PISA 2021 CREATIVE THINKING FRAMEWORK (THIRD DRAFT)

April 2019

OECD member countries and Associates decided to postpone the PISA 2021 assessment to 2022 to reflect post-Covid difficulties. This draft vision was created before the crisis. The final version will reflect the new name of the cycle “PISA 2022”.

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The case for assessing creative thinking

Why assess creative thinking?

1. Creative insights and advances have driven forward human culture across the world in diverse areas (Hennessey and Amabile, 2010[1]): in the sciences, technology, philosophy, the arts and humanities. Creative thinking is thus more than simply coming up with random ideas. It is a tangible competence, grounded in knowledge and practice, that supports individuals in achieving better outcomes, oftentimes in constrained and challenging environments. Organisations and societies around the world increasingly depend on innovation and knowledge creation to address emerging challenges (OECD, 2010[2]), giving urgency to innovation and creative thinking as collective enterprises.

2. While it is true that creative thinking drives the types of innovation that have a society-wide impact, it is also a more universal and democratic phenomenon than one might first believe. That is to say that every individual, to a greater or smaller degree, has the potential to think creatively (OECD, 2017[3]). Furthermore, there is a general consensus among psychologists and educators alike that creative thinking, understood as engagement in the thinking processes associated with creative work, can improve a host of other individual abilities, including metacognitive capacities, inter- and intra-personal and problem-solving skills, as well as promoting identity development, academic achievement, future career success and social engagement (Beghetto, 2010[4]; Plucker, Beghetto and Dow, 2004[5]; Smith and Smith, 2010[6]; Torrance, 1959[7]; National Advisory Committee on Creative and Cultural Education, 1999[8]; Spencer and Lucas, 2018[9]; Long and Plucker, 2015[10]; Barbot, Lubart and Besançon, 2016[11]; Barbot and Heuser, 2017[12]; Gajda, Karwowski and Beghetto, 2017[13]) (Higgins et al., 2005[14]).

3. Developing an international assessment of creative thinking can encourage positive changes in education policies and pedagogies. The PISA 2021 creative thinking assessment will provide policymakers with valid, reliable and actionable measurement tools that will help them to make evidence-based decisions. The results will also encourage a wider societal debate on both the importance and methods of supporting this crucial competence through education. This work in PISA is connected to another OECD project that aims at supporting new pedagogies that can foster creative thinking. For the past years, the OECD's Centre for Educational Research and Innovation (CERI) has been leading an eleven-country study on ways of teaching and assessing creative and critical thinking with encouraging early results[1].

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[1] Since 2015 CERI has led an exploration of the teaching and assessment of Creative Thinking in 11 countries – Brazil, France, Hungary, India, Netherlands, Russia, Slovak Republic, Spain, Thailand, United Kingdom (Wales), and United States. Taking at its starting point the work piloted by Lucas, Claxton and Spencer (2013[124]) in England, it has prototyped a new teacher-friendly conceptual framework to think about creative and critical thinking in the classrooms in primary and secondary education. It has developed OECD rubrics on creative and critical thinking meant to support teachers to develop or improve pedagogical activities that nurture the creative and critical thinking skills of their students. An international network of

What is the role of education in creative thinking?

4. A fundamental role of education is to equip students with the competences they need – and will need – in order to succeed in society. Creative thinking is a necessary competence for today's young people to develop (Lucas and Spencer, 2017[15]). It can help them adapt to a constantly and rapidly changing world, and one that demands flexible workers equipped with '21st century' skills that go beyond core literacy and numeracy. After all, children today will likely be employed in sectors or roles that do not yet exist, using new technologies to solve novel problems. Educating for creative thinking can help young people to adapt to develop the capacities to undertake work that cannot easily be replicated by machines and address increasingly complex local and global challenges with out-of-the-box solutions.

5. The importance of nurturing creative thinking in school also extends beyond the labour market. Schools play a crucial role in helping young people to discover, develop and define their talents – including their creative talents. Schools play a vital role in making children feel that they are part of the society they live in, and that they have the creative resources to contribute to its development (Tanggaard, 2018[16]).

6. Creative thinking can also benefit the way in which students learn by supporting the interpretation of experiences, actions and events in novel and personally meaningful ways (Beghetto and Kaufman, 2007[17]). Student imagination and curiosity can drive the learning process: creative thinking can thus be a vehicle for understanding, even in the context of predetermined learning goals (Beghetto and Plucker, 2006[18]). In order to increase students' motivation and interest at school, new forms of learning that engage with the creative energies and recognise the creative potential of all students need to be developed. Such development may particularly help those students who show little interest in school, and guide them students to express their ideas and achieve their potential (Hwang, 2015[19]).

