

Exploring the concept of 21st century skills: a review of the literature

Research and Innovation

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Executive summary

A move towards a knowledge economy has led to a shift in the skills needed in today's workforce. As AQA explores vocational qualifications and prepares for specification reform, it is an opportune time to think about how we integrate skills-based learning into our assessments. In this report, we explore the concept of 21st century skills.

There have been many attempts to define and systemise the 21st century skill set into frameworks. We focused upon six frameworks that were either most commonly cited in the literature or were UK specific in their design and implementation. We found from comparing and analysing these frameworks that the six most-cited 21st century skills were collaboration, communication, creativity, critical thinking, digital literacy and problem solving (see Table 9).

Having identified the skills, we considered them from three perspectives: how each is defined in the literature; how each is taught in the classroom; and how each is assessed. As we explored the research, we found specific teaching styles and examples of assessments for each of these skills, most of which included a performance-based element.

Twenty-first century skills continue to be a lively point of discussion in education and policy. How we choose to teach and assess each of these skills brings its own challenges and considerations, with each skill requiring its own definition and assessment instrument. A key theme that emerged from the literature is the complexity of separating these skills for teaching and assessment.

Introduction

We have moved into an age of automation, where the ability to apply and critique knowledge has become vital to the workplace (van Laar et al., 2017). This means developing a skill set that allows an individual to adapt to and engage with many roles. However, the notion of a 'transferable' skill set is contested in the research literature, as it assumes that skills learnt in one context are automatically relevant to another (Fettes et al., 2020), which may not be the case.

The term '21st century skills' came into use in the late 20th century, although there is no universally accepted definition (Tight, 2021). Salas-Pilco (2013) describes these skills as 'those capabilities that empower young learners and enable them to cope with the demands of the present century' (p. 11). The Department for Education published a paper in 2003 titled *21st Century Skills: Realising our Potential* (Department for Education, 2003), which aimed to establish a national strategy to ensure individuals had the right skills to 'be both employable and personally fulfilled' (p. 11); skills that go beyond core subject knowledge, such as English or maths. Terms such as transferable skills, key skills, employability skills, or 'soft' skills have been used over the years to describe a similar skill set. Fettes et al. (2020) highlight work by the Confederation of British Industry in 1990, which emphasised the importance of developing employability skills for young people. Looking back even further, to the 1970s, the Further Education Unit developed the idea of a core skills curriculum for vocational students (Further Education Unit, 1979, as cited in

Fettes et al., 2020). It is clear, therefore, that 21st century skills are not a new concept and that policy discussions around skills in education have a long history.

What makes 21st century skills unique is the incorporation of digital skills, reflecting the growth and reliance on these skills in everyday life. The concept of 21st century skills was developed as ICT was becoming accessible to the general public and playing an increasing role in the modern workplace. We now live in a world where ICT is 'pervasive in the workplace and there is a high demand for ICT-proficient employees' (van Laar et al., 2020, p. 1). With the ever-growing impact of globalisation and the move towards a society focused on knowledge acquisition and processing, 21st century skills are highly relevant, and digital skills are a central component.

Employer engagement in skills policy and qualification design

'Education policy discourse is based on skills' (Wheelahan et al., 2022, p. 475). This opening line from a research paper by Wheelahan et al. (2022) highlights the ongoing discussion of skills in education. At AQA, we think of skills in the context of teaching and assessment. However, there is a question as to where skills-based learning can fit into the current curriculum, which primarily values knowledge-based learning.

Employer engagement in educational policy has been a feature since the end of the 19th century (Huddleston & Laczik, 2018), and is likely to continue. In their paper reflecting on employer engagement, Huddleston (2020) talks of 'policy amnesia' (p. 25): that education and skills policy continues to repeat itself over time, rather than learning from its failures. Two persistent issues with skills-based learning are the lack of investment by employers in developing these skills and the mismanagement of employer involvement at policy level.

Employer engagement can involve employers working with schools to influence skill development and educational achievement (Huddleston, 2020). Activities that could be useful include mentoring, careers sessions or even 'arm's length' activity such as money for football kits (Huddleston, 2020). However, this type of engagement is dependent on employers volunteering their time, as they are under no obligation from the government to engage in this outreach.

The 14–19 Diplomas, which existed from 2005–2010, are an example of a failed attempt at involving employers in developing qualifications. The reason for this is that employers were asked to help design qualifications, an area that they do not have expertise in. Expectations in terms of the nature and scale of the voluntary input required from employers were unrealistic.

Employer involvement in qualification design is re-emerging with T-levels (discussed below); the hope being that these qualifications will prove a success in the employer–education space. However, the issues that have been discussed still apply and will need to be taken on board.

T-levels and skills-based learning

Currently, the government is rolling out T-levels in the vocational education sphere. These two-year courses are broadly equivalent to three A-levels (Department for Education, 2022) and include 45 days' work experience. The courses are developed with employers and educators, and are designed to prepare learners for the workplace or further study. Employers have been asked to provide content for industry-based assignments and support the assessments in certain ways (Huddleston, 2020). Examples of subjects include Childcare, Accounting and Engineering. The success or failure of this policy will not become clear for a few years.

How can we implement workplace skills into education?

Fettes et al. (2020) discuss the issues young people face in applying generic skills to the workplace. Despite the fact that young people now have more years of schooling and achieve higher levels of qualification (Kashefpakdel & Percy, 2016; Mann et al., 2017), they still find entering the labour market challenging. Fettes et al. (2020) explored how these skills can be 'developed, recognised and utilised in the workplace' (p. 194). They highlighted the following points:

- Employability is more than one-off preparation that can be taught in school. New workers need support to become familiar with how the workplace functions.
- The assumption that skills are transferable is not helpful. It may be more useful to think of skills being contextualised and recontextualised between education and work environments. It is important that individuals are able to manage change and adapt to new workplaces. Self-regulation and metacognition may be skills that enable young workers to manage these variations.
- It is important to be clear to workers about the skills they require and give them opportunities for development.

Frameworks for 21st century skills

Discussion of 21st century skills has spanned more than three decades. There have been many initiatives that have attempted to define and systemise the skill set into frameworks (van Laar et al., 2020). In this section, we summarise the key frameworks and illustrate their similarities and differences in terms of the skills included (see Table 9).

The frameworks have been developed with the support of international organisations, governments, consulting firms, education experts and others (Salas-Pilco, 2013). They differ in their complexity and have been developed for differing contexts (Scott, 2015). The frameworks are not necessarily designed to directly influence education or assessment; however, they highlight the skills needed for education and the workplace in the current economy (van Laar et al., 2020).

We focused on the five most-cited frameworks in the literature, as summarised in Chalkiadaki (2018). We also looked at a UK-specific framework, the Skills Builder Universal Framework. Although it has not been explicitly defined as a 21st century skills framework, it shares some of the same goals as the other frameworks. In particular, it aims to highlight a skill set that will prepare students for the future workplace, beyond the 'hard' skills included in the curriculum.

