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Filled with skills: An analysis of four International AS and A Levels.

Irenka Suto, Sarah Nelson, Judith Roberts, Aman Sidhu and Lesley Spence

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Abstract:
A holistic education should nurture a range of skills that are essential for thriving in a fast-changing world, including higher-order thinking skills. These skills are deeply intertwined with knowledge and many in the assessment community agree they should not be assessed in isolation. Curricula structured around long-established subject disciplines and assessed via written examinations are often considered "knowledge rich". This article reports on how they also foster a range of higher-order skills that are important to students' futures.

We conducted a systematic analysis of Cambridge International AS & A Levels in English Language, Geography, Physics, and Psychology. To suites of specimen examination papers, we applied a skills coding framework based on Marzano and Kendall's (2007) educational taxonomy, which encompasses problem-solving and metacognitive skills among other thinking skills. We incorporated additional codes for systems thinking components from an environmental sustainability framework.

The analysis revealed a broad and rich coverage of higher-order thinking skills, as well as lower-order thinking skills such as retrieval, with variations across subjects. For example, while systems thinking is not mentioned in formal assessment objectives, it is present in Geography, Physics, and Psychology examinations. Although we did not explore this comprehensively, the study also suggested the examinations demand exam techniques that include metacognitive and problem-solving skills, further demonstrating higher-order thinking skills' integration within these qualifications.

Filled with skills: An analysis of four International AS and A Levels

Irenka Suto, Sarah Nelson, Judith Roberts, Aman Sidhu and Lesley Spence (Cambridge International Education)

Introduction

In an educational landscape shaped by rapid global change, there is an increasing emphasis on cultivating the thinking skills that students will need in the future. Such skills are interwoven with disciplinary knowledge. This article explores how curricula traditionally viewed as "knowledge rich", which are structured around established subject disciplines and examined through written examinations, may also provide fertile ground for nurturing higher-order thinking skills, which are a major category of so-called "future skills". Through a systematic analysis of Cambridge International AS & A Levels in four subjects, our study investigated the presence of thinking skills within their assessments. In this article we focus particularly on our analysis of three higher-order thinking skills: problem-solving, systems thinking, and metacognitive skills.

Which skills are needed for the future?

Before examining the concept of higher-order thinking skills, it is worth first considering the nature and value of skills more broadly. A "skill" is: "The ability to do an activity or job well, especially because you have practised it" (Cambridge Dictionary, 2025). Some educationalists regard skills as "learned abilities" (e.g., Kotsiou et al., 2022; McGuinness, 2018), and these may be mental or physical. The question of which skills young people need in order to be well prepared for the future is important for curriculum developers and other educationalists. Courses and qualifications should prepare students not only for their next steps in education, but also for their professional and social lives beyond that. There is growing evidence that a range of skills are important predictors of a variety of life outcomes in multiple countries (Rammstedt et al., 2024), and they are a core element of a holistic approach to education (Klafki, 2000).

Around the turn of the century, the skills considered important for the future tended to be loosely labelled *21st century skills* (Suto, 2013). However, language in the field is evolving, and as the decades have progressed, many researchers and educationalists have referred to *future skills* and *future-ready skills* instead (Kotsiou et al., 2022), referring mainly to mental rather than to physical abilities. *Transferable skills* and *transversal skills* are also used (e.g., UCAS, 2025; UNESCO, 2014). The OECD's Future of Education and Skills 2030 project has adopted the broader term *21st century competencies* in its Learning Compass framework, which they use to include knowledge, attitudes and values, alongside skills (OECD, 2025).

Kotsiou et al. (2022) conducted a major scoping review of 99 different frameworks of *future skills*, using this term in its broadest sense to encompass knowledge, attitudes, values, and competencies, as well as skills that would meet the dictionary definition above. Their aim was to consolidate the frameworks identified in over a decade of literature by making sense of the overlapping terminology employed by different academics and organisations. The researchers found the published literature to be profuse, covering 341 distinct "future skills" terms.

Despite the lack of consensus in the literature around the importance of different individual future skills, the researchers identified considerable overlap across the 99 frameworks. They extracted nine meta-categories of future skills:

1. Higher-order thinking skills
2. Dialogue skills
3. Digital and STEM[1] literacy
4. Values
5. Self-management
6. Lifelong learning
7. Enterprise skills / Innovation
8. Leadership
9. Flexibility.

The researchers placed the 341 terms used within the frameworks into multiple conceptual groups within each meta-category. Although there was a degree of subjectivity in the categorising and grouping process, and the "values" meta-category coheres least well with our dictionary definition of "skill" (Cambridge Dictionary, 2025) or with the multifaceted concept of "competency" (OECD, 2025), the nine meta-categories are well evidenced. Each one comprises at least two distinct categories and covers at least eight different "future skills" terms drawn from multiple sources in the literature. The meta-categories are helpful in distilling a large body of information down to something much easier to comprehend and utilise.

Higher-order thinking skills

Kotsiou et al.'s (2022) analysis underscores the importance of higher-order thinking skills as one of a number of meta-categories of abilities that are considered necessary for students to be future-ready. We chose this, and thinking skills in general, as the focus for our analysis of the skills involved in Cambridge International AS & A Levels.

1 Science, Technology, Engineering and Mathematics.

Broadly speaking, higher-order thinking skills entail cognitive processing beyond simple recognition and recall of information and may require a higher level of consciousness (Bloom et al., 1956, Marzano, 2001). The label "higher-order" is commonly used because the skills are positioned high up in hierarchical taxonomies of educational objectives. For example, in the cognitive domain of Bloom et al.'s original taxonomy of 1956, the authors describe five levels of "skills and intellectual abilities" which they position above knowledge (which is at Level 1 of their cumulative hierarchy). These range from Comprehension (Level 2) to Evaluation (Level 6). Today, these skills and abilities, and related ones, are frequently termed "thinking skills" (e.g., Soozandehfar & Adeli, 2016; Zohar & Dori, 2003). However, Anderson, Krathwohl and colleagues' (2001) revision of Bloom's taxonomy refers mainly to "cognitive processes" and similarly, Marzano (2001), the author of another well-established educational taxonomy, refers to mental "processes", "procedures" or "operations" in addition to "skills". In this article we mostly use the term "thinking skills", since it is accessible to teachers, students, and assessors and it is helpful in distinguishing these skills from physical and psychomotor skills.