7. Just like any other ability, creative thinking can be nurtured through practical and targeted application (Lucas and Spencer, 2017[15]). For some educators, developing students' creative thinking skills may seem to imply taking time away from other subjects in the curriculum. In reality, students can think creatively in arrange of subjects. Creative thinking can be developed while promoting the acquisition of content knowledge through approaches that encourage exploration and discovery rather than rote learning and automation (Beghetto, Baer and Kaufman, 2015[20]). Teachers need to understand how creative thinking can be recognised, the circumstances that encourage it, and how they can effectively guide students to become more creative in their thinking. A greater understanding of how creative thinking unfolds may in turn motivate teachers to allow their students to take time "incubating" creative ideas in their learning processes (Csikszentmihalyi, 1996[21]).

experts and teachers has defined creative thinking as "coming up with new ideas and solutions". According to the CERI framework, creative thinking has 6 dimensions: (1) feel, empathise, observe, describe relevant experience and information; (2) explore, seek and generate ideas; (3) make connections, integrate other disciplinary perspectives; (4) stretch and play with unusual, risk or radical ideas; (5) envision, express, produce, prototype new product (or solution or performance); (6) appreciate the novelty of solution and or its possible consequences.

Evidence-centred design as a general framework for the PISA 2021 assessment

8. Evidence-centred design (ECD) (Mislevy, Steinberg and Almond, 2003[22]) provides a conceptual framework for developing innovative and coherent assessments that are built on evidence-based arguments, connecting what students do, write or create on a computer platform, with multidimensional competences (Shute, Hansen and Almond, 2008[23]; Kim, Almond and Shute, 2016[24]). ECD starts with the basic premise that assessment is a process of reasoning from evidence to evaluate specific claims about students' capabilities. In essence, students' responses to the assessment items and tasks provide the evidence for this reasoning process, and psychometric analyses establish the sufficiency of the evidence for evaluating each claim. Using ECD as an organising framework for the PISA 2021 creative thinking assessment can help to address a series of important test design questions, namely: which creative thinking constructs or processes does each task within the assessment reveal? Do the proposed scoring methods effectively recognise and interpret the evidence generated by students' responses and interactions with the assessment platform? How is all of the evidence that is generated by students' choices synthesised across multiple tasks? Is all of the evidence for a particular construct comparable when different students attempt different tasks?

9. ECD provides a strong foundation for the development of a valid assessment of the complex and multidimensional construct of creative thinking. It requires documented, explicit linkages among the test purpose, the claims made about the test takers and the evidence supporting the claims. Adopting the ECD process for the PISA 2021 creative thinking assessment requires the following sequence of steps:

1) *Domain definition:* reviewing the relevant literature and engaging with experts to define the domain of creative thinking in an educational context. This foundational work clarifies the creative thinking competences that policy makers and educators wish to promote, and the types of creative expressions that 15-year-old students can achieve and that can be most meaningfully and feasibly assessed in PISA.

2) *Construct definition:* describing the precise construct the PISA test will assess and specifying the claims that can be made about the relevant attributes of test takers on the basis of the assessment. In ECD terminology, this step is generally referred to as defining the Competency or Student Model (Shute et al., 2016[25]).

3) *Evidence identification:* describing the evidence that needs to be generated in the test to support the subsequent claims made about test-takers (i.e. the behaviours or performances that demonstrate the skills being assessed, for example what students might select, write or produce, and which constitute evidence for the claims). In ECD, this is referred to as defining the Evidence Model. This step includes providing rules for scoring the tasks and for aggregating scores across tasks that extract the evidence required to support the claims (including process data stored in log files).

4) *Task design:* identifying, conceptualising and prototyping a set of tasks that provide the desired evidence within the constraints of the PISA assessment. This stage corresponds to the Task Model step in ECD terminology.

5) *Test development:* assembling the tasks into test formats that support all of the stated assessment claims with sufficient evidence. This corresponds to the Assembly Model step in ECD terminology.

6) *Cross-cultural validation:* ensuring that all assessment instruments provide reliable and comparable evidence across countries and cultural groups. This step is generally not discussed in ECD approaches, but is clearly important in the context of PISA.

7) *Analysis and reporting:* illustrating appropriate, meaningful and easy-to-communicate representations of the assessment results.

10. Validation and pilot studies can increase the iterative nature of this design cycle: for example, the analysis of validation data can inform choices regarding evidence identification and task design.

11. The structure of this framework document follows this sequence of evidence-centred design steps. First, creative thinking is outlined, both in general and specifically in an educational context. Then, the elements of the construct and the methods of evidence identification and collection are explicitly set forth. Finally, the framework discusses issues related to validation and reporting.

Defining the assessment domain

What is creative thinking?