Before discussing these key frameworks, we should acknowledge the importance of the Delors Report (Delors, 1996). This report was produced by the Delors Commission and published for the United Nations Educational, Scientific and Cultural Organization. It was designed to provide debate about the purpose of education, with the potential to effect policy change. It was one of the first attempts to identify key competencies for the 21st century (Scott, 2015), and remains an important document to this day.

The report emphasised 'learning through life' (i.e. an individual should be developing their skills over their lifetime) and four pillars of education.

Table 1 The four pillars of education in the Delors Report

Learning to know	Learning to do
General knowledge to be able to work in depth on something.	Occupational skills and the competence to deal with different situations.
Learning to live together	Learning to be
Personality and communication.	Autonomy and personal responsibility.

The four pillars represent a positive ideal of what education can do for learners. However, it is not clear how these would translate into educational practice. For example, under ‘learning to be’, how should ‘personal responsibility’ be interpreted in an educational context? Also, in terms of assessment, how would autonomy be measured? The framework is therefore more a basis for reflection than a practical guide to educational reform.

This framework was superseded as the move towards an information-based society accelerated at the beginning of the 21st century, meaning that new skills (i.e. digital/ICT literacy) needed to be incorporated. This brings us to the key frameworks that this report will focus on.

Each framework is described in turn, with a brief history of its conception and an outline of the skills that it identifies. A table summarising the most-cited skills across these frameworks is provided, and we go on to discuss these skills in more detail in the following section of the report.

enGauge 21st Century Skills

The enGauge 21st Century Skills framework is one of the early examples of an explicit 21st century skills framework. A major emphasis is placed upon digital skills. The framework was the product of a collaboration between the North Central Regional Educational Laboratory and the Metiri Group. The purpose of the project was to ‘[foster] 21st century competences in students, teachers, and administrators’ (Voogt & Roblin, 2012, p. 302).

Table 2 enGauge 21st Century Skills framework

Digital literacy	Inventive thinking
<ul style="list-style-type: none"> • Basic, scientific, economic and technological literacies • Visual and information literacies • Multicultural literacy and global awareness 	<ul style="list-style-type: none"> • Adaptability, managing complexity and self-direction • Creativity, curiosity and risk taking • Higher-order thinking and sound reasoning
Effective communication	High productivity
<ul style="list-style-type: none"> • Teaming, collaboration and interpersonal skills • Personal, social and civic responsibility 	<ul style="list-style-type: none"> • Prioritising, planning and managing for results • Effective use of real-world tools

- Interactive communication
- Ability to produce relevant, high-quality products

European Parliament and Council

The European Union devised its own framework for 21st century skills titled Key Competences for Lifelong Learning. This framework was based on research findings from the Organisation for Economic Co-operation and Development (OECD), particularly those derived from the DeSeCo programme; eight competences were identified:

- communication in the mother tongue
- communication in foreign languages
- mathematical competency and basic competencies in science and technology
- digital competency
- learning to learn
- social and civic competencies
- sense of initiative and entrepreneurship
- cultural awareness and expression.

Partnership for 21st Century Learning

The Partnership for 21st Century Learning (P21, 2007) was a US initiative to develop a unified vision for learning in the 21st century. It involved a collaboration between teachers, education experts and individuals in business. A key goal was to position 21st century skills at the centre of K-12 education (Voogt & Robin, 2010).

Through its collective efforts, P21 created the Framework for 21st Century Learning. The framework was split into three skill sets and twelve components, as shown in Table 3.

Table 3 P21 framework

Three skill sets	Learning and innovation	Digital literacies	Life and career skills
Twelve components	<ul style="list-style-type: none"> • Core subjects • Critical thinking and problem solving • Communication and collaboration • Creativity and innovation 	<ul style="list-style-type: none"> • Information literacy • Media literacy • Information and communication technology literacy 	<ul style="list-style-type: none"> • Flexibility and adaptability • Initiative and self-direction • Social and cross-cultural interaction • Productivity and accountability

- Leadership and responsibility

Trilling and Fadel (2009) reorganised and compressed the P21 framework into seven skills, all beginning with the letter ‘C’: critical thinking and problem solving; creativity and innovation; collaboration, teamwork and leadership; cross-cultural understanding; communication and media fluency; computing and ICT fluency; career and learning self-reliance. They also identified three ‘R’ skills: Reading, wRiting and aRithmetic. The framework is summarised in Table 4, below. Of particular interest for assessment are the learning and innovation skills: communication, collaboration, critical thinking and creativity.

Table 4 Trilling and Fadel’s (2009) reorganised version of the P21 framework

3Rs	7Cs
Reading	Critical thinking and problem solving
wRiting	Creativity and innovation
aRithmetic	Collaboration, teamwork, and leadership
	Cross-cultural understanding
	Communication and media fluency
	Computing and ICT fluency
	Career and learning self-reliance

The P21 framework embodies more than just a description of important skills, and continues to be implemented to this day. As Salas-Pilco (2013) noted, the framework includes a support system of ‘standards, assessment, curriculum, instruction, professional development and learning environments, which provide a better consistency to the whole framework’ (p. 16).

OECD – DeSeCo and the New Millennium Learners

The OECD has been discussing 21st century skills as a concept since 1997. It set up the Definition and Selection of Competencies: Theoretical and Conceptual Foundations (DeSeCo) programme, to develop an international consensus of competencies that were essential for the 21st century. Led by a team in Switzerland, the project involved multidisciplinary experts working with stakeholders and policy analysts to decide which competencies were most important. The final report on this work was produced by Rychen and Salganik (2003), who listed three key competencies from their research:

- using tools interactively
- interacting in heterogenous groups
- acting autonomously.

The OECD expanded on this work in 2009, as detailed in a paper by Ananiadou and Claro (2009), with the DeSeCo programme feeding into a new conceptual framework. An analysis of teaching and assessment practices in the OECD’s member countries identified competencies and skills that

were used to form the basis of its New Millennium Learners framework, which comprised the following three dimensions:

- *information* – information as a source (searching, selecting, evaluating and organising information), information as a product (restructuring and modelling of information) and the development of own ideas (knowledge)
- *communication* – effective communication, collaboration and virtual interaction
- *ethics and social impact* – social responsibility and social impact.

Assessment and Teaching of 21st Century Skills

The Assessment and Teaching of 21st Century Skills (ATC21S) is a multi-stakeholder international partnership between the University of Melbourne, Cisco, Intel and Microsoft (Binkley et al., 2010, 2012). The aim of the project was to create operational definitions of 21st century competencies, to allow for the design of assessment tasks in the classroom. Twenty-first century skills were categorised into four broad categories, with ten core competencies (Griffin et al., 2012). The framework also highlighted the 'core curriculum': five key areas of learning where the 21st century skills can be applied (summarised in Table 5, below).