We chose to explore thinking skills in our study of Cambridge International AS & A Levels because, although curricula structured around traditional subject disciplines at advanced secondary level are often recognised as being rich in both factual and conceptual knowledge, their thinking skills content is often overlooked (Christodoulou, 2014). An extensive body of psychological and educational research indicates that knowledge and skills are deeply intertwined and support the development of one another (see Hirsch, 2006; Willingham, 2021). Arguably, a curriculum (and a comprehensive assessment of it) cannot effectively address one without the other.

Although knowledge and skills are linked inextricably, higher-order thinking skills cannot be assumed to be universally present in knowledge-rich summative examinations at the end of secondary education. A major analysis of the Republic of Ireland's Leaving Certificate revealed a greater focus on skills in recalling factual knowledge in their examinations than on skills in critical thinking and problem-solving (Burns et al., 2018). These findings cohere with those from an earlier analysis (Cullinane & Liston, 2016).

There are also several other reasons for our focus on higher-order thinking skills. Firstly, although these skills are not new and can be traced back to antiquity (Suto, 2013), their classification as "future skills" is uncontroversial and there is widespread international agreement on their importance. All or almost all the 99 frameworks reviewed by Kotsiou et al. (2022) include higher-order thinking skills, indicating they are valued across employers, academics, and international organisations. The most widely included of all 341 "future skills" terms is problem-solving. It is found in 54 of the 99 frameworks and falls within this meta-category.

Secondly, higher-order thinking skills are essential for addressing climate change and building a sustainable future. The World Bank's report on education for climate action explores the notion of "green skills" (Sabarwal et al., 2024). The authors emphasise the importance of critical thinking and related skills for solving both academic and socio-emotional problems, as well as considering STEM and other subject-specific skills. Similarly, Cambridge International Education's curriculum framework for climate change education (to be published early in 2026) includes critical thinking and problem-solving skills within its *Evaluating* and *Responding* strands, and UNICEF ECARO (2025) include skills in decision-making, problem-solving, and systems thinking, among others, in their guidance on climate-responsive education.

Finally, higher-order thinking skills are also crucial for the appropriate and effective use of artificial intelligence (AI) tools (Luckin, 2024). In the workplace, for example, workers must decide which tools to trust and must enter data into them judiciously. When solving problems, they must identify and assess the applicability of AI to specific tasks and create prompts that generate optimal content. Skills in evaluating the accuracy, reliability, and relevance of the outputs are essential, and AI-generated content that is judged to be of sufficient quality must then be used ethically. Moreover, higher-order thinking skills are essential for the successful development and maintenance of the AI tools themselves. In addition to AI developers, technology companies will need experts who can identify biases in AI models and evaluate them to ensure compliance with regulations.

Although our analysis covers a wide range of higher-order thinking skills (and also lower-order thinking skills for completeness), and we report our main findings on all of these, this article concentrates on three areas of higher-order thinking skills in particular. These linked areas are: (i) systems-thinking skills, (ii) problem-solving skills, and (iii) metacognitive skills. We chose the first two areas because they feature particularly prominently in discourse around environmental and sustainability concerns and AI usage (Hannon & Peterson, 2021; Luckin, 2024; Sabarwal et al., 2024; UNICEF ECARO, 2025). We chose metacognition because it is a longstanding area of interest for Cambridge International Education[2] due to its importance within an active teaching and learning approach, and because of its strong links with wellbeing (Varshney & Barbey, 2021), which has become topical since the pandemic. Although Kotsiou *et al.* (2022) group metacognitive skills within their "lifelong learning" meta-category of future skills and include self-regulation and self-control within their "self-management" meta-category, these are regarded by other authors as higher-order thinking skills (discussed subsequently).

Systems thinking

One of the earliest formal definitions of "systems thinking" is offered by Richmond (1994), who described it as "the art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure" (p. 6). He argued that systems thinkers learn to position themselves to see both the forest and the trees in a system, with one eye on the generic and the other eye on the specific. Richmond originally conceptualised systems thinking as both a paradigm for professionals and a learning method, with the skills entailed being integral to both (ibid.). Since then, the field has burgeoned, definitions

2 Information about Cambridge International's thinking on metacognition can be found at: https://www.cambridgeinternational.org/support-and-training-for-schools/leading-learning-and-teaching-with-cambridge/metacognition/

have evolved, and systems thinking has been conceptualised in a variety of ways. Following an analysis of eight definitions, including those of educationalists Sweeney and Sterman (2000) and Hopper and Stave (2008), Arnold and Wade (2015) proposed the following all-encompassing definition:

> "Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system." (p. 675).

This definition is in keeping with the essence of Richmond's early view of systems thinking as a discipline that requires mastery of a "whole package of thinking skills" which are needed to explore issues and solve those problems that involve systems (Richmond, 1997). The thinking skills involved include analysing and comprehending how components interact. Overall, the approach aims to identify patterns, feedback loops, and other systemic factors that contribute to the overall behaviour of the system. Sometimes, seemingly small adjustments to a component can have far-reaching impacts (Stroh, 2015). Systems thinking is therefore a valuable tool for making informed decisions that consider the broader context and long-term consequences of actions. Proponents argue that pressing global issues such as war, famine, poverty, and climate change, are fundamentally the result of systemic failures (Arnold & Wade, 2015; Meadows, 2008; Stroh, 2015).

Some of the preeminent authors on systems thinking, such as Stroh (2015) and Meadows (2008), focus primarily upon these enormous challenges, as well as business management issues. However, it is important to stress that systems thinking is not confined exclusively to the realm of executive and international leadership (Richmond, 1997; Sweeney & Sterman, 2000), and it cannot be acquired by professionals overnight. Cambridge English include it as a core area of their teaching and learning framework for environmental sustainability, which is for young, teenage, and adult language learners (Blue, 2022; Cambridge English, 2022). Guides and interventions such as those of Sweeney (2001) and Hopper and Stave (2008) have been created to help children explore interconnections within systems.