12. PISA employs a definition of creative thinking that is relevant to 15-year-old students around the world. Creative thinking in PISA 2021 is defined as *the competence to engage productively in the generation, evaluation and improvement of ideas, that can result in original and effective solutions, advances in knowledge and impactful expressions of imagination.*

13. This definition of creative thinking is aligned with the one proposed by the Creative Thinking Strategic Advisory Expert Group (OECD, 2017[3])[2]. It highlights the fact that students in all contexts and across all levels of education need to learn how to engage productively in the practice of generating ideas, how to reflect upon ideas by valuing both their relevance and novelty, and how to iterate upon ideas until they reach a satisfactory outcome. It has also been informed by the guidance of interdisciplinary experts and a comprehensive review of the literature on creativity.

14. While creative thinking is still an emerging construct, the broader yet intrinsically related construct of creativity has a strong research tradition. Plucker, Beghetto and Dow (2004[5]) define 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", reflecting its multidimensional and social nature.

15. Achieving creative outcomes requires the capacity to engage in creative thinking, but it can also demand a wider and more specialised set of attributes and skills, such as intelligence, domain knowledge or artistic talent. For example, the 'Big C' creativity that is associated with technology breakthroughs or art masterpieces demands that creative thinking be paired with significant talent, deep expertise and high levels of engagement in a particular area, as well as the recognition from society that the product has value.

[2] The Strategic Advisory Board defined creative thinking as '…the process by which we generate fresh ideas. It requires specific knowledge, skills and attitudes. It involves making connections across topics, concepts, disciplines and methodologies'. This definition builds on the five dimensional model by Lucas, Claxton and Spencer (2013), that identifies five creative thinking habits - being inquisitive, being imaginative, persevering, collaborating and being disciplined.

Conversely however, ‘little c’ or everyday creativity (e.g. creatively arranging family photos in a scrapbook; combining leftovers to make a tasty meal; or finding a creative solution to a complex scheduling problem at work (Kaufman and Beghetto, 2009[26])) can be achieved by nearly all people capable of engaging in creative thinking.

16. Overall, the literature agrees that ‘little c’ creativity can be developed through practice and honed through education. The PISA 2021 test of creative thinking will thus focus on tasks related to this ‘little c’ creativity in order to minimise the importance of innate talent for performance and to put a stronger focus on the malleable capacity of individuals to engage in creative thinking. This type of creative thinking can be applied not only to learning contexts that mainly require the expression of one’s inner world, such as creative writing or the arts, but also to other areas where the generation of ideas is functional to the investigation of issues, problems or society-wide concerns.

Domain generality versus domain specificity

17. A ‘domain’ can be understood as “any specific area of knowledge, such as art literature, history, or astronomy” or “the set of representations that underlie and support thinking in a specific area of knowledge” (Baer, 2011[27]). Researchers have long debated whether creative abilities are domain specific: are creative people creative in everything they do, or only when engaging in specific activities? This debate on the nature of creativity logically extends to creative thinking: is creative thinking in science different to creative thinking in the arts? Are those who can easily generate ideas to explain a scientific phenomenon also good at generating ideas for a story?

18. The first generation of creative thinking tests mainly reflected the notion of domain generality, based on the idea that a set of general attributes influence creative endeavours of all kinds. Researchers like (Torrance, 1959[7]) assumed that the performance of individuals in creativity tests could be generalised, and that creative performance in one domain could be transferred to another. However, more recent studies tend to reject this assumption. They rather claim that the skills and traits necessary for creative performance are specific to and thus differ by domain (Baer, 2011[27]), or present models of creativity that integrate aspects of both approaches (e.g. Kaufman and Baer (2005[28])).

Domains of creative engagement

19. Related to the debate on the domain specificity of creativity is the question of *which* and *how many* domains of creativity might exist. Over the years, various creativity theorists and researchers have attempted to establish the different domains of creativity, with research on this topic most notably coming from the various works of Kaufman (et al.) (2004[29]; 2005[28]; 2006[30]; 2009[31]; 2012[32]). In more recent work, he distinguishes five different domains of creative engagement: everyday, scholarly, performance, scientific, and artistic (Kaufman, 2012[32]).

20. Others have reported similar groupings of domains of creativity: Runco and Bahleda (1986[33]) distinguish between ‘artistic’ and ‘scientific’ spheres of creative activity. According to Amabile (1983[34]; 1996[35]), creative tasks can be categorised into the three broad domains of verbal, artistic and problem-solving. Similarly, Chen et al. (2006[36]) identify the domains of verbal, artistic and maths. Elsewhere, the separation of artistic and verbal domains of creativity is supported by Conti et al. (1996[37]) who found no correlations in participant performances across the two domains.

