints limiting my performance		Analysing, delegation, planning, prioritising, identifying procrastination, scheduling
CI3 - Self-mastery	CI3.1 - Achievement orientation	Working toward a self-imposed and defined standard of excellence	CI3.1.1 - I evaluate and implement successful goal setting strategies CI3.4.1 - I actively seek out information to achieve my goals and measure my own performance against those goals CI3.1.2 - I motivate myself and regulate my emotions in pursuit of my goals CI3.1.3 - I set achievable, realistic and challenging priorities		Goal setting, proactiveness
	CI3.2 - Confidence	Belief in oneself or one's own abilities	CI3.2.1 - I have a sense of optimism and focus on things that matter most and appreciate my blessings and do not dwell on the negatives CI3.2.2 - I recognise my strengths and know how to use my weaknesses so that it does not come as a liability CI3.2.3 - I accept criticisms and compliments graciously CI3.2.4 - I acknowledge everyone's worth, give compliments and show appreciation		Self-esteem, sense of self-efficacy, assertiveness, courage, self-belief
	CI3.3 - Growth mindset	Believe competencies can be improved over time	CI3.3.1 - I focus on improving how I do what I do CI3.3.2 - I believe I can improve with effort and enjoy stretching myself, treating each day as a learning experience CI3.3.3 - I am a lifelong learner who seeks growth, development and embraces challenge CI3.3.4 - I believe that failure is an opportunity to learn and grow		Knowledge about oneself as a learner, learn from failure
	CI3.4 - Sense of purpose	Aligns personal values, expectations and ambition with purpose	CI3.4.1 - I anticipate trends and evolving needs, developing continuous improvements and opportunities for innovation CI3.4.2 - I have an increasing sense of the coherence of the different parts of my life CI3.4.3 - I have chosen a theme, purpose or aspiration for my life		Personal growth / embracing, futurity, lifelong values

Responsible Citizen:

Responsible Citizen	Sub-competence	Description	Experiences & outcomes	Tasks & Activities	Cognitive outcomes
Overarching competence				*Tasks & activities the learner would actually 'do'*	*The skills, strategies and concepts that are being developed*
RC1 - Ethical & Sustainable Thinking	RC5.1 - Global contextualisation	Assess the consequences and impact of ideas, opportunities and actions	RC5.1.1 - I explore the state of the planet, the interconnectedness and what it means RC5.1.2 - I identify ways in which I can personally contribute to the problems RC5.1.3 - I critically observe and evaluate business opportunities, impact and market trends using a sustainability lens RC5.1.4 - I anticipate sustainability challenges that might affect economy and society		Ecological worldview, sustainabilitymindset
	RC5.2 - Systems thinking	Develop a holistic approach to reality	RC5.2.1 - I consider the long-term consequences and implications when analysing situations and making decisions RC5.2.2 - I recognise social, environmental, and sustainability needs that can be addressed through an entrepreneurial approach from a systems perspective RC5.2.3 - I recognise either/or solutions, understand their limitations, and practice both+and thinking to accept paradoxes and create inclusive solutions RC5.2.4 - I identify how losing sight of the law of natural cycles has created unsustainability RC5.2.5 - I identify complementary characteristics of differentiation and interconnectedness, developing inclusive decisions and actions that contribute to the sustainability of the whole RC5.2.6 - I am aware of the differences within and between sectors, especially those of language, culture and key performance indicators		Systems thinking,
RC2 - Responsible decision making	RC4.1 - Contextual awareness	Gather situational information	RC4.1.1 - I evaluate personal abilities to make informed decisions RC4.1.2 - I observe myself in situations, particularly difficult or stressful situations and make choices in the moment		Inquiring authentically,
	RC4.2 - Options analysis	Evaluating every possible pathway	RC4.2.1 - I base decisions on a range of considerations RC4.2.2 - I analyse and evaluate how present decision-making affects my wellbeing and future career choices RC4.2.3 - I encourage consideration of new approaches based on evidence and best practice		Rational approach, behavioural approach, knowledge about why and when to use a given strategy, thinking effectual, thinking associational
	RC4.3 - Consequential impact	Effect, risk & influence	RC4.3.1 - I anticipate the impact of decisions and change and attempt to mitigate negative effects RC4.3.2 - I consider the risks and consequences of actions and decisions with short, medium and long term impact RC4.3.3 - I am aware of and takes responsibility for the impact of my decisions		Risk taking /loss awareness
	RC4.4 - Decidedness	Makes effective and efficient decisions	RC4.4.1 - I implement choices and demonstrate the ability to take responsibility RC4.4.2 - I recognise the benefits of setting limits and boundaries for myself and others RC4.4.3 - I accurately judge when to push back requests from others and say 'no' or 'yes, if' RC4.4.4 - I make decisions when it is impossible to have all the facts available and take difficult or unpopular decisions if needed RC4.4.5 - I take full responsibility for my decisions and remains open to revisiting a decision to address changing circumstances		Decision-making,
	RC4.5 - Personal integrity	Having strong moral principles	RC4.5.1 - I make constructive and respectful choices acting in an open, honest and inclusive manner RC4.5.2 - I take prompt and effective action to deal with unprofessional or unethical behaviour RC4.5.3 - I make and commit to decisions with integrity and transparency RC4.5.4 - I take responsibility for decisions taken and give others recognition for success RC4.5.5 - I maintain high ethical standards, not compromising them to advance personal or professional agenda		RCthical awareness,
RRC3 - Global consciousness	RC4.1 - Global citizenship	Actively engage with the world	RC4.1.1 - I evaluate how communities address issues to ensure that diverse social and cultural identities, roles or interests are included RC4.1.2 - I examine how values influence communities and how choices and actions affect the world around me RC4.1.3 - I determine the degree to which human activities affect the well-being of communities RC4.1.4 - I evaluate megatrends and their global impact RC4.1.5 - I can identify basic human needs and its impact on cultural, societal, economic systems		
	RC4.2 - Global inquiry	Investigate the world	RC4.2.1 - I identify my responsibility and positively contribute as an involved citizen in a global community RC4.2.2 - I identify an issue, generate a question, and explain the significance of locally, regionally, and globally focused researchable questions RC4.2.3 - I use a variety of sources to identify and weigh relevant evidence in addressing a globally significant researchable questions RC4.2.4 - I analyse, integrate, and synthesise evidence to construct coherent responses to globally significant researchable question RC4.2.5 - I develop an argument based on compelling evidence that considers multiple perspectives and draws defensible conclusions		Broadening horizons, community awareness, interconnectedness
	RC4.3 - Affirmative action	Translate ideas into action	RC4.3.1 - I identify and create opportunities for action to address situations, events, issues, or phenomena in ways that improve conditions RC4.3.2 - I act in creative and ethical ways to contribute to improvement locally, regionally, or globally and assess the impact of the actions taken RC4.3.3 - I reflect on my capacity to advocate for and contribute to improvement locally, regionally, or globally RC4.3.4 - I volunteer time and efforts to support local or global initiatives		Global sustainability, humility

Effective Contributor:

Effective Contributor	Sub-competence	Description	Experiences & outcomes	Tasks & Activities	Cognitive outcomes
Overarching competence				*Tasks & activities the learner would actually 'do'*	*The skills, strategies and concepts that are being developed*
81 - Social awareness	EC1.1 - Empathy	Awareness of another person's feelings	EC1.1.1 - I demonstrate the ability to put myself 'in someone else's shoes', to understand their situation and feelings from their point of view EC1.1.2 - I empathise with others, to understand social and ethical norms		Compassion,
	EC1.2 - Diversity	Recognises cultural diversity	EC1.2.1 - I am aware of cultural values, assumptions and biases and avoid stereotyping EC1.2.2 - I examine perspectives of other people, groups, or schools of thought and identify the influences on those perspectives EC1.2.3 - I embrace other people's unique perspectives and take an active interest EC1.2.4 - I show and promote respect and sensitivity towards gender, cultural and religious differences and encourage diversity whenever possible		Accepting, respecting others, appreciating diversity, ethical framing, holding multiple viewpoints
	EC1.3 - Social Perceptiveness	Awareness of others' reactions and their meaning	EC1.3.1 - I identify verbal, physical and situational cues that indicates how others may feel and responds to those cues in a manner that contributes to successful interactions EC1.3.2 - I help out based on understanding of other people's needs and feelings EC1.3.3 - I use tact and discretion in dealing with sensitive information or resolving delicate issues, paying attention to nonverbal cues		Social efficacy,
EC2 - Collaboration	EC2.1 - Persuasion and negotiation	Employing a range of influencing strategies	EC2.1.1 - I persuade others by explaining benefits and advantages using factual examples EC2.1.2 - I develop a line of reasoned argument to persuade others, using positive language and logic EC2.1.3 - I handle objections to my arguments by identifying common ground and tactfully challenging opposing views EC2.1.4 - I listen to the needs of others and look for compromise and agreement		Rapport, influencing,
	EC2.2 - Conflict management	Positively manage resistance	EC2.2.1 - I anticipate and proactively choose strategies to prevent conflict EC2.2.2 - I demonstrate an ability to co-exist civilly in the face of unresolved conflict EC2.2.3 - I am comfortable managing conflicts of interests or differences of opinion EC2.2.4 - I analyse and demonstrate how conflict-resolution skills contribute to work within a group EC2.2.5 - I take action to resolve tensions and problems by identifying suitable solutions		Managing difficult conversations, conflict resolution
	EC2.3 - Working with teams	Collaborative effort of a group	EC2.3.1 - I examine various attitudes, cultures, values and behaviours for developing meaningful interpersonal relationships EC2.3.2 - I value, respect, and support individual team members and encourage them to contribute their perspectives, skills or knowledge EC2.3.3 - I build rapport and keep other team members in the loop EC2.3.4 - I actively seek contributions and views from others and foster collaboration through shared leadership, responsibility or ownership EC2.3.5 - I work collaboratively with team members to create team spirit EC2.3.6 - I support a compassionate climate and working environment sensitive to the needs of all team members and acknowledge and appreciate the efforts of others EC2.3.7 - I exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal EC2.3.8 - I confidently express views or needs without either aggression/ dominance / undue submissiveness towards others		Collaboration and team building, delegating, assertiveness
	EC2.4 - Valuing partners	Develops internal and external collaboration	EC2.4.1 - I identify common interests and goals and carry out joint initiatives with a range of partners and stakeholders EC2.4.2 - I actively build and maintain internal and external partnerships to achieve progress on objectives and shared interests EC2.4.3 - I cultivate and maintain extensive information networks with a wide range of partners EC2.4.4 - I seek out relationships that are mutually beneficial EC2.4.5 - I develop a network of trusted mentors and peers that enhances positive outcomes throughout my life		Relationship building,
EC3 - Inspirational leadership	EC3.1 - Vision	Work towards your vision of the future	EC3.1.1 - I identify purpose and the likely direction of change and inspire those working with me to think about where to go next EC3.1.2 - I look to the future and can see opportunities and potential EC3.1.3 - I think and act with a long-term, futuristic perspective and purpose EC3.1.4 - I articulate and arouse enthusiasm for a shared vision and tasks EC3.1.5 - I imagine the future and exhibit the courage to take risks and pursue new ideas EC3.1.6 - I demonstrate the confidence to implement innovative ideas - to turn ideas into action EC3.1.7 - I visualise future scenarios to help guide effort and action		Visualisation, strategic thinking, abstraction
	EC3.2 - Empowering others	Nurturing capability	EC3.2.1 - I have the humility to work in the background, creating the space for others to take the lead on particular issues and to grow in confidence and capability EC3.2.2 - I coach others, challenging and asking questions to help them work out the answers for themselves EC3.2.3 - I provide space for others to be creative and to take risks so that they can develop their own capabilities and approaches EC3.2.4 - I empower team members to share and co-build a clear vision and to act on it EC3.2.5 - I cater to intrinsic motivation to empower others		Motivating, inspiring, coaching
	EC3.3 - Change management	Engage people in embracing change	EC3.3.1 - I embrace changes when presented with them EC3.3.2 - I encourage others to drive change initiatives forward by creating momentum and excitement about what needs to be done EC3.3.3 - I take a holistic view of change using feedback and lessons learnt EC3.3.4 - I establish shared purpose and measures of performance EC3.3.5 - I set the direction for new initiatives, explaining relevant scope, reasons and needs EC3.3.6 - I demonstrate an understanding of impact of change and manage risk accordingly EC3.3.7 - I evaluate potential consequences of different courses of action, anticipating future developments and impact		Managing change and uncertainty, change catalyst
EC4 - Communicating Impactfully	EC4.1 - Linguistic competence	Words & rules	EC4.1.1 - I use vocabulary and language conventions, for example, grammar, punctuation and spelling effectively EC4.1.2 - I use syntax, for example, sentence structure effectively EC4.1.3 - I use expressive and receptive language including grammar, syntax and symbols		Textual analysis, using language
	EC4.2 - Discourse competence	Cohesion & coherence	EC4.2.1 - I articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts EC4.2.2 - I shape language and communication purposefully in different genres, using cohesion and coherence and understand how ideas are connected through patterns of organisation EC4.2.3 - I know how to interpret the larger context and how to construct longer stretches of language so that the parts make up a coherent whole EC4.2.4 - I achieve a fluent conversational style by using pauses, changes in volume, and changes in emphases EC4.2.5 - I present highly complex arguments, information and ideas in an easy to understand, highly engaging and informative way EC4.2.6 - I hold the attention of the audience throughout to drive home the required message convincingly		Written communication, creative writing, composition, storytelling, communication design, message clarity
	EC4.3 - Sociolinguistic competence	Appropriateness	EC4.3.1 - I am aware of social rules of language e.g. formality, politeness, directness EC4.3.2 - I use effective body language, eye contact, facial expressions, non-verbal gestures and tone of voice to convey messages EC4.3.3 - I am aware of cultural references, for example, idioms, expressions, background knowledge EC4.3.4 - I know how to use and respond to language appropriately, given the setting, the topic, and the relationship among the people communicating EC4.3.5 - I communicate effectively to convey information in a manner that is easily understood by diverse audiences EC4.3.6 - I convey warmth, enthusiasm, concern in my voice where appropriate EC4.3.7 - I engage with others to make a relevant contribution, ensure that everyone has an opportunity to contribute and encourage them to take account of others' points of view or alternative solutions		Using voice and connotation, expression
	EC4.4 - Strategic competence	Appropriate use of communication strategies	EC4.4.1 - I use techniques to recognise and repair communication breakdowns, how to work around gaps in my knowledge of the language, and how to learn more about the language in context EC4.4.2 - I plan and assess the effectiveness of communication and maintain interest with appropriate pace and content EC4.4.3 - I project confidence and authority with highly knowledgeable audiences even when the subject matter is unfamiliar or unprepared EC4.4.4 - I anticipate and respond to the needs of an audience, adapting content and style to suit them EC4.4.5 - I establish credibility quickly and effectively and respond quickly and effectively to unforeseen questions or challenges EC4.4.6 - I develop points and arguments from initial simplicity to final comprehensiveness, giving the overall work a logical progression of ideas EC4.4.7 - I respond in ways appropriate to my role, exploring and expanding on contributions to reflect on, clarify or adapt thinking EC4.4.8 - I utilise multiple media and technologies, and know how to judge their effectiveness as well as assess their impact		Presentation skills, audience segmentation, medium selection, using multimedia, professionalism, visual communication, elaborating explanations, responding to requests

Digitally Astute:

Competence	Sub-competence	Description	Experiences & outcomes	Tasks & Activities	Cognitive outcomes
Overarching competence				*Tasks & activities the learner would actually 'do'*	*The skills, strategies and concepts that are being developed*
T1 - Digital Literacy	T1.1 - Staying safe	Safe and responsible use of technology	T1.1.1 - I understand, mitigate and manage various cyber-risks through safe, responsible, and ethical use of technology T1.1.2 - I handle with discretion all personal information shared online to protect the privacy of myself and others T1.1.3 - I understand the nature of digital footprints and their real-life consequences, and manage them responsibly, to actively build a positive digital reputation		privacy management, personal cyber security management, digital footprint management, privacy management, balanced use of technology
	T1.2 - Ethical principles	Awareness of ethical conduct and digital law	T1.2.1 - I am aware of professional, legal, cultural, ethical and social responsibilities T1.2.2 - I understand and exercise my powers and right to online participation (e.g., personal data protection, freedom of expression, to be forgotten) T1.2.3 - I understand and manage intellectual property rights (e.g., copyrights, trademarks, and patents) when using and creating content and technology		Intellectual property rights management, GDPR awareness, confidentiality, privacy, copyright, security awareness, governance, compliance
	T1.3 - Societal impact	Impact, contribution, and relationship of technologies on business, the economy, politics, and the environment	T1.3.1 - I analyse technologies taking into consideration sustainability, scientific and technological developments T1.3.2 - I examine a range of materials, processes or designs to consider their environmental, social and economic impact T1.3.3 - I present conclusions about the impact of technologies on the economy, politics and the environment T1.3.4 - I comprehend and analyse the impact of technologies on individuals, organisations and society, including ethical, legal, security and global policy issues		Digital citizen identity, digital empathy, social implications of technology,
	T1.4 - Effective use	Searching, processing and managing information responsibly	T1.4.1 - I select and use digital technologies to access, select relevant information and solve real world problems T1.4.2 - I find, organize, analyse, and evaluate media and information with critical reasoning and justify my selection in terms of validity, reliability and have an awareness of plagiarism T1.4.3 - I use digital tools to design and develop significant digital artifacts (e.g., multi page website, online portfolio, simulation) to achieve a purposeful outcome	SQL, Microsoft tools, Google Tools,	Organisation, managing structured data, systems administration
	T1.5 - Digital purpose	Drive, growth and impact	T1.5.1 - I identify and develop myself as a competent changemaker in the digital economy T1.5.2 - I engage in civic participation for the well-being and growth of local, national, and global communities using technology T1.5.3 - I skilfully manage my online relationships through cooperation, conflict management, and persuasion T1.5.4 - I communicate with an online audience effectively to exchange messages, ideas, and opinions reflecting wider business or societal discourses		Digital changemaker identity, civic use of technology
	T1.6 - Cyber resilience	Prepare for, respond to and recover from cyber attacks	T1.6.1 - I identify, mitigate, and manage commercial or community cyber-security risks online and manage different levels of cyber threats T1.6.2 - I explore the impact of cyber-security for business and industry and the consequences this can have		Behaviour cyber-risk management, commercial and community cyber-risk management, organisational cyber security management,
T2 - Computing literacy	T2.1 - Technology trends	Mindful of popular technology in society or industry	T2.1.1 - I join technology related forums and read innovative technology related research, blogs, articles and books T2.1.2 - I follow people on social media who inspire me and attend technology seminars and events for information and inspiration T2.1.3 - I discuss the most popular technology trends and describe how they are affecting industries and society		Technology savvy, global awareness of developments/opportunities
	T2.3 - Network & cloud computing	Awareness of linked computer systems	T2.3.1 - I explain how network topologies and protocols enable users, devices, and systems to communicate with each other T2.3.2 - I examine common network vulnerabilities (e.g., cyberattacks, identity theft, privacy) and their associated responses T2.3.3 - I examine the issues (e.g., latency, bandwidth, firewalls, server capability) that impact network functionality T2.3.4 - I evaluate the scalability and reliability of networks and how networks communicate, their vulnerabilities and issues that may impact their functionality		Network design, network security management, cloud management,
	T2.4 - Hardware & software provision	Application and interactions of hardware and software	T2.4.1 - I compare levels of abstraction and interactions between application software, system software, and hardware layers T2.4.2 - I use troubleshooting strategies to solve routine hardware and software problems T2.4.3 - I explain and demonstrate how specialised computing devices can be used for problem solving, decision-making and creativity in all subject areas T2.4.4 - I apply organisational skills to identify and use appropriate hardware and software resources when maintaining or developing a computer-based system	Software design,	Software lifecycle management skills, evaluate software systems, hardware architecture, software architecture,
	T2.5 - System control	Technology process to maintain, adapt, develop or troubleshoot computer-based systems	T2.5.1 - I investigate ideas and generate proposals and solutions that meet specifications and recognised standards T2.5.2 - I apply a range of problem-solving techniques when maintaining or developing computer-based systems T2.5.3 - I apply a range of conventions and standards when implementing a maintenance or development solution T2.5.4 - I apply organisational skills to identify and use appropriate hardware and software resources when maintaining or developing a computer-based system T2.5.5 - I choose the appropriate selection and application of computer-based system components T2.5.6 - I identify, define and analyse computing problems and requirements appropriate for solution	Systems diagrams, data structures	Technology evaluation and selection, process reengineering techniques, technology standards and procedures, system performance monitoring & analysis, system specification techniques,
T3 - Digital design	T3.1 - Digital design and development	Designing, building and testing computing solutions	T3.1.1 - I select appropriate development tools to design, build, evaluate and refine computing solutions to process and present information whilst making reasoned arguments to justify my decisions T3.1.2 - I identify and develop myself as a change agent and co-creator of the digital ecosystem T3.1.3 - I synthesise, create, and produce information, media, and technology in an innovative and creative manner selecting and using the 'best' digital tools or resources to create an artifact or solve a problem T3.1.4 - I construct, analyse, evaluate and formulate success criteria, solution specifications including task outlines, designs and test plans, appropriate techniques with a specified solution T3.1.5 - I apply design and development principles in the construction of software systems of varying complexity	Computer aided drawing (CAD), digital fabrication process, electronic concepts, testing cycles, testing debugging, SCRUM/agile Product Dev, user research, analysing needs and product requirements to create a design	Digital co-creator identity, application development lifecycle processes, design principles, functional design, testing methodologies, rapid prototyping, usability testing, UX Design, UI Design, lean /agile methodology,
	T3.2 - Media literacy	Critically evaluate, create or manipulate media	T3.2.1 - I recognise how entertainment media communicate values & ideology T3.2.2 - I critically evaluate how differences in values and life experience shape people's media use and message interpretation T3.2.3 - I appreciate risks and potential harms of digital media and apply ethical judgment and social responsibility to communication situations T3.2.4 - I apply and use relevant facts and concepts, relevant design methods and techniques, appropriate communication methods to present information T3.2.5 - I demonstrate effective media and communications skills	Advanced interactive digital multimedia, digital presentation, digital marketing, 2D digital motion media, social media, adobe creative cloud,	Media & information literacy, analysis, evaluation, grouping, induction, deduction, synthesis, abstraction, visual literacy, content creation literacy, videography
	T3.3 - Web technologies	Essentials of web creativity	T3.3.1 - I deploy industry-standard tools and languages to create engaging and reliable responsive web apps T3.3.2 - I explore cutting-edge technologies and design principles to shape the web of tomorrow	Web design, 2D representation, search engine optimisation (SEO), Google analytics	Graphical design and interpretation, Interface design principles, cognitive psychology
T4 - Computational thinking	T4.1 - Modelling & simulation	Build a mathematical model	T4.1.1 - I create models and simulations to help formulate, test, and refine hypotheses T4.1.2 - I form a model from a hypothesis generated from research and run a simulation to collect and analyse data to test that hypothesis		Computational literacy, graphical models, simulations
	T4.2 - Manipulating algorithms	Awareness of the impact of algorithms on society	T4.2.1 - I explain how a recursive solution to a problem repeatedly applies the same solution to smaller instances of the problem T4.2.2 - I generate, process, analyze, present meaningful information from data T4.2.3 - I develop, use, and apply artificial intelligence (AI) and related algorithmic tools and strategies in order to guide informed, optimised, and contextually relevant decision-making processes		Algorithm design and development, thinking procedurally, logically, concurrently, abstractly, recursively, artificial intelligence
	T4.3 - Data analysis	Sorting through big data and driving insight from it	T4.3.1 - I create an appropriate multidimensional data structure that can be filtered, sorted, and searched T4.3.2 - I create, evaluate, and revise data visualization for communication and knowledge T4.3.3 - I analyse complex data set to answer a question or test a hypothesis T4.3.4 - I design questions to either qualify or disqualify potential solutions to specific problems or opportunities taking account of stakeholder interest T4.3.5 - I analyse data and related trends, patterns and gaps T4.3.6 - I distill critical elements and identify relevant links by using appropriate analytical methods	Modelling,	Collection, visualisation, transformation, inference, evaluation, data engineering, data mining, data compression techniques, logical data modelling, data layout and access techniques, neural networks for computer vision, big and distributed data,
	T4.4 - Programme creation	Designing, manipulating and building code	T4.4.1 - I use a development process in creating a computational artifact that leads to a minimum viable product and includes reflection, analysis, and iteration T4.4.2 - I use an iterative design process, including learning from making mistakes, to gain a better understanding of the problem domain T4.4.3 - I engage in systematic testing and debugging methods to ensure program correctness T4.4.4 - I demonstrate how to document a program so that others can understand its design and implementation T4.4.5 - I understand constructs and data structures in a textual programming language and the relationship between high level language and the operation of computer	Python, Javascript, HTML, CSS, C++	Abstraction, data and AI literacy, object-oriented programming methodologies, managing reusable code, contemporary programming tools, natural language processing