Moreover, the rudimentary skills required for systems thinking may also be embedded in less explicitly labelled materials for schools, only to be developed further and applied to real-world challenges later in life. For example, systems thinking in natural science can be conceived of as describing or analysing natural phenomena, events, or circumstances – physical, chemical, biological, or some combination thereof – as if they were systems (Lavi & Bertel, 2024). At the school level, it involves observing, hypothesising, testing, analysing, and drawing conclusions about simple systems such as ecosystems or reaction pathways, based on evidence. Empirical studies, which also occur in the social sciences and economics, can be regarded as systems per se, since variables must be controlled systematically.

Problem-solving skills

A problem exists when someone has a goal but does not initially know how to achieve it, and problem-solving occurs when someone directs their cognitive processing at achieving that goal (Mayer, 2013). The overarching problem-solving process has been deconstructed differently by different generations of researchers (e.g., Bransford & Stein, 1984; Jonassen & Hung, 2012[3]; Newell & Simon, 1972). Broadly speaking, however, the thinking skills used early in the process include identifying, defining, deconstructing and representing the problem. Next, skills relating to analysing relationships between aspects or elements of the problem, and generating, evaluating and selecting solutions, follow on from these. Skills in planning, executing, monitoring and evaluating the success of solutions can also be used. Mayer (2013) suggests that when utilising problem-solving skills, the problem-solver draws upon a range of knowledge types, including facts, concepts, procedures, strategies, and beliefs. This view concurs with that of Marzano and Kendall (2007) who place problem-solving as a discrete operation within the "knowledge utilisation" level of thinking in their educational taxonomy.

While problem-solving and systems-thinking skills share significant overlap, especially in their emphasis on analysing relationships, anticipating consequences, and iterative decision-making, they are not synonymous. Not all problems relate to systems, and not all systems thinking is about solving problems. Research by Maani and Maharaj (2002) demonstrates that although systems thinking can enhance problem-solving performance, particularly in complex and ill-structured contexts, it can also include distinct cognitive processes which go beyond traditional problem-solving frameworks and may be used in other situations.

Analogical thinking skills play a pivotal role in problem-solving, and can even enhance it (Gick & Holyoak, 1980). They enable individuals to transfer knowledge from a familiar domain to a novel or less familiar one. As Jonassen and Hung (2012) explain, analogical problem-solvers often retrieve mental models of past problems, or generalisations of them, known as "schemas" from their memories, to support this transfer. These schemas comprise semantic representations of the entities involved in a problem, their structural relationships, and the process for resolving the unknown in that situation (Rumelhart & Norman, 1988). In the context of mathematical problem-solving, Assmus, Förster, and Fritzlar (2014) argue that analogical thinking skills facilitate the understanding of complex relationships, especially when students can abstract beyond surface features to recognise deeper structural parallels.

The development of analogical thinking is at the crux of the argument for breadth of knowledge, skills and understanding being important for future-ready learners. For example, Epstein (2019) challenges the idea that specialisation is the key to success in a rapidly changing world, especially at an elite or leadership level. He draws on the psychological research of Kahneman and Klein (2009), illustrating their findings with examples from finance, music, and sports, to argue that generalists, equipped with a broad range of experiences, excel at lateral thinking.

3 Jonassen and Hung (2012) note that in early research in the field, problem-solving was treated as a unidimensional and linear solution-seeking process, but more recently, research has expanded to include multidimensional models of problem-solving.

That is, they are better at approaching problems from alternative angles. Analogical thinking can be viewed as an essential tool within a broader lateral thinking toolkit for problem-solving.

Arguably, it follows that generalists are better equipped to adapt to new situations, and therefore, to thrive in the "wicked" learning environments that will become increasingly common. In these environments, goals could easily change, next steps are ambiguous, and feedback on progress may be delayed, inaccurate, or non-existent (Hogarth, 2001; Hogarth et al., 2015). Politics is a classic example. Epstein (2019) argues that when used laterally, generalists' analogical thinking skills help them to solve what Rittel and Webber (1973) named "wicked" problems. These problems are multifaceted, and their interconnected and ever-changing nature makes them difficult to define and solve. They are characterised by incomplete or contradictory information, multiple stakeholders with different perspectives and interests, and a lack of established problem-solving approaches preordained by past experts. For example, sustainability was identified as a wicked problem in Cambridge International Education's (2024) engineering convocation on climate change education.

Conversely, "kind" learning environments are well defined and constrained. Goals are fixed, next steps are clear, and feedback on progress is timely and accurate (Hogarth, 2001). Examples include learning a new language or learning how to cook a well-known dish. "Kind" problems have well-defined rules and boundaries (Hogarth, ibid.). Examples include many traditional examination questions in mathematics and physics. Analogical thinking skills can also be useful here, but they are used *within* the subject discipline to match the question to one in a mental bank of known question types, rather than in a lateral thinking, interdisciplinary sense. Such questions do not require consideration from a completely new angle. Kind problems are not necessarily easy to solve but approaches to finding a solution have been well articulated and are reusable (e.g., Poler et al., 2025). The definability and consistency of kind problem-solving processes such as those encountered in financial procedures, chess, or computer programming means they can be automated by AI and other technologies relatively easily (Maharaj et al., 2021). Wicked problem-solving, on the other hand, is likely to remain the preserve of humans for longer.

Metacognition

Finally, metacognition is "thinking about one's own thinking"; that is, thinking about the contents and processes of one's own cognition (Winne & Azevedo, 2022). The term describes the thinking skills and knowledge involved when students plan, monitor, evaluate and make changes to their own learning behaviours, and reflect upon them afterwards. There is an extensive research literature showing that metacognition plays important roles in most cognitive tasks, from everyday behaviours to problem-solving to expert performance (ibid.). According to Hattie's (2009) analysis of educational interventions and their impact on student achievement, developing metacognitive strategies has a strong positive impact on students' learning outcomes. The Education Endowment Foundation (2018) reports that the use of metacognitive strategies can be worth the equivalent of an additional eight months' progress when used well.