Table 5 ATC21S framework

Categories	Competencies	Core curriculum
Ways of thinking	Creativity and innovation Critical thinking, problem solving and decision making Learning to learn, metacognition	Home language Mathematics Science History Arts or Humanities
Ways of working	Communication Collaboration (teamwork)	
Tools for working	Information literacy ICT literacy	
Living in the world	Citizenship – locally and globally Life and career Personal and social responsibility (cultural awareness and competence)	

Skills Builder Universal Framework

The Skills Builder Universal Framework is an attempt to define a set of essential skills – ‘those highly transferable skills that everyone needs to do almost any job, which support the application of specialist knowledge and technical skills’ (Ravenscroft & Baker, 2020, p. 2). We highlight this framework in particular as 1) it is a UK-developed framework, and 2) it is developing influence quickly in the education space.

The framework lists eight essential skills, as shown in Table 6.

Table 6 Eight essential skills of the Skills Builder Universal Framework

Listening	The receiving, retaining and processing of information or ideas
Speaking	The oral transmission of information or ideas
Problem-solving	The ability to find a solution to a situation or challenge
Creativity	The use of imagination and the generation of new ideas

Staying positive	The ability to use tactics and strategies to overcome setbacks and achieve goals
Aiming high	The ability to set clear, tangible goals and devise a robust route to achieving them
Leadership	Supporting, encouraging and developing others to achieve a shared goal
Teamwork	Working cooperatively with others towards achieving a shared goal

Each skill is broken down into a series of steps to complete, guiding learners towards mastery of a skill. For example, the skill of listening begins at Step 0, described as ‘I listen to others without interrupting’ and develops through to Step 15: ‘I listen critically and look beyond the way speakers speak or act to objectively evaluate different perspectives’ (Ravenscroft, 2020).

The framework is used by over 700 organisations who identify as part of the Skills Builder Partnership; this includes over 500 schools and colleges. A key focus of the framework is to develop students’ employability skills, alongside their more academic learning within the core curriculum.

Most commonly cited skills from the frameworks

There have been many papers comparing and contrasting the frameworks (Chalkiadaki, 2018; Joynes et al., 2019; Salas-Pilco, 2013; van Laar et al., 2017, 2020; Voogt & Roblin, 2010, 2012), and highlighting the similarities and differences between them.

Using the P21 framework as a reference point, Chu et al. (2017) placed similar concepts from different frameworks in the same row (see Table 7).

Table 7 A comparison of 21st century skills frameworks in accordance with the P21 skill sets

P21 (skill sets)	OECD (dimensions)	ATC21S (categories)
Learning and innovation skills	Communication	Ways of thinking Ways of working
Information, media and technology skills	Information	Tools for working
Life and career skills	Ethics and social impact	Living in the world

Chalkiadaki (2018) grouped the common skills from the aforementioned frameworks into four categories: personal skills, social skills, information and knowledge, and digital literacy. Chalkiadaki compared and collated these frameworks to produce a useful summary (see Table 8). Yet, Chalkiadaki admits that the categorisation they created ‘is hardly accurate and concrete as a number of the skills could equally be placed under one or more categories’ (p. 10). They add that ‘the vagueness of the terminology adds to the complexity of the discussion of the 21st (century) skills’ (p. 10).

Table 8 Summary and categorisation of common 21st century skills by Chalkiadaki (2018)

<p>Personal skills</p> <ul style="list-style-type: none"> • Self-development and autonomy • Creativity • Problem-solving and critical thinking • ‘Presence in the globalised environment’ 	<p>Social skills</p> <ul style="list-style-type: none"> • Communication and collaboration • Cultural awareness and global awareness • Leadership
<p>Information and knowledge</p> <ul style="list-style-type: none"> • Learning • Information management 	<p>Digital literacy</p>

The most recurrent skills and competences identified from our own comparison of the frameworks were collaboration, communication/social skills, creativity, critical thinking, digital/ICT literacy, and problem solving. In Table 9, below, we highlight the frameworks where each of these skills are mentioned, either in these exact terms or similarly expressed.

Table 9 Summary and matching of most commonly cited frameworks to key 21st century skills

	enGauge	European Parliament	P21	OECD	ATC21S	Skills Builder
Collaboration	✓	✓	✓	✓	✓	✓
Communication/social skills	✓	✓	✓	✓	✓	✓
Creativity	✓		✓		✓	✓
Critical thinking	✓		✓		✓	
Digital/ICT literacy	✓	✓	✓	✓	✓	
Problem solving			✓		✓	✓

Critique of frameworks

Not all agree with these specific constructs of 21st century skills, and some go as far as to disregard the label of 21st century skills entirely. Kirschner and Stoyanov (2020) suggest that ‘future-proof learning’ is a preferable term. Their rationale is that the majority of the skills have been defined and recognised for some time; only information literacy and information management are unique to the 21st century. Kirschner and Stoyanov worked with 95 experts from various fields

(education, human resources, IT, business) in Europe and North America to collate ideas and thoughts on how best to prepare students for the insecurity of future employment and non-existent professions. Metacognitive skills, particularly critical thinking, high-level thinking, reflection and efficacy, were highlighted as the most important.

Malcolm Tight (2021) critiqued the concept of 21st century skills from a higher education perspective. We focus on their concerns around pedagogy and measurement. Firstly, how do you teach these skills? Tight believes that curricula need to be designed to integrate these skills, yet this is a complex task. Do we regard each skill as general or specific, disciplinary or centralised? The frameworks themselves do not provide much in the way of guidance here.

If we can teach these skills then we also need to be able to assess them. Tight describes how many of the assessments designed to measure these skills are reliant upon student self-report or direct measurement. Student self-report is the more popular method of measurement; however, this can be problematic. For example, do students overestimate their own skills? Are they critical enough of their own capabilities? Tight also highlights that a lot of the skills are multifaceted and cannot be defined by a singular definition.

21st century skills – definitions, teaching and assessment

Our exploration of frameworks in the previous section led us to focus on the six most commonly cited skills identified: collaboration, communication, creativity, critical thinking, digital literacy and problem solving. In this section, we discuss how these skills can be taught and assessed, and reflect on some of the unique challenges they pose in the classroom. We also explore the multidimensional aspects of each skill and consider whether these are separable constructs.

Collaboration

Definition

A suitable definition of collaboration, for the purposes of assessment, is provided by Hesse et al. (2015). They describe collaboration as ‘the activity of working towards a common goal’ (p. 38). The Skills Builder Universal Framework uses the term ‘teamwork’ instead, yet with a very similar definition: ‘working cooperatively with others towards a shared goal’ (Ravenscroft, 2020, Teamwork section). This is a broad description, as working with other people is a complicated and nuanced process. However, it captures what collaboration would entail in the classroom and operationalises it sufficiently for it to be a teachable skill.

The literature on 21st century skills emphasises that collaboration is not simply to enhance learning other content: it is an important skill in itself (Kuhn, 2015). With this in mind, we need to find a way of assessing the individual’s collaboration skills, which is more difficult than analysing the collaboration skills of a whole group.

Attempting to operationalise collaboration requires identifying sub-skills to focus upon. Stevens and Campion (1994) provided a much-cited summary of the requirements for teamwork, which are divided into interpersonal skills and self-management skills:

- interpersonal skills
 - conflict resolution
 - collaborative problem solving

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- communication
 - self-management skills
 - goal setting and performance management
 - planning and task coordination.