Appendix 3 – Participant information sheet - educator

Lancaster University

Participant information sheet - Educator

Title of project and researcher details

Innovation Studios in Scottish Schools
Researcher: Mrs Joanna S Maclean
Supervisor: Prof D Passey
Course: PhD (Educational Technologies).

You are being invited to take part in a research project into the use and perceived efficacy of design thinking studios. This is part of my work towards gaining a PhD at the University of Lancaster.
Before you decide if you want to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the information on this page carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the study about?

The purpose of this study is to investigate innovation studios as part of the learners' journey. I hope to find out if there are factors that make this approach more or less effective in terms of pupil learning, and what educators' and learners' views are on the approach itself. I hope to have completed my data collection by the end of 2020. You are being asked to take part because you have been observing/participating in the innovation studio and your views and opinions are crucial to ongoing research into the strategy.

What will I be asked to do if I take part?

If you decide to take part, I will arrange to interview you about your views on the strategy itself, and on its impact on learning. The interview will last about 20 minutes and will be arranged at a time to suit you, on the school premises. I will audio-record the interview; a transcript will be returned to you for checking before I use it in my analysis. Taking part in this project is entirely voluntary. Should you decide to participate, you are still free to withdraw at any time, without giving a reason. I will be finished gathering information by 2020.

What are the possible benefits of taking part?

Taking part in this study will allow you to share your experiences of innovation studios and might lead to further integration in the school curriculum. Your insights will help us understand the role that innovation studios can play in the process of learning and teaching.

Do I have to take part?

No. It's completely up to you to decide whether you take part. Your participation is voluntary.

What if I change my mind?

If you change your mind, you are free to withdraw at any time prior to the group interview. If you want to withdraw, please let me know, and I will extract any ideas or information you contributed to the study and destroy them. However, it is difficult and often impossible to take out data from one specific participant when this has already been anonymised or pooled together with other people's data. For this reason, data provided more than 2 weeks before a decision to withdraw will not be able to be deleted.

What are the possible disadvantages and risks of taking part?

The interview will take around 20 minutes of your time.

Will my data be identifiable?

After the group interview, only I, the researcher conducting this study will have access to the ideas you share with me. The only other person who will have access to what you contributed is a professional transcriber who will listen to the recordings and produce a written record of what you have said. The transcriber will sign a confidentiality agreement. My PhD supervisor will have access to a written form of your ideas, but these will be completely anonymised. I will keep all personal information about you

Lancaster University

confidential, that is, I will not share it with others. I will remove any personal information from the written record of your contribution. I will keep the information from the interview in a file on my computer. When I have finished writing my study, I will destroy all the information, but publishers may require me to retain this for 10 years or more following publication. When I write about what I have found out, your name will not be mentioned.

How will we use the information you have shared with us and what will happen to the results of the research study?

I will present my findings in the thesis I am writing for my PhD. I may also present these at an education conference and use the information to write a journal article. I will provide a written summary of my findings for all participants and can come back to you to discuss this with you if you wish. You may request a copy of the dissertation.

How my data will be stored?

Your data will be stored in encrypted files (that is no one other than me will be able to access them) and on password-protected computers. I will store hard copies of any data securely in locked cabinets in my office. I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic). In accordance with University guidelines, I will keep the data securely for a minimum of ten years.

Reviewed of the study

This study has been reviewed and agreed upon by the Department of Educational Research Ethics Forum, University of Lancaster.

What if I have a question or concern?

If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact me, Mrs Joanna Maclean (Joanna.maclean@kelvinside.org) or my supervisor

Prof Don Passey
Professor of Technology Enhanced Learning
Director of Studies, Doctoral Programme in e-research and Technology Enhanced Learning
Department of Educational Research
Lancaster University, LA1 4YD
Email :d.passey@lancaster.ac.uk / 01524 592314
Professor of Technology Enhanced Learning
Director of Studies, Doctoral Programme in e-Research and Technology Enhanced Learning
Department of Educational Research
Lancaster University
LA1 4YD

Prof Carolyn Jackson
Head of Department, Doctoral Programme in e-research and Technology Enhanced Learning
Department of Educational Research
Lancaster University, LA1 4YD
Email :c.jackson2@lancaster.ac.uk / 01524 592883

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact:

Mr Ian Munro
Rector
Kelvinside Academy
33 Kirklee Road
rector@kelvinside.org
0141 357 3376

Thank you for considering your participation in this project.

Appendix 4 – Consent form - educator

Lancaster University

CONSENT FORM - Educator

Project Title: Innovation Studios in Scottish Secondary Schools
Name of Researcher: Joanna Maclean **Email:** joanna.maclean@kelvinside.org

Electronic Form

Please tick each box:

1. I confirm that I have read and understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time during my participation in this study and within 2 weeks after I took part in the study, without giving any reason. If I withdraw within 2 weeks of taking part in the study my data will be removed. ☐
3. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher, but my personal information will not be included and I will not be identifiable. ☐
4. I understand that fully anonymised data will be offered to the Lancaster University data repository and will be made available to genuine research for re-use (secondary analysis). ☐
5. I understand that my name will not appear in any reports, articles, or presentations without my consent. ☐
6. I understand that any interviews will be audio-recorded and transcribed and that data will be protected on encrypted devices and kept secure. ☐
7. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study. ☐
8. I agree to take part in the above study. ☐

________________________ ________________ ________________
Name of Participant Date Signature

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher ______________________ **Date** ___________ Day/month/year

One copy of this form will be given to the participant and the original kept in the files of the researcher

Appendix 5 - Interview questions - educator

Lancaster University

Interview Questions - Educator

Title of project and researcher details

Innovation Studios in Scottish Schools
Researcher: Mrs Joanna S Maclean
Supervisor: Prof D Passey
Course: PhD (Educational Technologies).

Introduction

- Thank you so much for agreeing to help me with this project and signing the consent form.
- Just a reminder that everything discussed will remain confidential and be anonymised during transcription.
- I hope to interview all the staff that have been involved in this 8-week block of innovation studio sessions and it should take no more than 20 to 30 minutes.
- I am conscious of how busy you are and appreciate the time you are taking to help further our knowledge and understanding of the innovation studio on the learning and teaching process.

The Studio:

- What did you think of the studio?
- What did you like?
- What would you change if you were running it again?