Metacognition is widely considered to have two dimensions: metacognitive knowledge and metacognitive regulation (Cambridge International Education, 2019). Metacognitive knowledge includes the student's knowledge of their own cognitive abilities (e.g., I have trouble remembering dates), the student's knowledge of the nature of particular tasks (e.g., the ideas in this report are complex), and the student's knowledge of different strategies, including when to use these strategies (e.g., if I break telephone numbers into chunks, then I will remember them) (Brown, 1987; Flavell, 1979). In contrast, metacognitive regulation describes how students monitor and control their thinking processes in situ. For example, they may realise the strategy they are using to solve a mathematical problem is not working (monitoring) and therefore try another approach (controlling their thinking and actions) (Nelson & Narens, 1990). The ability to monitor effectively is known as *calibration* (Winne & Azevedo, 2022).

Metacognition has been described as the engine of self-regulated learning (Winne, 2022). At a metacognitive level, students essentially engage in the systematic collection and analysis of data related to their own learning experiences. They evaluate the suitability of specific strategies for given contexts, judge their effectiveness, consider the effort invested, and reflect on how their abilities are perceived by others (Winne, 2022). As their evidence accumulates, students iteratively construct and refine a personal framework for understanding optimal learning. In doing so, they adopt the role of learning scientists, actively investigating and improving their own knowledge and skills (Winne, 2022). It follows that metacognition is critical to the notion of agency, which features frequently in discussions of future-ready learners (e.g., Hannon & Peterson, 2021). Self-regulating learners are empowered to make choices, set goals, and thereby take responsibility for their own learning and life courses.

There is some debate about the positioning of metacognitive skills within frameworks and taxonomies of educational objectives. In their future skills framework, Kotsiou et al. (2022) include self-regulation and self-control within their broad "self-management" meta-category, together with skills relating to resilience, wellbeing, positivity, and self-confidence, among others. However, they include metacognition within their "lifelong learning" meta-category. In contrast, in Marzano and Kendall's (2007) educational taxonomy, metacognitive skills in goal-setting and monitoring are positioned above those in analysis and knowledge utilisation within their mental processing domain. Metacognition is conceptualised as an executive control system, which entails and regulates the use of analytical, problem-solving, evaluative, and related skills.

Method

We embarked on the present study with the aim of articulating the higher-order thinking skills covered in some Cambridge International AS & A Levels. While assessment objectives for these qualifications invariably include higher-order thinking skills, we wanted our analysis to explore them at a more granular level and to include three specific types of skills that we believe to be particularly important for the future, but which are not always emphasised in assessment objectives: systems thinking, problem-solving, and metacognitive skills. Our overall approach was to audit a broad range of thinking skills, both higher and lower order (for completeness), in a small but diverse selection of AS and A Level subjects, drawing mostly on definitions from an established educational taxonomy that would be familiar and intuitive to teachers and other educators.

AS and A Level subjects

We selected four Cambridge International AS & A Level subjects for inclusion in the research. We chose English Language, Geography, Physics and Psychology on the grounds that: (i) they are popular but contrasting mainstream subjects in many countries; (ii) there is limited optionality within the assessment model, facilitating the manageability of the research; and (iii) subject expertise within the research team was high. For each subject, we collated the materials comprising the formal intended curriculum. These were the most recently released syllabuses, the specimen examination papers, and their mark schemes. For each of English Language, Geography and Psychology, there were four specimen examination papers. Papers 1 and 2 must be passed to achieve an AS Level, and Papers 3 and 4 must be taken in addition to these to achieve the full A Level. For Physics, there were five examination papers in total. Papers 1, 2 and 3 must be passed to achieve an AS Level, and Papers 4 and 5 must be taken in addition to achieve an A Level.

Skills coding framework

We created a bespoke framework for coding a broad range of thinking skills, both lower- and higher-order. This was based largely upon the "mental procedures" domain of Marzano and Kendall's (2007) New Taxonomy of Educational Objectives (summarised in the Appendix). The domain comprises six levels of mental processing. From lowest to highest, these are: (i) *Retrieval*; (ii) *Comprehension*; (iii) *Analysis*; (iv) *Knowledge utilisation*; (v) *Metacognition*; and (vi) *Self-system thinking* (beliefs and motivations determining the level of engagement). Each of the levels is divided into multiple "operations" which, in the language of Bloom et al. (1956) and many subsequent educationalists, could be described as sub-levels of "skills" or of "skills groups", as well as "mental processes". For example, within the knowledge utilisation level, "skills" in decision-making, problem-solving, experimenting and investigating are included in multiple frameworks reviewed by Kotsiou et al. (2022).

We chose to draw from Marzano and Kendall's (2007) taxonomy because it had been used successfully in previous research within our organisation (Suto et al., 2020). In the earlier study, it scored most highly in a review of nine published educational taxonomies, which were evaluated against six predetermined selection criteria, including credibility in terms, underpinning theory and / or empirical basis, accessibility, and usability. In addition to these criteria, for the present study we added the selection criterion of including a rich coverage of higher-order thinking skills. In particular, we sought a taxonomy that included skills relating to (i) systems thinking, (ii) problem-solving, and (iii) metacognition. As articulated by Irvine (2017), Marzano and Kendall (2007) compares favourably to the Anderson et al. (2001) revision of Bloom's taxonomy in this respect.

For example, problem-solving can be seen as represented in three elements of Marzano and Kendall's (2007) cognitive system: problem-solving is a discrete operation (sub-skill) within the *Knowledge utilisation* level; and, additionally, skills in comprehending the problem, analysing it, and monitoring the development of potential solutions, are covered by the *matching* and *classifying* operations within the *Analysis* level.

Like the other educational taxonomies reviewed by Suto et al. (2020), Marzano and Kendall (2007) do not distinguish between kind and wicked problem-solving, since the thinking skills required for them are not fundamentally different. Therefore, in addition to coding thinking skills, coders were invited to make holistic judgements about the nature of the problems encountered by students within the examination questions. This was done using the descriptions of kind and wicked problem-solving given earlier in this article, which are based heavily on the work of Hogarth (2001) and Epstein (2019), and which were discussed at length beforehand within the research team.

A further strength of Marzano and Kendall's (2007) cognitive system is its coverage of metacognition. It is conceptualised in terms of self-regulatory skills, and treated as an important, active system of thinking skills. This is in contrast with Bloom and his colleagues (1956), who considered metacognition to be inert knowledge about cognition.