This conception is simple to understand and provides a set of sub-skills that can be used to teach and measure collaboration. For example, conflict resolution (discussing and coming to an agreement on a task) is an important aspect of the future workplace, and embedding this early on will help students to become better team players.

Teaching

Collaboration is a multidisciplinary skill, requiring students to have multifaceted skills and knowledge, such as reading, presentation, information, and computer skills (Chu et al., 2012). Teaching collaboration involves various subject teachers to guide students in developing these different skills. However, there is no evidence that simply engaging in more group work improves collaboration skills (Lai et al., 2017). As Rotherham and Willingham (2010) noted, students need to practise collaboration and receive feedback and teaching in order to develop these skills.

In their review of collaboration teaching and assessment, Lai et al. (2017) considered features of activities that could be considered to help develop collaborative skills:

- *Group formation:*
 - *Size of groups:* How many students are placed in a group is an important consideration when thinking about collaborative activities. Research has shown that groups of three versus groups of six are more successful for communication (Lowry et al., 2006), and that smaller groups are less likely to have students disengage from participation (Lam, 2015).
 - *Assignment of groups:* Self-selecting groups can introduce issues of bias (e.g. high-achieving students choosing other high achievers). However, students choosing peers who they know they work well with could lead to a positive outcome. On the other hand, teachers changing the combination of students may help to diversify experience and foster learning from one another.
- *Role assignment:* Students are given a role to play within a group (e.g. moderator, starter, summariser). In an experiment looking at online moderation, a study found that students who were assigned as moderators were more engaged in moderating behaviours than students who were given no role (De Wever et al., 2008). It could be that role assigning may help to focus students on an aspect of collaboration they need to improve upon, giving them explicit space to concentrate on this.
- *Providing feedback:* Peer review is one example of feedback that can be used to support teamwork. This could be achieved via an online peer evaluation system, where students can be scored on their collaborative behaviour with simple Likert-scales and short statements (Brutus & Donia, 2010; Anson & Goodman, 2014).

The key point is that activities focused upon developing collaboration should be planned and considered. Collaborative learning entails collective intellectual efforts among students and/or between students and teachers.

Collaborative learning has also been found to be useful in fostering student inclusion and diversity. The teaching of this skill involves students having intellectual and social interactions. This allows for differences in knowledge, skills and attitudes to be shared among students, and potentially be turned into benefits.

Assessment

Analysing group dynamics within collaborative activities is complex, and trying to separate out and measure individual performances within those activities is an extra challenge for teachers (Binkley et al., 2012, p. 46).

Collaboration (and communication) skills are typically assessed using ongoing observation of student group work or a web-based collaboration tool such as wiki-based project writing (see Chu et al., 2012). Self-assessment questionnaires relating to perceived social skills have been used by Notari and Baumgartner (2010) for evaluating the level of collaboration of students in a group project.

A common task used to assess collaboration is collaborative problem solving, in which students work together (or with virtual collaborators) to solve a problem. The PISA 2015 Collaborative Problem Solving (CPS) assessment is a famous example of this type of task:

[It] measures students' capacity to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution, and pooling their knowledge, skills and efforts to reach that solution. (OECD, n.d.)

The PISA 2015 CPS task was the first large-scale international assessment of collaborative problem-solving; 125,000 students across 52 countries and economies participated. PISA identified four processes for individual problem solving and three key competencies specific to collaborative problem solving. From this, they developed an assessment matrix of 12 skills to be measured, as summarised in Figure 1, below.

	(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Establishing and maintaining team organisation
(A) Exploring and understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Understanding roles to solve the problem
(B) Representing and formulating	(B1) Building a shared representation and negotiating the meaning of the problem (common ground)	(B2) Identifying and describing tasks to be completed	(B3) Describing roles and team organisation (communication protocol/rules of engagement)
(C) Planning and executing	(C1) Communicating with team members about the actions to be/being performed	(C2) Enacting plans	(C3) Following rules of engagement, (e.g. prompting other team members to perform their tasks)
(D) Monitoring and reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organisation and roles

Note: The 12 skill cells have been labelled with a letter-number combination referring to the rows and columns for ease of cross-referencing later in the document.

Figure 1 Assessment matrix developed by the OECD for the PISA 2015 CPS task (OECD, 2017)

The task was administered on a computer, and students were asked to complete collaborative assessments. The students interacted with computer simulations of humans, referred to as computer agents. This enabled the OECD to control the behaviour of the simulated human, allowing the assessment to focus on the performance of the individual student. The computer agents were programmed to be more or less cooperative, and to always bring the problem back to the same state. The student had to make the correct collaborative decision to advance the task and solve the problem. The Xander unit, for example, asked students to answer questions about a fictional country called Xander (Mo, 2017). In one task, the simulated humans argued about whether they should discuss how to approach the question or just get started. The student had to select from a set of four responses; the response agreeing to discuss the approach was marked as the correct answer (represented by B1 in Figure 1).

AQA has carried out its own work in this area. Dr Ruth Johnson (AQA) and Dr Ayesha Ahmed (University of Cambridge) led a project to develop a toolkit to assess collaboration (Ahmed, 2018; Johnson, 2017). They worked with 15-year-old students who collaborated on a problem-solving task in groups of three. Students were asked to program a robotic car to drive along a road, distinguished by two black lines on a mat. Based on their observations of how the students worked together, the researchers created an assessment toolkit for use in the classroom. These resources provide a solution to the issue of assessing individual contribution in a collaborative task, using multiple sources of feedback: teacher-reported feedback, self-assessment and peer assessment. With this method, assessment is based around teacher-led feedback yet is also a reflective activity for the students involved, helping them to both recognise and learn how to be better collaborators.

Summary

- Collaboration is a complex process that involves working with others towards a collective goal.
- Aspects of collaboration that can be taught and measured include conflict resolution, collaborative problem solving, communication, goal setting and performance management, and planning and task coordination.
- Activities for developing collaboration must be structured and purposeful; simply getting students to work together will not teach them the skills they need.
- Assessments of collaboration may use tools to measure collaboration in context (e.g. online collaborative tasks), as well as self-assessment and peer assessment. Collaborative problem solving is often used to assess collaborative ability. This involves working with other students or, in some cases, with simulated collaborative situations.

Communication

Definition

In a 2014 survey, the Pew Research Center found that of 10 skills taught in school, communication was regarded by 90% of participants as the most important skill for getting ahead in life (Goo, 2015). Jacobson-Lundeberg (2016) describes communication as 'a gateway skill to other 21st century skills' (p. 87). For example, communication skills are vital to successful collaboration.

The skill of communication is difficult to define as it involves various sub-domains (Metusalem et al., 2017). Examples of communication sub-domains include informing, persuading, questioning, entertaining and arguing. Another aspect of communication that can vary is the format; for

example, it may take the form of speaking, reading, email, essay, social communication or public speaking.