Teaching and Learning:

- What were the strengths of the studio?
- What competencies did you feel the students developed? (List top 20 MC?)
- What computing skills did you see them learn?
- What do you think the challenges of the studio were?
- What do you think of this type of learning for students?

Assessment:

- What did you think about the reflective blogs?
- What did you think about the final presentation?
- How does this compare with current assessment processes?

Future:

- What are the contrasts between the DDTS and normal school?
- Is there anything that you would like to see from the DDTS in the 'normal' curriculum?
- Is 2-weeks the right amount of time for this activity?
- Any other comments/thoughts?

Appendix 6 – Participant information sheet - learner

Lancaster University

Participant information sheet - Learner

Title of project and researcher details

Innovation Studios in Scottish Schools
Researcher: Mrs Joanna S Maclean
Supervisor: Prof D Passey
Course: PhD (Educational Technologies).

As well as working in the school, I am also a PhD student at Lancaster University. I would like to invite you to take part in a research study that I am carrying out about your experiences in the innovation studio. Please take time to read the following information carefully before you decide whether you wish to take part.

What is the study about?

A research project is a way to learn more about something. You are being asked to take part because your class took part in the innovation studio. The purpose of this study is to find out what you think of your time in the innovation studio, what you like or don't like about it, and whether you feel that it helps you to learn better. You are being invited to take part in a research project into innovation studios in school, along with the rest of your class. At the end of your 2 weeks in the innovation studio, you will be asked questions about your experience. Before you decide if you want to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the information on this page carefully and discuss it with others in the class and your parent/carer if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What will I be asked to do if I take part?

If you decide to take part, I will ask you some questions about what you think about the innovation studio. You will be in a group with other children from your class. You do not have to answer any questions that you don't want to. This will take less than 10 minutes and we will do this during class time. I will record your answers on a voice recorder so that afterwards I can listen carefully to what you said. I will look at your innovation studio learning log and will also be looking at and taking some notes during class looking at the learning and teaching. I will be finished gathering information by 2020. You do not have to take part in this study, and if you decide not to, or your parent/carer does not wish you to take part, you will still be part of the class the same as you are now.

What are the possible benefits of taking part?

Taking part in this study will allow you to share your experiences of the innovation studio and might lead to further integration in the school curriculum. Your insights will help us understand the role that design thinking studios can play in your education.

Do I have to take part?

No. It's completely up to you to decide whether or not you take part. Your participation is voluntary. If you decide not to take part in this study, this will not affect your studies and the way you are assessed on your course.

What if I change my mind?

If you change your mind, you are free to withdraw at any time prior to the group interview. If you want to withdraw, please let me know, and I will extract any ideas or information you contributed to the study and destroy them. However, it is difficult and often impossible to take out data from one specific participant when this has already been anonymised or pooled together with other people's data, so your data cannot be extracted later than 2 weeks after the group interview.

What are the possible disadvantages and risks of taking part?

You will be out of class for around 10 minutes.

Lancaster University

Will my data be identifiable?

After the group interview, only I, the researcher conducting this study will have access to the ideas you share with me. The only other person who will have access to what you contributed is a professional transcriber who will listen to the recordings and produce a written record of what you have said. The transcriber will sign a confidentiality agreement. My PhD supervisor will have access, but only to anonymised ideas that I write into my thesis. I will keep all personal information about you confidential, that is, I will not share it with others. I will remove any personal information from the written record of your contribution. You are asked not to disclose information outside of the interview and with anyone not involved in the group interview without the relevant person's express permission. I will keep the information from the group discussion and from my notes about your learning in a file on my computer. When I have finished writing my study I will destroy all the information, 10 years after my thesis is completed. When I write about what I have found out, your name will not be mentioned.

How will we use the information you have shared with us and what will happen to the results of the research study?

When I have gathered all of the information from everyone who is taking part I will write about what I have learned in a PhD thesis, which is a long essay, which I have to complete for the course I am studying on. This will be read and marked by my teachers at university. I may also present the results of my studies at academic conferences. I will tell you and the other learners who have taken part what I have found out about what you think about design thinking studios. I will also tell other educators in the school. I will destroy all of my notes and recordings when the project is completed.

How my data will be stored

Your data will be stored in encrypted files (that is no one other than me will be able to access them) and on password-protected computers. I will store hard copies of any data securely in locked cabinets in my office. I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic). In accordance with University guidelines, I will keep the data securely for a minimum of ten years, or as long as any publisher requires.

What if I have a question or concern?

If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact me, Mrs Joanna Maclean (Joanna.maclean@kelvinside.org) or my supervisor

Prof Don Passey
Professor of Technology Enhanced Learning
Director of Studies, Doctoral Programme in e-research and Technology Enhanced Learning
Department of Educational Research
Lancaster University, LA1 4YD
Email :d.passey@lancaster.ac.uk / 01524 592314

Prof Carolyn Jackson
Head of Department, Doctoral Programme in e-research and Technology Enhanced Learning
Department of Educational Research
Lancaster University, LA1 4YD
Email :c.jackson2@lancaster.ac.uk / 01524 592883

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact:

Mr Ian Munro
Rector
Kelvinside Academy
33 Kirklee Road
rector@kelvinside.org / *0141 357 3376*

Thank you for considering your participation in this project.

Appendix 7 – Consent Form - learner

CONSENT FORM - Learner

Project Title: Innovation Studios in Scottish Secondary Schools
Name of Researcher: Joanna Maclean **Email:** joanna.maclean@kelvinside.org

Electronic Form

Please tick each box:

1. I confirm that I have read and understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time during the 2 weeks prior to my participation in this study without giving any reason. I understand that as part the focus group I will take part in, my data is part of the ongoing conversation and cannot be destroyed. I understand that the researcher will try to disregard my views when analysing the focus group data, but I am aware that this will not always be possible. ☐
3. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher, but my personal information will not be included and I will not be identifiable. ☐
4. If I am participating in the focus group I understand that any information disclosed within the focus group remains confidential to the group, and I will not discuss the focus group with or in front of anyone who was not involved unless I have the relevant person's express permission. ☐
5. I understand that fully anonymised data will be offered to the Lancaster University data repository and will be made available to genuine research for re-use (secondary analysis). ☐
6. I understand that my name will not appear in any reports, articles, or presentations without my consent. ☐
7. I understand that any interviews will be audio-recorded and transcribed and that data will be protected on encrypted devices and kept secure. ☐
8. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study. ☐
9. I agree to take part in the above study. ☐

______________	______________	______________	______________
Name of Participant	Class	Date	Signature

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher ______________________ Date ___________

One copy of this form will be given to the participant and the original kept in the files of the researcher

Appendix 8 – Group interview questions - learner

Group Interview Questions - Learner

Title of project and researcher details

Innovation Studios in Scottish Schools
Researcher: Mrs Joanna S Maclean
Supervisor: Prof D Passey
Course: PhD (Educational Technologies).

Introduction

- Thank you so much for agreeing to help me with this project and signing the consent form.
- Please be honest with all your answers; everything you will say will be confidential and then anonymised during transcription.
- Please don't discuss anything that anyone else says during this group interview without asking them first.
- I will ask everyone in your class the same questions and the whole interview should take between 5 – 15 minutes.
- Thank you for helping further our knowledge and understanding of the innovation studio on the learning and teaching process.

Your product:

- What did you design?
- Why did you want to do that?
- What worked well?
- What would you change?

The Studio:

- What did you think of the studio?
- What did you like?
- What would you change if you were participating again?

Teaching and Learning:

- What did you learn in the studio?
- What skills did you feel you developed?
- What computing skills did you learn?
- What did you find challenging?
- Did you find this type of learning motivational?

Assessment:

- What did you think about the reflective blog?
- What did you think about the final presentation?

Future:

- How does it differ from normal school?
- Is there anything that you would like to see from the studio session in the 'normal' curriculum?
- Is 2-weeks the right amount of time for this activity?
- Any other comments/thoughts?