Since Marzano and Kendall's (2007) cognitive system does not reference or cover systems thinking explicitly, we supplemented it with four codes for systems-thinking skills from Cambridge English's Sustainability Framework (Blue, 2022; Cambridge English, 2022). These are:

- Identifying components and their roles within a system
- Finding connections within and between systems
- Understanding observable and hidden consequences
- Identifying the potential for alternative outcomes.

These codes are not specifically related to English language teaching, and they go beyond the more generic skills in comprehension and analysis that are included in Marzano and Kendall (2007) and that are also needed in systems thinking. We deemed the four codes to be more applicable for coding assessment materials that had not been explicitly designed with systems thinking in mind, compared to those in other frameworks. (For example, they do not evaluate the use of field-specific technical terms such as "stock" and "flow". See Arnold and Wade, 2017, for a review of other frameworks.)

Overall, we considered the combined result to be a sufficiently comprehensive thinking skills coding framework. This is because it covers the thinking skills that we regard as particularly important for future-ready learners. Additionally, it includes lower-order thinking skills for completeness, such as recognising and recalling information, and executing procedures.

Coding procedure

For each subject, a subject specialist within the research team familiarised herself with the syllabus, examination papers, and mark schemes, and discussed any points of uncertainty or interest with the developers of the qualifications. The research team then met to discuss how to apply the framework consistently to the four A Level subjects. We recognised there would be some subject-specific differences, but we also identified common approaches wherever they were meaningful. This "standardisation" discussion entailed sharing or working through examples together from each subject until general understandings of the coding framework crystallised.

Each subject specialist then applied the skills coding framework to the examination papers in her subject, referring to the mark schemes and syllabus as needed. Each question part of each question in each examination paper was coded individually and could be allocated multiple codes. For example, a question part could entail both *recalling* (an operation within *Retrieval*) and *integrating* (an operation within *Comprehension*). The coding process was iterative; codings of question parts were frequently compared across subjects, then refined if needed. Any differences in approach were resolved through discussion, enabling broad consensus in how the coding framework was applied. The subject specialists' final codings were checked by the lead researcher, who gained an overview across all four subjects and was satisfied with the degree of consistency.

Consideration of "exam technique" skills

Early in our efforts to apply the skills coding framework, it became apparent that higher-order thinking skills not only relate to the specifics of the assessed content of examination papers but are also a critical part of a student's general test-taking strategy. During their education, many students develop essential test-taking skills, often known as exam technique. These include understanding instructions, time management, test-taking strategies, reviewing and checking work, and maintaining focus and concentration.

Many of these skills are more generic than subject specific. One example is that of using metacognitive skills when continuously checking for errors in responses, such as misinterpretations of questions, mistakes in calculations, and typos. Additionally, subject-specific exam techniques also play a role. Being able to identify the appropriate knowledge and method to apply, and the appropriate length of response to produce, can be a critical form of kind problem-solving. It entails analogical thinking skills, since students match questions to those in their mental banks of known question types. For example, in the Physics questions analysed, the content or method to use is rarely stated. Typically, students need to identify that a particular question requires, for example, the use of one of Newton's laws (before then applying it).

In the English Language and Geography exams analysed, students must write essays in response to several questions. This process, while not explicitly assessing metacognition, requires them to demonstrate metacognitive awareness of their writing process and self-regulation. This is another example of subject-specific exam technique.

Systematic coding of the skills used as part of applying exam technique, either generic or subject specific, and illustrated in the examples above, was not part of our intended approach. Since such coding would have greatly increased the scope of the study and could have potentially obscured the findings on the skills relating to the subject-specific examination content per se, we decided not to extend our analysis in this direction.

Findings

This section presents the key findings of our study, beginning with an overview of the coding outcomes. Within this overview, findings relating to each level in the skills coding framework are briefly considered in turn. Following this, we provide a more detailed exploration of the findings relating to the three skills areas in which we were most interested: systems thinking, problem-solving, and metacognitive skills.

Overview

Table 1 shows the skills covered within the examination paper content of each AS and A Level subject (i.e., the skills that were judged to be assessed in at least one question in that subject). In Geography, Physics and Psychology, the skills identified are broadly similar at AS Level and A Level. In English Language, in contrast, we identified a wider range of skills at AS Level than at A Level. Note that, as described earlier, each question could be coded with more than one skill, if relevant.

Table 1: Coverage of thinking skills at AS and A Level

Subject	Level	Retrieval	Comprehension	Analysis	Knowledge utilisation	Metacognition	Self-system	Systems thinking
English Language	AS	Executing	Symbolising Integrating	Matching Generalising Analysing errors	Decision-making Problem-solving (kind)	Process monitoring Monitoring accuracy	Examining efficacy	
	A	Executing	Integrating	Specifying	Decision-making			
Geography	AS	Recognising Recalling Executing	Integrating	Matching Classifying Generalising Specifying	Decision-making			Identifying components and their roles Finding connections within and between systems Understanding observable and hidden consequences
	A	Recognising Recalling Executing	Integrating	Matching Classifying Analysing errors Generalising Specifying	Decision-making			Identifying components and their roles Finding connections within and between systems Understanding observable and hidden consequences

Subject	Level	Retrieval	Comprehension	Analysis	Knowledge utilisation	Metacognition	Self-system	Systems thinking
Physics	AS	Recognising Recalling Executing	Integrating Symbolising	Analysing errors Generalising Specifying	Decision-making Problem-solving (kind) Experimenting	Process monitoring		Identifying components and their roles Finding connections within and between systems Understanding observable and hidden consequences
	A	Recognising Recalling Executing	Integrating Symbolising	Classifying Generalising Specifying	Decision-making Problem-solving (kind) Experimenting Investigating			Identifying components and their roles Finding connections within and between systems Understanding observable and hidden consequences
Psychology	AS	Recalling Executing	Integrating	Matching Analysing errors Generalising Specifying	Decision-making Problem-solving (kind) Experimenting			Identifying components and their roles Finding connections within and between systems Understanding observable and hidden consequences Identifying potential for alternative outcomes
	A	Recalling	Integrating	Matching Classifying Analysing errors Generalising Specifying	Decision-making Problem-solving (kind) Experimenting			Identifying components and their roles Understanding observable and hidden consequences Identifying potential for alternative outcomes

Definitions of the operations within each of the levels in the skills coding framework are given in the Appendix.