Metusalem et al. (2017) identified eight core communication skills that they considered particularly salient when thinking about the production and reception of communication:

- *identify desired outcomes* – determine one or more desired results or consequences of the communication (e.g. identify a speaker’s main argument)
- *craft clear messages* – create messages that accurately convey intended meaning, appropriately utilising non-linguistic cues like body language or visual aids (e.g. using grammatically correct sentences)
- *model others’ minds* – recognise and account for others’ knowledge, beliefs, dispositions and emotions (e.g. awareness of audience’s level of expertise on a topic)
- *adhere to conventions* – follow the rules or norms of specific disciplines or contexts (e.g. write/speak with the appropriate level of formality)
- *account for social and cultural differences* – identify and account for variability in social and cultural norms (e.g. recognition of cultural differences in communicative norms)
- *select appropriate channels* – utilise the most appropriate communicative channel (e.g. determine whether a face-to-face conversation is needed or if remote is fine)
- *active listening* – actively attend to a sender’s message, withhold judgement, monitor and clarify understanding (e.g. request clarification if needed)
- *deep reading* – critically analyse text/speech, monitor comprehension, draw inferences, question and reflect (e.g. critically analyse an argument).

This list highlights the wide-ranging and complex nature of communication, and can help to identify behaviours to analyse and develop with students when improving communication.

Teaching

As discussed in the definition subsection, there are multiple forms of communication – e.g. speaking, writing, reading – and these represent different methods for teaching communication. Metusalem et al. (2017) describe these methods as ‘teaching communication skills holistically within particular communicative domains’ (p. 15). Metusalem et al. divide the various forms of communication into production skills (e.g. oral presentations, interpersonal communication) and reception skills (e.g. reading comprehension, active listening). In other words, how we *give* information and how we *receive* information.

Below are some examples of the different formats that production skills can take.

- *Public speaking*: Oral presentations are a key element of schooling. The ability to deliver an oral presentation is an important life skill, and the anxiety that people can experience makes it even more important for students to get help developing this skill. Teachers can help by giving students specific objectives for their speeches, facilitating feedback from peers in the classroom, and offering opportunities to practise in class. Further design principles for teaching public speaking can be found in van Ginkel et al. (2015).

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- *Interpersonal communication*: It is important in the workplace to be able to communicate effectively with others. Whether building rapport or asking for information, clear communication is key. One approach to teaching these skills is to use role-playing, with clear feedback provided as to how the scenario went and whether students acted appropriately within the scenario.
 - *Writing*: Writing is a requirement of many modern jobs, and the ability to be clear and concise is important. Teaching students to communicate effectively in writing is already covered to some extent in English classes; however, more explicit instruction on how to achieve clarity in their writing may be needed. Strategies for doing this may involve students planning their writing beforehand, being clear about the message they need to convey and writing with that message in mind.

Below are some examples of reception skills.

- *Active listening*: Understanding another person's point of view and intention means you can respond appropriately. Active listening can be taught in a paired conversation, wherein you get students to ask questions, explore topics of interest and react appropriately to the conversation.
- *Reading comprehension*: The ability to read in order to understand meaning is incredibly important. Whether it is a bank statement or an academic paper, both require the ability to extract meaning from writing. Strategies to teach reading comprehension include comprehension monitoring, wherein students are asked to check their understanding of a text as they read to ensure they maintain comprehension throughout. Another method is paraphrasing: reducing the text to its main points using the reader's own words demonstrates understanding of a text.

Assessment

Situational judgement tests have been used to assess student judgement in work-related situations; for example, in medical entry exams. A student is given a scenario and is asked to select the most appropriate response or to indicate what he or she would do in that situation. These measures have been used in the literature to capture communication and collaboration skills (McDaniel et al., 2001, 2007). They can be seen as a form of role-playing, asking students to occupy a position for which they are in training.

The production and reception skills discussed in the teaching subsection are also a useful guide for creating assessment tasks. Oral presentations are a popular example (Metusalem et al., 2017). Teachers can assess public-speaking skills and how well students are able to present information to an audience. This may be done using a rubric or through formative feedback on how well the student did. Written essays are another example of communicative assessment. Students may be taught how to communicate an argument or message in a long-form essay. The literature suggests that the methods used to teach communication are similar or the same as the methods used for assessment.

Summary

- Communication is regarded as one of the most important skills in the modern world. It particularly requires our attention as it is interwoven into many other skills.

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- Communication can be defined in a number of ways, dependent upon the medium being used to communicate (e.g. speech, writing).
 - There are various methods for teaching communication, including oral presentation, role-play and reading.
 - Assessing communication depends on the form of communication you are focusing on, e.g. oral or written.

Creativity

Definition

Creativity is regarded as important to a student's education; however, finding a consistent definition in the literature for the purposes of teaching and assessment design is difficult. Lucas (2016) captures the confusion, stating that '[creativity] is broad, vague, and daunting for many teachers' (p. 287). Treffinger et al. (2002) found 120 definitions for creativity in the papers they examined, eventually separating them into four categories: generating ideas, digging deeper into ideas, openness and courage to explore ideas, and listening to your 'inner voice'. However, the definition of creativity as 'the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context' (Plucker, Beghetto, & Dow, 2004, p. 90) has been cited many times in the literature.

In their review of creativity assessment, Barbot et al. (2011) similarly highlight the multidimensional nature of creativity, summarising it as a combination of cognitive, conative (personality and motivational traits) and emotional factors, which dynamically interact with the environment the individual is in. It is this shifting combination of factors that allow creative work to flourish. According to this description, creativity cannot be subsumed under a single definition; it needs to be thought of in its full complexity.

In English education policy, there has been confusion over the years as to the place that creativity should hold within education. While the National Advisory Committee on Creative and Cultural Education (1999) seemed to signify that creativity should be embedded into the curriculum, it remains unclear as to the value that should be placed on it (Lucas et al., 2012). Creativity is often associated solely with the arts; as such, critics argue that creativity 'is being "squeezed out" by changes made to the National Curriculum' (Davies et al., 2018, p. 880).

Despite creativity being endorsed in government policy and literature, there is still a lack of clarity on how it can be fostered in education (Newton & Newton, 2014). This skill is, however, regaining prominence on an international level. The OECD's PISA 2021 contains a measure of creative thinking, and the PISA tests carry major significance for governments all over the world (Cremin & Chappell, 2021).

Teaching

Of all the skills, creativity may be the least immediately intuitive for teaching. As outlined in the previous subsection, there are numerous definitions of creativity, and many of these are not adequately precise to support the teaching and learning of this skill.

Lai et al. (2018), in their summary of creativity teaching, highlight creative problem solving and divergent thinking as two potential methods of teaching. Lai et al. focus on teaching cognitive strategies to support creativity, such as teaching metacognitive awareness to help students think

explicitly about their creative process. Lai et al. also suggest that improvisation and role-playing games could encourage creativity, as both require students to create something from nothing in the moment.

Assessment

The lack of a clear definition of creativity has led to much debate about the assessment of this skill.