Appendix 9 - Inclusion criteria for the review

Criterion type	Inclusion Criteria
Topic	Literature must relate directly to one of the research questions
Recency	Literature should have been published between 2000 and 2020
Age-range	Literature should relate to school-age pupils (5-18 years)
Geographical spread	Global
Research base	Initially, the requirement was only for literature based upon empirical research (either qualitative or quantitative); however, a scarcity of research in this domain required this to be opened up – see below.

Literature search and terms used

Type of literature	How sourced
Journal articles	Searching the online databases Scopus (Elsevier), ERIC (US Dept. of Education), Taylor & Francis Online Journals, OneFile (GALE), Proquest Business Collection, Social Sciences (Web of Science), Design and Applied Arts Index (DAAI), ABI/INFORM Global, SpringerLink, ScienceDirect Journals, Arts & Humanities, Emerald Insight, Sage Journals, ProQuest Entrepreneurship, Directory of Open Access Journals (DOAJ), JSTOR Archived Journals, Education Research Complete (EBSCO), Educationline
'grey' literature	Issue papers, policy statements, studies in schools
Books on the theme of future skills, innovation, design thinking	, Chapters in books which may not include design thinking in the title Library at Lancaster University
UK and Scottish Government websites	Scottish Government, Education Scotland, The Standards Site, National Improvement Framework
World Wide Web	Including Google Scholar, Google, Wikipedia, OECD and other non-academic sites
Other	LinkedIn, Twitter, Personal Library
Search terms:	
Future skills AND/OR 21st-century AND/OR Social Constructivism AND/OR Design thinking AND/OR Immersion studio AND/OR Digital education	educational framework, competencies, innovation school, curriculum, learner, pupil, research, innovation, model, benefits, barriers

Appendix 10 – Example design brief and self-reflection for learners

Future Humans: Cyborg Enhancements

Today, instead of waiting for natural selection to run its course, we are actively controlling the changes in physical and genetic traits in our species. Technological advancements are happening faster than ever before, and we now have the ability to enhance every aspect of the human body, from appearance to physical strength, to memory. We're approaching an age in which 3D printed organs, augmented vision through telescopic contact lenses, personalised drugs to enhance performance, and brain-computer interfaces to control neuroprosthetic limbs with the mind are no longer ideas of the future. There are now people who classify themselves as "biohackers" who have gone as far as to implant magnets in their fingers to sense magnetic fields, give themselves special eye drops to induce temporary night vision, implant RFID chips in their hands to get through subway stalls seamlessly, and insert sound-transmitting magnets in ears to receive audio from a recording device. Hugh Herr, head of the Biomechatronics group at the MIT Media Lab, believes that with the advancement of Bionics, people may elect to amputate their legs and add specialised prosthesis to augment their capabilities, subverting the limitations of their normal legs. But with all these augmentations, larger questions abound: how they should be used and by whom? Who should make decisions around these societal and bodily adaptations? What are the advantages and pitfalls of genetic alterations or becoming part machine? How will they eventually lead back to genetic evolution?

In this studio, students will explore the ethical, social, and technical implications of a biologically transformed cyborg society to test and question the limits of these human-designed interventions. Students will design and create body extensions that range from practical to provocative. Students will explore the power of digital design (computer-aided drafting, 3D modelling), rapid prototyping tools (laser cutters, 3D printers), mechanical design, and body attachment techniques to create enhancements that push the limits of what it means to be a human.

Task:
Discuss where you began, how you progressed, and where you ended this week working on your project in terms of its :

- *Initial ideas from the brainstorming*
- *Moving from the first sketch to prototype 1*
- *How the precedent research impacted your next prototype*
- *Next steps for your project*

As part of the discussion, reflect on the feedback you received from coaches and the design decisions you made based on this feedback.
You will have multiple simultaneous paths – technical and conceptual -- write about them all.
Relate this discussion to specific images you posted, by the title of the image. Discuss how your decisions relate to your Thesis Statement and indicate if you changed your thesis and why.
We want to know how the work you did this week supports your overall project goals. Be specific.
What portions of your project still need to be figured out?
Describe your next immediate steps and lay out a general schedule for the time remaining in the studio.

Appendix 11 – Metacognitive awareness inventory questionnaire

1. I ask myself periodically if I am meeting my goals.
2. I consider several alternatives to a problem before I answer.
3. I try to use strategies that have worked in the past.
4. I pace myself while learning in order to have enough time.
5. I understand my intellectual strengths and weaknesses.
6. I think about what I really need to learn before I begin a task.
7. I know how well I did once I finish a test.
8. I set specific goals before I begin a task.
9. I slow down when I encounter important information.
10. I know what kind of information is most important to learn.
11. I ask myself if I have considered all options when solving a problem.
12. I am good at organizing information.
13. I consciously focus my attention on important information.
14. I have a specific purpose for each strategy I use.
15. I learn best when I know something about the topic.
16. I know what the teacher expects me to learn.
17. I am good at remembering information.
18. I use different learning strategies depending on the situation.
19. I ask myself if there was an easier way to do things after I finish a task.
20. I have control over how well I learn.
21. I periodically review to help me understand important relationships.
22. I ask myself questions about the material before I begin.
23. I think of several ways to solve a problem and choose the best one.
24. I summarize what I've learned after I finish.
25. I ask others for help when I don't understand something.
26. I can motivate myself to learn when I need to.
27. I am aware of what strategies I use when I study.
28. I find myself analysing the usefulness of strategies while I study.
29. I use my intellectual strengths to compensate for my weaknesses.
30. I focus on the meaning and significance of new information.
31. I create my own examples to make information more meaningful.
32. I am a good judge of how well I understand something.
33. I find myself using helpful learning strategies automatically.
34. I find myself pausing regularly to check my comprehension.
35. I know when each strategy I use will be most effective.
36. I ask myself how well I accomplish my goals once I'm finished.
37. I draw pictures or diagrams to help me understand while learning.
38. I ask myself if I have considered all options after I solve a problem.
39. I try to translate new information into my own words.
40. I change strategies when I fail to understand.
41. I use the organizational structure of the text to help me learn.
42. I read instructions carefully before I begin a task.
43. I ask myself if what I'm reading is related to what I already know.
44. I re-evaluate my assumptions when I get confused.
45. I organize my time to best accomplish my goals.
46. I learn more when I am interested in the topic.
47. I try to break studying down into smaller steps.
48. I focus on overall meaning rather than specifics.
49. I ask myself questions about how well I am doing while I am learning something new.
50. I ask myself if I learned as much as I could have once I finish a task.
51. I stop and go back over new information that is not clear.
52. I stop and reread when I get confused.