Retrieval

We found that many examination questions across the four subjects required students to demonstrate *Retrieval* skills. The demands for *recalling* were prominent in Geography, Physics, and Psychology: most questions were coded as requiring this operation. *Recognising* was also a requirement in many Geography and Physics questions. The English Language papers placed a more limited emphasis on *Retrieval*. Although most questions required *executing*, none were coded as requiring the other two operations within this lowest level of thinking skills. Overall, the high occurrence of *Retrieval* skills indicates that they are a foundational expectation across the subjects.

Comprehension

Comprehension skills were widely embedded in questions, with students in all subjects frequently required to *integrate*, that is, to refine knowledge to crucial characteristics organised in a frugal generalised form. Almost all Geography questions required this operation. In addition, the English Language examinations included *symbolising* in a minority of questions at AS Level, and the Physics examinations included this operation at both AS and A Level.

Analysis

All four subjects were found to cover *Analysis* very thoroughly. Many questions placed considerable emphasis on analytical skills, requiring students to *match*, *classify*, *analyse errors*, *generalise*, and / or *specify*. We coded each subject as covering either four or all of these five operations, which indicates a broad spectrum of analytical requirements. *Specifying* was particularly prevalent across Physics and in the English and Geography A Level papers, where in a large majority of questions students were expected to construct a new application of a known generalisation or principle. In Psychology, *analysing errors* was a frequent requirement.

Knowledge utilisation

At the *Knowledge utilisation* level, we found all four subjects require decision-making, although only in a minority of questions. Physics and Psychology were found to require the greatest breadth of operations within this level, particularly where questions involved inquiry-based or scenario-driven challenges. While the English Language examinations included just one question entailing problem-solving between them, Physics and Psychology included problem-solving (discussed subsequently) and experimenting (*producing and testing hypotheses to understand physical / psychological phenomena*) in a significant proportion of their questions. For all of the questions involving problem-solving, the problems were kind in nature. Physics was the only subject to include *Investigating*, which is *producing and testing hypotheses about historical, current or future events*.

Metacognition

Metacognitive operations were coded in a very limited number of questions, and only in English Language and Physics. Examples of *process monitoring* and *monitoring accuracy* were identified and are discussed in detail subsequently.

Self-system

Self-system operations were minimally represented in the examination papers, with only *examining efficacy* being coded, and only in English Language at AS Level. This indicates that students are rarely required to engage with personal beliefs, motivation, or self-evaluation during the examinations.

Systems thinking

English Language was found to be the only subject not to include *systems thinking* skills, which are discussed in detail below.

Systems thinking

Systems thinking was coded in the examination papers for Geography, Physics and Psychology, where students were tasked with *identifying components and their roles*, *finding connections within and between systems*, and *understanding observable and hidden consequences*. Psychology questions also included *identifying potential for alternative outcomes*. In Geography, systems thinking could be identified in many questions as there are many opportunities to recognise components and their interactions, feedback mechanisms, scale and interconnectivity, and cause and effect. Multiple questions were found to require students to evaluate systems and predict responses to change. For example:

> "'Solid waste disposal is the most important sustainable management issue in urban areas.' To what extent do you agree with this statement? Use examples to support your answer."

This question was coded as requiring *identifying components and their roles*, *finding connections within and between systems*, and *understanding observable and hidden consequences*.

Physics and Psychology both place a strong emphasis on the empirical approach, and the experiments within them can be regarded as systems. For example, in one Physics question, students need to design a laboratory experiment to test the relationship between the electromotive force (E) induced and the distance (x) between two coils of wire. In particular, they need to determine whether the relationship between E and x can be described by $E = IZe^{-kx}$. It is stated that the plan must include details about:

- "the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken."

The emphasis on planning can also be seen in this Psychology question:

> "Schizophrenia can be treated biochemically with drugs, such as antipschotics, but they are not always effective.
>
> Plan an experiment to investigate the effectiveness of antipsychotic drugs to treat schizophrenia.
>
> Your plan must include details about:
>
> - sampling technique
> - a directional or non-directional hypothesis.
>
> State **two** reasons for your choice of sampling technique."

A good plan for both Physics and Psychology will explain the type of experiment and choice of experimental design. Both require the student to think about the system as a whole. A good plan will also define an independent variable, a dependent variable, and controls, all of which are interacting components in the system. The choice of techniques will affect how components interact, since it will affect the quality and quantity of the data collected in the experiment; its consequences must be thought through carefully. Beyond these general principles (found in all experimental sciences) there are subject-specific considerations. For example, Psychology considers sampling techniques and ethics, and Physics considers uncertainty and risk assessments.

Problem-solving

As explained previously, the skills coding framework identifies problem-solving as a distinct operation within *Knowledge utilisation*. At the *Analysis* level, analogical thinking is embedded in the *matching* and *classifying* operations, which involve recognising similarities across knowledge and organising knowledge into meaningful categories. These two skills support the categorisation of problems and the identification of equivalences, which are key components of effective problem-solving.

In English Language, only one question was coded as requiring problem-solving (within the *Knowledge utilisation* level):

> "Your headteacher has asked you to produce a leaflet called Leaving Home. The leaflet will be aimed at older teenagers who are going to live in another town or city to go to university.
>
> Write the text for the leaflet, using no more than 400 words. In your writing, give advice and guidance on how to manage living away from your family for the first time."

This question was coded as a kind problem. There is a clear objective, and defined parameters are set in relation to the content, text type and audience that students must take into account in their response. It was not also coded as requiring *matching* or *classifying*.

Surprisingly, in Geography, we did not identify *problem-solving* when applying this code from the skills coding framework (although *matching* and *classifying* were required both at AS and A Level for some questions not involving problems). In Physics, examination questions at both AS and A Level were coded as requiring *problem-solving*; this was also the case for *matching* and *classifying*, indicating the need for analogical thinking skills. The problems encountered in Physics were all found to be kind. This is because established procedures could be reused for each given scenario. For example:

> "The average kinetic energy E_K of a molecule of the gas is given by the expression
>
> $$E_K = \frac{3}{2}kT$$
>
> where k is the Boltzmann constant and T is the thermodynamic temperature.
>
> The gas is heated at constant pressure so that its temperature rises by 125 K.
>
> (i) Show that the new volume of the gas is 4.75×10^{-2} m^3."