The idea that young people could come out of school labelled as a level 7 imaginer or grade C collaborator is horrific – yet clearly some evaluation of success is necessary. (Lucas & Claxton, 2009, p. 25)

The above quote represents one of the difficulties with assessing creativity, which is that the use of a summative measure could be a reductionist method of assessment. Despite these challenges, there is a long history of assessing creativity (Plucker & Makel, 2010).

Creativity has been measured by researchers using the Torrance Tests of Creative Thinking (TTCT; Torrance, 2000). The test is a measurement of divergent thinking; that is, thinking that leads to new information or new ideas. It was developed over 60 years ago and has gone through a number of iterations. It is the most well-known, and most used, test for measuring creativity (Almeida et al., 2008).

The test measures creativity via two different constructs. The first is the TTCT-Verbal construct, which is a set of subtests that present students with a probe requiring a verbal response. One example is the unusual uses task. Students are presented with a picture of an object (e.g. tin can, brick, book) and asked to list as many uses for this object as they can think of. The idea is to assess students' ability to think of inventive and novel uses for the object beyond those that are obvious. The other construct is the TTCT-Figural tasks, which require a non-verbal response. One example is the picture construction task, in which children are given a shape (e.g. a triangle, a jelly bean) on a sheet of paper. They are then asked to use this shape as the main feature of a picture. They can draw whatever they want, giving them the freedom to use this shape to express themselves.

Originally, each of these tasks was marked on four scales: fluency (number of relevant responses), flexibility (variety of categories of shifts in responses), originality (considering relevant novelty responses) and elaboration (number of details used to extend a response).¹ The hope is that these two types of tasks, together with the scales, can help to identify aspects of creativity in students. Although, there is debate about whether the four scales can be independently assessed (Lai et al., 2018). The longevity of the TTCT is likely due to the simplicity of its implementation, and the fact that it seems to provide a measurable concept of creativity.

Another method of assessing creativity is via self-report, reflecting on one's own processes and achievements. This could be through self-rating scales (Runco et al., 2014), or writing essays about creative works that have been produced. The issue is the ability to 'fake' these scales, as they rely on an individual being truthful.

The last method discussed in Lai et al. (2018) is an assessment of the final creative products (e.g. paintings, poetry). Lai et al. (2018) discuss the method of 'consensual assessment', which requires

¹ However, the flexibility scale was removed from the figural tasks, as the flexibility scores could not be differentiated from the fluency scores (Kim, 2006).

experts of a particular domain to arrive at a consensus rating of creativity for a piece of work. This is achieved through a blind review of students' work, with the experts independently rating the comparative creativity of the different pieces of work (Baer & Kaufman, 2019, p. 28). Research on the method suggests that there are high levels of agreement between the experts, with levels of inter-rater reliability typically 0.80 or higher (Baer & Kaufman, 2019, p. 28). However, the technique is resource intensive, as assembling groups of expert judges is logistically complicated and can be expensive (Baer & McKool, 2009, p. 10).

In practice, most assessments of creative works are conducted using a rubric (Lai et al., 2018), which may have separable dimensions like uniqueness, usefulness etc. Rubrics are often used because this method of assessment is easier to implement and is also reliable, especially when used with trained raters (Jonsson & Svingby, 2007; Clary et al., 2011). However, there is debate about whether all of the elements included in a rubric are related to creativity (Lai et al., 2018), reflecting the aforementioned difficulty of defining this skill.

Summary

- Creativity is a multidimensional skill that is difficult to summarise.
- Teaching creativity can be challenging; it may involve focusing on specific features of creativity (e.g. metacognitive awareness, improvisation) for development.
- Assessing creativity can be problematic, partly because of the need to define what creativity is.

Critical thinking

Definition

Critical thinking has a long history in education, and is often regarded as vital in educational settings (Dwyer et al., 2014). It is a key skill and an important indicator of the quality of a student's learning (Alsaleh, 2020). There is no consensus on the definition of critical thinking. Two schools of thought on this topic have been identified by Sternberg (1986):

- *philosophical approach* – focuses on what makes the ideal critical thinker versus how people actually think
- *cognitive approach* – focuses on the quality of critical thinking being conducted and the actions or behaviours exhibited by successful critical thinkers.

Philosophers have described critical thinking as 'reflective and reasonable thinking that is focused on deciding what to believe or do' (Ennis, 1985, p. 45), while cognitive psychologists have described it as 'the use of those cognitive skills or strategies that increase the probability of a desirable outcome' (Halpern, 1998, p. 450). For assessment purposes, the concern is around how critical thinking can be explicitly taught and evidenced, even if philosophers may deem this reductionist (Lai, 2011).

Cambridge Assessment produced their own definition of critical thinking, based upon their review and synthesis of research. They describe critical thinking as 'the analytical thinking which underlies all rational discourse and enquiry ... characterised by a meticulous and rigorous approach' (Cambridge Assessment, n.d.-a, p. 1). Their research revealed that critical thinking is highly valued among teachers as a transferable skill that is important in everyday decision making (Cambridge Assessment, n.d.-b).

When deciding how to define critical thinking for education, it is important to consider whether the skill is in fact generic and transferable or whether it is context-specific, meaning that different subjects require a different type of critical thinking. In their meta-analysis of this area, Abrami et al. (2015) suggest that the prevailing view of psychologists is to adopt a generic traits approach; critical thinking is a skill to master that can be applied across different contexts.

Teaching

Alsaleh (2020) concluded from their literature review that critical thinking is a teachable skill; it has the necessary theoretical grounding, and it is possible for the skill to be practised in real settings. However, they also highlighted disagreement over certain questions related to the teaching and learning of this skill:

- Where in the curriculum should critical thinking skills be taught?
- What critical thinking skills can be taught?
- How should critical thinking skills be taught and assessed?
- Can technology promote students' critical thinking skills?

Focusing on the first issue, the question is whether students need a dedicated course on critical thinking, or whether it a generalised skill that can be taught across subjects. In the past, AQA offered A-level Critical Thinking as a standalone qualification, focusing on established theories and practices to develop skills such as reasoning, decision making and formulating clear arguments.

In their review of teaching and assessing critical thinking, Ventura et al. (2017) highlight that the main focus of research on critical thinking teaching has focused on argument analysis and creation. Constructing an argument is a specific skill associated with critical thinking. It involves judging a claim, evaluating evidence around this claim, and then developing a response in favour or against. This can be done through explicit instruction. For example, Bensley and Spero (2014) used a method called direct infusion, where a group of students were taught how to apply the rules of psychological arguments and critical reading. These students scored better on a critical reading test compared with groups who were given less explicit instruction. Collaborative learning can also be a successful way to explore argument development, with students engaging in critical thinking problems together (Ventura et al., 2017).

Dwyer et al. (2012) attempted to measure argumentation skills in the context of critical thinking through the use of argument mapping, wherein a text-based argument is represented in a flowchart, with different points set out in boxes and the linking between these points highlighted. Students who engaged in the argument mapping course found themselves scoring better on critical thinking scales compared with other learners. This is just one example of teaching critical thinking; other methods include problem-based learning, scaffolded practice, questioning and class discussions (Alsaleh, 2020).