Appendix 12 – Metacognitive awareness inventory results

	Planning							7		
Name	I pace myself while learning in order to have enough time	I think about what I really need to learn before I begin a task	I set specific goals before I begin a task.	I ask myself questions about the material before I begin.	I think of several ways to solve a problem and choose the best one.	I read instructions carefully before I begin a task.	I organize my time to best accomplish my goals.	Count		
	4	6	8	22	23	42	45			
Student 1 before	1	1	1	0	1	0	0	4	57.14%	
Student 1 after	1	0	0	1	1	0	1	4	57.14%	0.00%
Student 2 before	1	0	0	1	1	1	1	5	71.43%	
Student 2 after	1	1	1	1	1	1	1	7	100.00%	28.57%
Student 3 before	1	0	0	1	0	0	1	3	42.86%	
Student 3 after	0	1	1	0	1	0	0	3	42.86%	0.00%
Student 4 before	1	1	1	1	1	1	1	7	100.00%	
Student 4 after	1	1	1	1	1	1	0	6	85.71%	-14.29%
Student 5 before	0	0	1	0	1	0	1	3	42.86%	
Student 5 after	0	0	1	1	0	1	1	4	57.14%	14.29%
Student 6 before	1	1	1	0	1	0	0	4	57.14%	
Student 6 after	0	1	0	0	1	0	0	2	28.57%	-28.57%
Student 7 before	0	1	0	1	0	1	0	3	42.86%	
Student 7 after	0	0	0	1	0	0	0	1	14.29%	-28.57%
Student 8 before	1	0	0	0	0	1	1	3	42.86%	
Student 8 after	1	0	1	0	0	1	0	3	42.86%	0.00%
Student 9 before	0	0	1	1	0	1	0	3	42.86%	
Student 9 after	1	0	1	1	0	0	0	3	42.86%	0.00%
Student 10 before	1	1	1	0	0	0	0	3	42.86%	
Student 10 after	1	1	1	0	1	1	1	6	85.71%	42.86%
Student 11 before	0	1	0	0	1	1	0	3	42.86%	
Student 11 after	1	1	0	0	1	1	1	5	71.43%	28.57%
Student 12 before	1	1	0	0	0	1	1	4	57.14%	
Student 12 after	1	0	0	0	1	1	1	4	57.14%	0.00%
Student 13 before	1	1	0	0	0	1	1	4	57.14%	
Student 13 after	1	1	1	0	0	1	1	5	71.43%	14.29%
	20	17	16	15	16	19	17			
	120						17.142857			
	Planning									
Before	9	8	6	5	6	8	7	49		
	69.23%	61.54%	46.15%	38.46%	46.15%	61.54%	53.85%	53.85%		
Mean								3.77		
SD								1.19		
After	9	7	8	6	8	8	7	53		
	69.23%	53.85%	61.54%	46.15%	61.54%	61.54%	53.85%	58.24%		
Mean								4.08		
SD								1.78		
Max	13	13	13	13	13	13	13	91		
Difference	0.00	-1.00	2.00	1.00	2.00	0.00	0.00	4.00		
Percentage differe	0.00%	-7.69%	15.38%	7.69%	15.38%	0.00%	0.00%	4.40%		

	Information Management Startegies										10		
Name	I slow down when I encounter important	I consciously focus my attention on	I focus on the meaning and significance of new informati	I create my own examples to make information more meaningf	I draw pictures or diagrams to help me underst	I try to translate new information into my own words.	I use the organizational structure of the text to help me	I ask myself periodically if I am meeting my	I try to break studying down into smaller steps.	I focus on overall meaning rather than	Count		
	9	13	30	31	37	39	41	43	47	48			
Student 1 before	1	1	1	0	1	1	0	1	0	1	7	70.00%	
Student 1 after	1	1	1	1	0	1	1	1	1	1	9	90.00%	20.00%
Student 2 before	1	1	0	1	1	1	1	1	1	1	9	90.00%	
Student 2 after	1	1	1	1	1	1	1	1	1	1	10	100.00%	10.00%
Student 3 before	1	1	1	1	1	1	1	1	0	1	9	90.00%	
Student 3 after	0	1	1	1	0	1	0	1	1	1	7	70.00%	-20.00%
Student 4 before	1	1	1	1	1	0	1	1	1	1	9	90.00%	
Student 4 after	1	1	1	1	1	0	1	1	1	1	9	90.00%	0.00%
Student 5 before	1	0	0	1	1	0	0	1	1	1	6	60.00%	
Student 5 after	1	0	0	1	1	0	0	0	1	1	5	50.00%	-10.00%
Student 6 before	1	1	0	1	0	1	1	0	0	1	6	60.00%	
Student 6 after	1	1	1	1	0	1	0	1	1	1	8	80.00%	20.00%
Student 7 before	1	0	0	1	1	1	0	1	1	1	7	70.00%	
Student 7 after	1	1	0	1	1	1	1	0	1	1	8	80.00%	10.00%
Student 8 before	1	1	0	0	0	1	0	0	1	1	5	50.00%	
Student 8 after	1	1	1	0	0	1	1	0	1	1	7	70.00%	20.00%
Student 9 before	1	0	1	1	1	1	0	1	0	0	6	60.00%	
Student 9 after	1	1	1	1	1	1	0	1	0	0	7	70.00%	10.00%
Student 10 before	0	1	1	1	0	1	1	1	1	0	7	70.00%	
Student 10 after	1	1	1	1	1	1	1	0	1	0	8	80.00%	10.00%
Student 11 before	0	1	1	1	1	1	0	1	1	1	8	80.00%	
Student 11 after	1	1	1	1	1	1	0	0	1	1	8	80.00%	0.00%
Student 12 before	1	1	1	1	0	1	1	1	1	1	9	90.00%	
Student 12 after	1	1	1	1	0	1	1	1	1	1	9	90.00%	0.00%
Student 13 before	1	1	1	1	0	1	1	1	1	1	9	90.00%	
Student 13 after	1	1	1	1	0	1	1	1	1	1	9	90.00%	0.00%
	27	23	22	26	18	25	19	21	23	25			
	229									22.9			
	Information management strategies												
Before	11	10	8	11	8	11	7	11	9	11	97		
	84.62%	76.92%	61.54%	84.62%	61.54%	84.62%	53.85%	84.62%	69.23%	84.62%	74.62%		
Mean											7.46		
SD											1.51		
After	12	12	11	12	7	11	8	8	12	11	104		
	92.31%	92.31%	84.62%	92.31%	53.85%	84.62%	61.54%	61.54%	92.31%	84.62%	80.00%		
Mean											8.00		
SD											0.97		
Max	13	13	13	13	13	13	13	13	13	13	130		
Difference	1.00	2.00	3.00	1.00	-1.00	0.00	1.00	-3.00	3.00	0.00	7.00		
Percentage differe	7.69%	15.38%	23.08%	7.69%	-7.69%	0.00%	7.69%	-23.08%	23.08%	0.00%	5.38%		

	Comprehension Monitoring							7		
Name	I ask myself periodically if I am meeting my goals.	I consider several alternatives to a problem before I answer.	I ask myself if I have considered all options when solving a problem.	I periodically review to help me understand important relationships.	I find myself analyzing the usefulness of strategies while I study.	I find myself pausing regularly to check my comprehension.	I ask myself questions about how well I am doing while I am	Count		
	1	2	11	21	28	34	49			
Student 1 before	1	0	1	1	1	0	1	5	71.43%	
Student 1 after	1	0	1	0	1	1	1	5	71.43%	0.00%
Student 2 before	1	0	1	1	1	1	1	6	85.71%	
Student 2 after	1	1	1	1	1	1	1	7	100.00%	14.29%
Student 3 before	0	0	0	0	1	0	0	1	14.29%	
Student 3 after	1	0	0	1	1	1	0	4	57.14%	42.86%
Student 4 before	1	1	1	1	0	1	1	6	85.71%	
Student 4 after	1	1	1	1	1	1	1	7	100.00%	14.29%
Student 5 before	1	1	0	1	0	1	1	5	71.43%	
Student 5 after	0	1	1	1	0	0	0	3	42.86%	-28.57%
Student 6 before	0	1	1	0	0	0	0	2	28.57%	
Student 6 after	1	1	1	0	1	1	1	6	85.71%	57.14%
Student 7 before	0	0	0	0	0	1	1	2	28.57%	
Student 7 after	1	1	1	1	0	0	1	5	71.43%	42.86%
Student 8 before	1	0	0	1	0	1	0	3	42.86%	
Student 8 after	1	0	0	1	0	0	0	2	28.57%	-14.29%
Student 9 before	0	1	1	0	1	0	1	4	57.14%	
Student 9 after	1	1	0	0	1	1	1	5	71.43%	14.29%
Student 10 before	0	1	1	0	1	1	0	4	57.14%	
Student 10 after	0	1	1	1	1	1	1	6	85.71%	28.57%
Student 11 before	1	1	1	0	0	0	0	3	42.86%	
Student 11 after	0	1	1	1	0	0	1	4	57.14%	14.29%
Student 12 before	1	1	0	1	1	1	0	5	71.43%	
Student 12 after	1	1	1	0	1	1	1	6	85.71%	14.29%
Student 13 before	1	0	1	0	0	1	1	4	57.14%	
Student 13 after	1	0	1	1	1	1	1	6	85.71%	28.57%
	21	19	21	17	17	19	20			
	134						19.142857			
	Comprehension Monitoring									
Before	8	7	8	6	6	8	7	50		
	61.54%	53.85%	61.54%	46.15%	46.15%	61.54%	53.85%	54.95%		
Mean								3.85		
SD								1.54		
After	10	9	10	9	9	9	10	66		
	76.92%	69.23%	76.92%	69.23%	69.23%	69.23%	76.92%	72.53%		
Mean								5.08		
SD								1.42		
Max	13	13	13	13	13	13	13	91		
Difference	2.00	2.00	2.00	3.00	3.00	1.00	3.00	16.00		
Percentage differe	15.38%	15.38%	15.38%	23.08%	23.08%	7.69%	23.08%	17.58%		