This question[4] follows the problem-solving approach most commonly seen in Physics. The students need to identify the general principle (in this case the ideal gas law) and construct a new application of it for the scenario given.

All four Psychology examination papers were found to be rich in *problem-solving* and *matching*, and at A Level, *classifying* was also coded. Problems included those that might be encountered by a professional psychologist, for example:

> "Company X knows that customers use a compensatory decision-making strategy when purchasing expensive items from their website.
>
> Suggest **two** ways that knowledge of compensatory strategies could be used to design Company X's website to encourage customers to purchase an expensive item."

Here, the problem is that of how to design a website to increase sales, and the student is guided to solve it using compensatory strategies. The problem was coded as kind because it is clearly defined. Approaches to finding a solution have been well articulated and can be reused. It was not coded as requiring *matching* or *classifying*.

Interestingly, some questions explored problems which would be wicked in real life, but which were handled in a kind way within the A Level Psychology examinations. For example:

> "James has a mood (affective) disorder and has started to receive rational emotive behaviour therapy (REBT). At the first session, James tells the therapist that he has been having problems at work. He feels that he has nothing to contribute in his team. He also thinks that his manager does not like him, and this is causing him distress.
>
> Explain how REBT can help James with his distress."

4 It was not coded as requiring *matching* or *classifying*.

In practice, a clinical psychologist supporting James could experience this situation as a wicked problem. Feedback from James on his mood may be inconsistent, inaccurate, or non-existent. Factors affecting his mental health may be unknown and unpredictable, and he may choose not to engage with the treatment, or with the psychologist. However, the examination question does not expect students to adopt a wicked problem-solving approach. They will have been taught the benefits of REBT and are expected to recall them, that is, to reuse a preexisting problem-solving approach.

Metacognition

Although we expect that there is plenty of *Metacognition* within classrooms in which teachers take an active learning approach, we were uncertain how this would translate into assessed content. As mentioned previously, metacognitive operations were coded in a very limited number of questions, and only in English Language and Physics. Only one English Language question was identified as assessing *Metacognition*, specifically *process monitoring* and *monitoring accuracy*:

> "Your headteacher has asked you to produce a leaflet called Leaving Home. The leaflet will be aimed at older teenagers who are going to live in another town or city to go to university.
>
> ...
>
> Write a reflective commentary on your text[5], explaining how your linguistic choices contribute to fulfilling the task set by your headteacher."

Due to the variety of contexts in use for English Language questions and the small number of questions within each examination, it is not clear whether these skills would still be assessed in another version of the examination.

In Physics, metacognition was identified in a practical paper in which students follow an experimental method to collect data. They are instructed to "Repeat until you have six sets of values of *n* and *T*." Thus, the students need to use the metacognitive skill of *process monitoring* to decide when they have successfully completed this task.

Limitations

There were several limitations to our study. Applying the same skills coding framework across four diverse AS and A Level subjects enabled systematic comparisons to be made but there were also some drawbacks. In English Language, the definitions of some of the skills in the framework did not align with

5 The phrase "your text" refers to the student's response to an earlier linked question (question part), which we presented earlier, and which came in between the stimulus and the present question (question part): "Write the text for the leaflet, using no more than 400 words. In your writing, give advice and guidance on how to manage living away from your family for the first time."

those used to describe skills in Language subjects elsewhere, making coding less intuitive. For example, Nadas, Suto, and Grayson (2021) report a subject-specific definition for analysis as "close linguistic reading of textual materials", which differs conceptually from the definitions of the *Analysis* operations in the Appendix. In Geography, the absence of codings of *problem-solving*, despite reference to problem-solving in the assessment objectives, suggested the framework's definition was overly generic or at odds with how this skill is conceived within this subject discipline.

In Physics, since the *executing* operation within *Retrieval* did not distinguish between levels of mathematical fluency, it was felt to be too broad and generic. For example, *executing* was used to code very basic single-stage processes (e.g., converting a value from km to m) as well as to code far more sophisticated multi-stage mathematical processes involving logarithms. Also for Physics, there were some ambiguities around the coding of complex analytical skills[6] when alternative approaches to answering a question were possible. For Psychology, overlaps between the *experimenting* and *investigating* codes created coding ambiguities, and while skills in identifying weaknesses in experiments were easily coded, skills in identifying strengths lacked a clear equivalent code.

A broader concern with the analysis is that of whether limited instances of a coded skill, or indeed absences of it, may reflect incidental question phrasing rather than genuine skills coverage. This concern applies particularly to the coding of *Metacognition* and *Self-system* in the English Language examination papers, which comprise relatively few questions, meaning under-sampling could have occurred.

Discussion

This study of thinking skills in examinations for Cambridge International AS & A Levels is reassuring and encouraging in several ways. We have shown that the coverage of both higher-order and lower-order thinking skills is broad in all four subjects, at both AS Level and A Level. AS and A Level students must demonstrate in examinations a wide variety of skills in analysing and utilising knowledge, as well as more simply recalling and comprehending what they have learnt.

In this article, we focused upon systems thinking, problem-solving, and metacognitive skills because we consider them to be particularly important for the future. Although systems-thinking skills are not labelled as such in the qualifications' assessment objectives, we found plenty of examples of them within Geography, Physics, and Psychology. In the latter two subjects, this was due to their strong emphasis on the empirical approach. We found Physics and Psychology are also rich in problem-solving. Additionally, we identified small amounts of metacognitive skills within the content of English Language and

6 The *specifying* operation was coded extensively because there were many cases where students needed to "construct a new application of a known generalisation or principle". However, since these questions entailed calculations to analyse a specific scenario related to an area of physics, *matching* could, arguably, have also been coded here instead, as the students could have matched the type of problem in the examination with others they had encountered previously.

Physics. Taken together, our findings suggest that students who do well at AS and A Level are likely to be well equipped with at least some of the numerous "future skills" analysed by Kotsiou et al. (2022).