Assessment

Several standardised tests exist for evaluating critical thinking. These tests utilise multiple-choice questions in verbal, quantitative and figural forms. Examples include the Sternberg Triarchic Abilities Test (Sternberg, 2006), the Watson-Glaser Critical Thinking Appraisal (Watson & Glaser, 1980), the California Critical Thinking Skills Test (Facione, 1990), and the Cornell Critical Thinking Tests (Ennis & Millman, 2005). Test items are designed to assess different components of critical

thinking, such as inductive reasoning, deductive reasoning, drawing conclusions and evaluating arguments. These more traditional assessments of critical thinking are mostly framed as being domain-general (Ventura et al., 2017). They are simplistic to implement and capture specific aspects of critical thinking ability.

An alternative method of assessment involves the use of various task models. Ventura et al. (2017) summarised these activities designed to elicit students' critical thinking skills into three categories:

- *Writing tasks*: Writing tasks are extended pieces of work that allow students to draw on key critical thinking skills, such as analysis and evaluation. One example of a writing task can be found in the Collegiate Learning Assessment (CLA+; Council for Aid to Education, n.d.). Students are given evidence that they must organise and synthesise in order to decide on a certain course of action. Whatever conclusion they may draw, it is important that students demonstrate critical thinking. Students are assessed on aspects such as use of relevant information, constructing arguments and writing quality.
- *Simulation tasks*: Ventura et al. (2017) note that assessments that use simulations are particularly good for systems analysis; that is, solving specific problems in a simulated environment. For example, a problem could be a medical student being asked how they would diagnose a patient's condition. The range of activities that simulation tasks afford can elicit a broad range of responses, and there is the possibility to capture data about a student's process as well as their end product.
- *Concept map tasks*: Concept maps allow students to visually illustrate complex relationships between concepts (Ventura et al., 2017). For example, they can be used in science for mapping the lifecycle of a plant. It may be that students draw the concept map or use a computer to generate one.

Summary

- Critical thinking has a long history in education and is regarded as a vital skill.
- An important argument remains around whether to teach critical thinking as a general or subject-specific skill. The literature currently supports critical thinking being a general skill.
- Teaching critical thinking can be facilitated across subjects; for example, in the case of argument analysis.
- Assessment of critical thinking has been achieved through a variety of methods including writing, simulation and concept map tasks.

Digital literacy

Definition

Digital literacy in its broadest sense is being competent in the use of digital technologies. Buckingham (2015) grappled with defining this skill in an educational context. He presents first what he calls a 'functional definition' of digital literacy: an individual having the basic skills to do specific tasks on a computer. Buckingham highlights the use of such a definition by the Skills for Life survey, commissioned by the Department for Education and Skills (Williams et al., 2003). The survey split the ICT abilities into two levels (Williams et al., 2003, p. 12):

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- *level one* – understands most of the basic terminology in ICT; can use most of the standards features of word processors, spreadsheets etc.; knows about the different formats used by different programs and where/how to save data; can enter and bring in information (e.g. copy and paste/importing images) and standardise the presentation of various kinds of document
 - *level two* – all of the Level 1 skills; can search for and collect/assess information using search engines, databases etc.; use program tools proactively to maximise the value of the ICT he/she is using.

In this sense, ICT skills are about the ability to use computers effectively to complete functional tasks. However, the term 'digital literacy' goes beyond this basic ICT skill set. The word 'literacy' suggests more than simply the ability to use the technology; it involves the ability to be critical of information, as well as the ability to interpret and use knowledge, and to relate this knowledge to the wider world. McLoughlin and Alam (2011) regard digital literacy as a framework by which to integrate other literacies and skill sets, e.g. media literacy, information literacy. Digital literacy is likely to have become more important because of the vast amount of information that can be accessed online, and students need to have the skills to critically engage with and evaluate the information they find.

In their review of 21st century skills and digital skills, van Laar et al. (2017) provide a summary of digital literacy:

Overall, digital literacy is presented as a mind-set that enables users to perform intuitively in digital environments, and to both easily and effectively access the wide range of knowledge embedded in such environments (van Laar et al., 2017, p. 579).

One of the difficulties in defining digital literacy is the ever-changing nature of digital technology. At the beginning of the 21st century, the internet was still in its relative infancy, without the existence of widespread social media, wireless access through mobile phones and laptops, and a reliance upon this technology for a functioning society. For example, virtual reality (VR) technologies are now consumer products available to everyone. There is a new basic skill set for using this specific technology, as well as new issues related to the language of VR and how to *be* in this virtual space. What constitutes digital literacy will have to be revised over time.

Work is already underway to keep up with changes to information delivery. For example, disinformation and 'fake news' has become a more prevalent issue in culture. As noted in a report by the National Literacy Trust (2018), fake news, misinformation and propaganda is not a new phenomenon. History is full of examples of how misinformation has surrounded political events. However, it is technological developments that have allowed fake news and misinformation to take a new form. The ability to target, spread and create misinformation at speed and ease has changed how we engage with news and information (National Literacy Trust, 2018). This is a serious issue, which is being discussed in parliament (Digital, Culture, Media and Sport Committee, 2019):

It is hard to differentiate on social media between content that is true, that is misleading, or that is false, especially when those messages are targeted at an individual level. Children and adults need to be equipped with the necessary information and critical analysis to understand content on social media, to work out what is accurate and trustworthy, and what is not (Digital, Culture, Media and Sport Committee, 2019, point 302 of report).

The report by the National Literacy Trust (2018) also included some findings from student and teacher surveys about fake news. The following key points were emphasised:

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- Only 2% of children were identified as having the critical literacy skills they needed to tell if a news story is real or fake.
 - Half of the children surveyed were worried about not being able to spot fake news.
 - Half of teachers surveyed believe the national curriculum does not provide children with the literacy skills to spot fake news.

While digital literacy is not a new idea, its relevance has potentially increased. However, as highlighted by Buckingham (2019), the disagreement over what is meant by digital literacy creates issues. In a blog on his website, Buckingham states that the term digital literacy has become misleading. The difference between print and digital media may not be as distinct as some definitions suggest; the boundaries are somewhat blurred. Buckingham advocates focusing on a critical media education, pointing to the work done by media studies researchers as useful for this purpose.

Teaching

As with critical thinking, there are questions around how to implement digital literacy within education, i.e. should it be taught as a separate subject or integrated into the school curriculum (Webb, 2002)? Unlike most of the other skills discussed, ICT already exists as a school subject; for example, AQA offers Computer Science at both GCSE and A-level. However, the literacy aspect may not be being taught in these contexts.

Yang and Wu (2012) make the point that the internet has given learners more opportunities to explore personal interests and access information about these. However, they argue that this access does not automatically translate into digital literacy; for example, being able to identify misinformation and identify trustworthy sources. It is important to know how to use digital technologies to access information, and, in turn, how to use this information carefully and critically. This ability to judge information and critique how trustworthy it may be is closely linked to critical thinking.