	Debugging					5		
Name	I ask others for help when I don't understand something.	I change strategies when I fail to understand.	I reevaluate my assumptions when I get confused.	I stop and go back over new information that is not clear.	I stop and reread when I get confused.	Count		
	25	40	44	51	52			
Student 1 before	1	1	1	1	1	5	100.00%	
Student 1 after	1	1	1	1	1	5	100.00%	0.00%
Student 2 before	1	1	1	1	1	5	100.00%	
Student 2 after	1	1	1	1	1	5	100.00%	0.00%
Student 3 before	1	0	0	1	1	3	60.00%	
Student 3 after	1	1	1	1	1	5	100.00%	40.00%
Student 4 before	1	1	1	0	1	4	80.00%	
Student 4 after	1	1	1	0	1	4	80.00%	0.00%
Student 5 before	1	1	1	0	1	4	80.00%	
Student 5 after	1	1	1	1	1	5	100.00%	20.00%
Student 6 before	1	0	1	1	1	4	80.00%	
Student 6 after	1	1	1	1	1	5	100.00%	20.00%
Student 7 before	0	1	1	1	1	4	80.00%	
Student 7 after	0	1	0	0	1	2	40.00%	-40.00%
Student 8 before	1	1	1	1	1	5	100.00%	
Student 8 after	1	1	0	1	1	4	80.00%	-20.00%
Student 9 before	1	0	1	1	1	4	80.00%	
Student 9 after	1	1	1	1	1	5	100.00%	20.00%
Student 10 before	1	1	1	0	1	4	80.00%	
Student 10 after	1	1	1	1	0	4	80.00%	0.00%
Student 11 before	0	0	1	1	1	3	60.00%	
Student 11 after	1	1	1	1	1	5	100.00%	40.00%
Student 12 before	1	0	1	1	1	4	80.00%	
Student 12 after	1	1	1	1	1	5	100.00%	20.00%
Student 13 before	1	0	1	1	1	4	80.00%	
Student 13 after	0	0	1	1	1	3	60.00%	-20.00%
	26	22	27	25	28			
	128				25.6			
	Debugging							
Before	11	7	12	10	13	53		
	84.62%	53.85%	92.31%	76.92%	100.00%	81.54%		
Mean						4.08		
SD						0.67		
After	11	12	11	11	12	57		
	84.62%	92.31%	84.62%	84.62%	92.31%	87.69%		
Mean						4.38		
SD						0.98		
Max	13	13	13	13	13	65		
Difference	0.00	5.00	-1.00	1.00	-1.00	4.00		
Percentage differe	0.00%	38.46%	-7.69%	7.69%	-7.69%	6.15%		

			Evaluation						6		
Name			I know how well I did once I finish a test.	I ask myself if there was an easier way to do things after I finish a task.	I summarize what I've learned after I finish.	I ask myself how well I accomplish my goals once I'm finished.	I ask myself if I have considered all options after I solve a problem	I ask myself if I learned as much as I could have once I finish a task.	Count		
			7	19	24	36	38	50			
Student 1 before	100.00%		1	0	0	1	0	0	2	33.33%	
Student 1 after	100.00%	0.00%	1	0	0	1	0	1	3	50.00%	16.67%
Student 2 before	100.00%		0	1	0	1	0	1	3	50.00%	
Student 2 after	100.00%	0.00%	1	1	1	1	1	1	6	100.00%	50.00%
Student 3 before	60.00%		0	1	0	0	0	0	1	16.67%	
Student 3 after	100.00%	40.00%	0	0	0	0	1	1	2	33.33%	16.67%
Student 4 before	80.00%		0	1	1	1	1	1	5	83.33%	
Student 4 after	80.00%	0.00%	1	1	1	1	1	1	6	100.00%	16.67%
Student 5 before	80.00%		1	1	0	1	0	1	4	66.67%	
Student 5 after	100.00%	20.00%	1	1	1	1	1	1	6	100.00%	33.33%
Student 6 before	80.00%		1	1	0	0	1	0	3	50.00%	
Student 6 after	100.00%	20.00%	0	1	1	1	1	1	5	83.33%	33.33%
Student 7 before	80.00%		1	0	1	1	0	1	4	66.67%	
Student 7 after	40.00%	-40.00%	1	0	0	0	0	0	1	16.67%	-50.00%
Student 8 before	100.00%		0	1	0	0	0	0	1	16.67%	
Student 8 after	80.00%	-20.00%	0	1	0	0	0	0	1	16.67%	0.00%
Student 9 before	80.00%		1	1	1	1	1	0	5	83.33%	
Student 9 after	100.00%	20.00%	1	1	1	1	0	0	4	66.67%	-16.67%
Student 10 before	80.00%		1	1	0	0	1	1	4	66.67%	
Student 10 after	80.00%	0.00%	1	1	1	1	1	1	6	100.00%	33.33%
Student 11 before	60.00%		0	0	1	0	1	0	2	33.33%	
Student 11 after	100.00%	40.00%	0	0	1	1	1	1	4	66.67%	33.33%
Student 12 before	80.00%		0	1	0	1	0	1	3	50.00%	
Student 12 after	100.00%	20.00%	1	1	1	1	0	1	5	83.33%	33.33%
Student 13 before	80.00%		0	1	1	1	0	1	4	66.67%	
Student 13 after	60.00%	-20.00%	1	1	1	1	1	1	6	100.00%	33.33%
			19	21	15	20	16	20			
			111					18.5			
			Evaluation								
Before			6	10	5	8	5	7	41		
			46.15%	76.92%	38.46%	61.54%	38.46%	53.85%	####		
Mean									3.15		
SD									1.38		
After			9	9	9	10	8	10	55		
			69.23%	69.23%	69.23%	76.92%	61.54%	76.92%	70.51%		
Mean									4.23		
SD									1.93		
Max			13	13	13	13	13	13	78		
Difference			3.00	-1.00	4.00	2.00	3.00	3.00	14.00		
Percentage differe			23.08%	-7.69%	30.77%	15.38%	23.08%	23.08%	17.95%		

Appendix 13 – Meta-competencies survey

How often do you feel you use these competencies during your normal class?					
Normal school	1 never	2 sometimes	3 often	4 a lot	5 always
Creativity					
Adapting					
Planning & organising					
Strategy & management					
Critical thinking and problem solving					
Curiosity					
Self-awareness					
Self-regulation					
Self-mastery					
Ethical and sustainable thinking					
Responsible decision making					
Global consciousness					
Social awareness					
Collaborating					
Leadership					
Communicating					
Digital literacy					
Computing literacy					
Digital design					
Computational thinking					

How often do you feel you use these competencies during the DDTS					
DDTS	1 never	2 sometimes	3 often	4 a lot	5 always
Creativity					
Adapting					
Planning & organising					
Strategy & management					
Critical thinking and problem solving					
Curiosity					
Self-awareness					
Self-regulation					
Self-mastery					
Ethical and sustainable thinking					
Responsible decision making					
Global consciousness					
Social awareness					
Collaborating					
Leadership					
Communicating					
Digital literacy					
Computing literacy					
Digital design					
Computational thinking					