A clear strength of A Levels is their coverage of "kind" problem-solving. Many questions are designed to demonstrate that students can use well-established approaches, drawing upon their analogical skills to find an approach that works for each question. No "wicked" problem-solving was identified. This may be because examinations are designed to allow students to demonstrate what they can do, and not to catch them out. The need for highly reliable marking may be also a factor, as may the tight time restraints of examination conditions.

Surprisingly, in Geography, we did not identify any problem-solving when applying the skills coding framework. However, we identified several questions that could easily be altered to cover it. For example, this question appeared in the exams analysed but did not assess problem-solving:

> "'Some threats to coral reefs are greater than others.' To what extent do you agree with this statement? Use examples to support your answer."

It could be rephrased, as follows, to entail wicked problem-solving, for use during teaching rather than in an examination:

> "A marine conservation group is planning a campaign to protect a threatened coral reef. However, they have limited resources and must focus their efforts on addressing the most significant threats first. As an environmental analyst, assess and prioritise the threats to the reef, justifying which ones should be tackled as the highest priority. Use examples to support your reasoning."

This is a wicked problem because the threats to coral reefs are numerous and interconnected. Although threats to coral reefs are on the syllabus, each threat impacts the reef in different ways, some of which may be unclear at the present time, and addressing one threat might exacerbate another. There is often a lack of comprehensive data, and understanding of coral ecosystems is still evolving. There are multiple stakeholders involved who have different perspectives and interests. Also, there is no single solution: strategies that work in one region may not be effective in another region due to environmental, social, and economic contexts.

In Psychology, we found that problems that can be wicked in real life, such as treating someone's mental health condition, had been implicitly simplified to be more manageable, kind problems in our examinations. A similar approach could be adopted for Geography. While this might raise questions around authenticity, these may not be a significant concern at this stage of education. We might expect professional psychologists and geographers to handle wicked problems, displaying all the emotional self-regulation needed, but not necessarily young people at the end of their school education.

This finding raises serious questions about where wicked problem-solving might fit best within education. While transparency and the avoidance of unnecessary stressors are high priorities in examinations, the classroom could potentially provide the greater psychological safety that students need to tackle wicked problems.

Although we did not systematically code for “exam technique” skills in our study, it became apparent early in our coding process that higher-order thinking skills not only relate to the specifics of the assessed content of examination papers but are also a critical part of a student’s general test-taking strategy. General and subject-specific “exam technique” skills include a range of metacognitive skills which we found to be less explicit in the syllabus content, and also problem-solving skills. For example, analogical thinking skills are essential in examinations, since they enable students to match questions to equivalents in their mental bank of known question types within the subject discipline. It is possible that some of these exam technique skills could be beneficial to students later in life, if they can apply them in other contexts, such as professional assessments, and completing tasks and managing one’s workload in the workplace.

An important next step is to extend the study laterally, reviewing the thinking skills in other AS and A Level subjects. In the present study, four subjects were selected in part for their diversity, to represent a general snapshot of the many and varied A Level subjects that exist. A wider review of more subjects could indicate which A Levels complement one another in terms of their skills coverage, and where the gaps are. For example, we cannot tell yet whether there are any popular subject combinations that do not meaningfully include problem-solving at all, other than through examination technique.

Another potential next step would be to dig deeper into the four subjects covered so far. We could analyse the higher-order thinking skills encouraged in textbooks, schemes of work, and other resources for these AS and A Levels. This could highlight differences in what is encouraged in the classroom and what is currently assessed in high-stakes examinations. This is not to imply that all differences are necessarily unwelcome. Some skills may well require alternative assessment methods. Additionally, our skills audit could be broadened to include other meta-categories of “future skills” identified by Kotsiou et al. (2022).

Finally, information on skills coverage could be useful and inspiring for teachers. It could feed into new professional development courses to deepen pedagogical expertise in recognising and teaching skills content, and in understanding the interplay between skills and knowledge. Given that systems-thinking skills are not mentioned in assessment objectives, they could be new to some teachers. Further work is needed to better articulate and understand component skills, their precursors in younger students, and progression, in an age-appropriate way.

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Appendix: Summary of the mental processing domain of the New Taxonomy of Educational Objectives (adapted from Marzano and Kendall, 2007)

System	Level	Operation	Description of operation
6. Self-system		Examining overall motivation	Identifying your level of motivation to learn particular knowledge or increase competence in a given area and then identifying the interrelationships between one's beliefs about efficacy and importance, and emotional responses that govern motivation.
		Examining emotional response	Analysing the extent to which you have an emotional response to particular knowledge and its influence on motivation.
		Examining efficacy	Examining whether you believe you have the ability, power or resource to be competent with given knowledge or at a particular skill.
		Examining importance	Examining whether knowledge is important or meets a need or personal goal.
5. Metacognition		Monitoring accuracy	Determining the degree to which you understand given knowledge.
		Monitoring clarity	Determining the degree to which you are free from ambiguity about the knowledge.
		Process monitoring	Monitoring the success of a procedure while completing the procedure.
		Specifying goals	Forming clear goals and plans for accomplishing them.

System	Level	Operation	Description of operation
Cognitive system	4. Knowledge utilisation	Investigating	Producing and testing hypotheses about historical, current or future events.
		Experimenting	Producing and testing hypotheses to understand physical / psychological phenomena.
		Problem-solving	Trying to achieve a goal for which an obstacle is present.
		Decision-making	Using knowledge to choose between alternatives.
	3. Analysis	Specifying	Constructing a new application of a known generalisation or principle.
		Generalising	Inferring new generalisations from known data.
		Analysing errors	Determining whether information is reasonable and analysing it for logic errors and inaccuracies.
		Classifying	Organising knowledge into meaningful superordinate and subordinate categories
		Matching	Identifying similarities and differences between sections of knowledge.
	2. Comprehension	Symbolising	Creating a symbolic representation (usually an image) of the knowledge produced by integrating.
		Integrating	Refining knowledge to crucial characteristics organised in a frugal generalised form.
	1. Retrieval	Executing	Carrying out the steps in a procedure and producing a result.
		Recalling	Recollecting and generating additional information.
		Recognising	Deciding whether received information is accurate, inaccurate or unknown.