Assessment

Diagnostic inventories of students' perceived competence in information technology have been used to evaluate digital literacy. Chu (2012) made use of the Tool for Real-time Assessment of Information Literacy Skills (n.d.) to evaluate the information literacy of primary school students (aged 10–11 years old). This tool categorises information literacy into five categories: develop topic; identify potential sources; develop, use, and revise search strategies; evaluate sources and information; use information responsibly, ethically, and legally. Assessment is via multiple-choice questions that cover these areas, and the results help teachers to grade their students' information literacy.

Performance-based assessment in a virtual school or work situation has been used by Claro et al. (2012) for assessing information technology and communication literacy skills. Students were tested on three skills: information, communication and ethics. There was a story that flowed through the assessment, and, in each task, students were asked to complete an activity that required them to engage with one of the three skills listed above. For example, for the ethics skill, students were presented with a scenario followed by multiple-choice questions in which they had to choose the best advice for a virtual classmate, assessing students' ability to evaluate responsible use of ICT.

Summary

- Digital literacy is more than simply being able to use technology; it is also the ability to critically evaluate digital media.
- The teaching of digital literacy requires careful thought. Specifications need to explore themes such as misinformation, social media and virtual reality.
- Measures of digital literacy seem to focus on students' competence in using ICT, rather than their critical digital literacy skills.

Problem solving

Definition

Funke et al. (2018) describe problem solving as 'a bundle of skills, knowledge and abilities that are required to deal effectively with complex non-routine solutions in different domains' (p. 41). Students experience a problem when they want to reach a specific goal but do not routinely identify the appropriate pathway to get to it. To achieve the desired goal, they must use one or more higher-order thinking processes. These thinking processes are referred to as problem solving.

Problem solving can be either knowledge based or general. Knowledge-based problem-solving methods within a specific subject provide much better solution strategies than general problem-solving strategies (Anderson, 1987; Royer et al., 1993). According to Bransford and Stein (1984), problem-solving skills can be ordered into a five-stage process called IDEAL problem solver:

- I – identify the problem
- D – define and represent the problem
- E – explore possible strategies
- A – act on the strategies
- L – look back and evaluate the effects of your activities.

Teaching

There are controversies among educators, cognitive scientists, and psychologists regarding whether we should teach students problem-solving strategies that are general or subject-specific. The strategies for solving subject-specific problems are found to be less applicable across different subjects but more powerful within the specific curriculum. On the other hand, the general approach can be applied to any subject area, yet it has limited power within any specific curriculum. The research suggests that both general and subject-specific strategies are used by educators (Perkins & Salomon, 1989; Shuell, 1990).

Assessment

Problem solving has been part of large-scale assessments for some time now. Assessing problem solving is a complex endeavour. Due to the wide definition of the construct, capturing problem-solving ability requires different tool sets for different purposes. Problem-solving assessments usually involve tasks that require students to apply knowledge and skill in new situations.

Strategies for assessing problem-solving skills are well documented in the literature. Most problem-solving assessments are knowledge structured: they assess how a student perceives the structure of several subject-based concepts and facts, and how they process these concepts and facts to solve problems in the specific domain. As mentioned in the teaching subsection, the most powerful problem-solving strategies are specific to a subject area. For example, problem-solving assessment in mathematics may involve developing solution strategies or linking concepts to evaluate solutions. In science, problem solving might involve tasks such as undertaking scientific investigations or evaluation of results (see, for example, Quellmalz & Kozma, 2003). In English literature, problem solving may involve analyses of Shakespeare plays; for example, looking for frequent symbolism throughout the text.

Summary

- Problem solving involves exercising high-level thinking skills in tackling novel situations.
- Both general and subject-specific problem-solving strategies are taught by educators.
- Problem solving has been part of large-scale assessments for some time.

The multidimensional aspect of 21st century skills

In the previous section, we focused on each of the six skills in turn and attempted to summarise each one. However, in reality, it is difficult to separate some of these skills, as they involve multiple dimensions of learning that are interdependent (Chai et al., 2015).

Two of the skills that are closely aligned are collaboration and communication. Collaboration has been defined as working with others towards a common goal, and to do this will require communication with others. While communication can sometimes be a solo activity (e.g. when writing a report), it often involves working with others. For example, collaborating on a team project will involve a great deal of communication, even if each student writes their own report at the end. To try to assess the skills of collaboration and communication separately in this context may be difficult.

Collaborative problem solving is another example of how inseparable some of these skills are. Care et al. (2018) highlight that collaborative problem solving is particularly complex in that it looks at the broad domains of social and cognitive skills, and also calls on the specific skills of collaboration and problem solving. They say that this complexity makes measurement that much more challenging. For example, breaking down the overall score for a quantitative task in terms of the unique sub-skills demonstrated will require extensive consideration of the validity of the measures used.

Reflecting on the frameworks discussed in this review, it seems that what makes a 21st century learner is having a combination of these multidimensional skills. The overall goal is for students to possess all these skills; it therefore makes sense for there to be crossover between the skills.

Accepting that these skills are intertwined makes teaching and assessment challenging. However, if we think of project-based learning, there are opportunities to incorporate several 21st century skills: for example, communication, problem solving, digital literacy and critical thinking.

Conclusion

Twenty-first century skills are important to success not only in employment but also within education and life in general. With the so-called fourth industrial revolution upon us, preparing students for the future workplace is a necessity. A key question for us is how AQA can help to do this. We have identified the following key themes from our work for further consideration.

Build on what AQA is already doing to assess these skills

Many of the skills discussed in this review are already incorporated in our specifications, even if not explicitly. For example, collaboration and communication are part of everyday classroom teaching and learning. A valuable next step to build on this research would be to review our specifications and highlight where these 21st century skills are being taught and assessed, so as to avoid unnecessarily reinventing specifications.

Identify how to separate the different skills for assessment

A key theme is the complicated nature of thinking about these skills as separable constructs. Depending on the aim of the assessment, we may want to isolate the testing of a particular skill, and attempt to identify successful uses of that skill.

Recognise that skills were, are and will continue to be important in policy

The subject of employability and 'basic skills' continues to be a point of discussion for policy makers in education. There is an emphasis on being a lifelong learner, which means being able to adapt to and carry out many jobs. The belief is that the 21st century skill set will provide these generic competencies. However, we would recommend caution in adopting this narrative, as there needs to be a balance between the work and knowledge skill sets.

The 2021 white paper *Skills for Life* (Department for Education, 2021) illustrates how important the concept of skills is within education and the workplace. It is therefore essential that AQA continues to engage with this discussion and takes steps to provide students with the opportunity to develop these skills.

Consider what education is for

AQA's qualifications still very much reflect a knowledge-based curriculum, while 21st century skills align with the competencies expected by employers in the workplace. The question is how do we integrate these different types of skills? AQA is currently in the process of diversifying its qualifications in preparation for potential future reform; an awareness of the skill set valued by employers will play an essential part in underpinning and informing this process.

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