21. A comprehensive meta-analysis of empirical studies examining the domains of creativity supports the existence of a math/scientific domain that is consistently distinct from other domains of creativity (Julmi and Scherm, 2016[38]). The meta-analysis indicates that stable patterns are visible across studies, generally corresponding to "the factors 'hands on' creativity, empathy/communication and math/science identified by Kaufman and Baer (2004[29])."

Confluence approaches of creativity

22. 'Confluence approaches', or 'componential theories', describe creative thinking and creativity as multi-dimensional phenomena (Lucas, 2016[39]). Amabile's (1983[34]; 2016[40]) componential theory of creativity outlines four necessary components for any individual to produce creative work: domain-relevant skills, creativity-relevant processes, task motivation, and a conducive environment. The model specifies that creative production fundamentally requires some base resources or raw materials (i.e. domain-specific skills, including knowledge and technical skills), a set of processes or skills for combining these base resources in new ways (i.e. creativity-relevant processes, including appropriate cognitive styles such as breaking out of performance scripts and keeping response options open), and a driver in order to do so (i.e. task motivation). It also suggests that a number of environmental factors can serve as either inhibitors or facilitators of creative engagement. These four components include both relatively stable elements and elements that are more amenable to development and social influences.

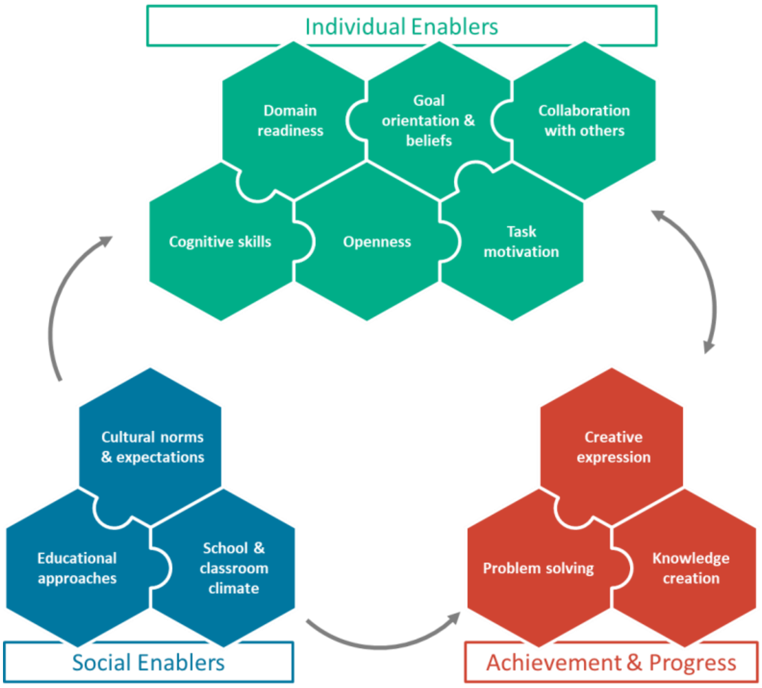
23. Sternberg and Lubart's (1991[41]; 1995[42]) 'investment theory of creativity' suggests that six distinct yet interrelated resources are necessary for creativity: intellectual skills (such as synthetic and analytical skills); domain-related knowledge; particular 'thinking styles' (such as a preference for thinking in new way); motivation; specific personality attributes; and an environment that is supportive and rewarding of creative ideas. Sternberg (2006[43]) later elaborated on the importance of the confluence of these resources, explaining that creative endeavours are far more complex than the simple sum of each respective component. Interactions between different components may lead to a variety of outcomes: for example, high levels in many components could multiplicatively enhance creative engagement; in contrast, there may be a minimum threshold for each component below which creative achievements are not possible, irrespective of the presence or the degree of other components.

Understanding and assessing creative thinking in the classroom

24. Confluence approaches of creativity emphasise the importance of various internal resources for successfully engaging in creative work, as well as the importance of the environment in which creative work takes place. They thus provide a useful schema for the PISA assessment of creative thinking. However, in order to better understand children's creative thinking, it is necessary to contextualise these approaches in a way that is relevant to students in their everyday school life (Glaveanu et al., 2013[44]; Tanggaard, 2014[45]).

25. Figure 1 sets out some key points of observation of creative thinking in the classroom, as well as the relationships between the respective elements. This model builds upon the five-dimensional model of creative thinking proposed by the Creative Thinking Strategic Advisory Expert Group (OECD, 2017[3]).

Figure 1. Enablers and manifestations of creative thinking in the classroom



26. Schools can influence several dimensions of students' internal resources (described henceforth as 'individual enablers') for engaging in creative thinking, including: cognitive skills; domain readiness (domain-specific knowledge and experience); openness to new ideas and experiences; willingness to work with others and build upon others' ideas (collaboration); willingness to persist towards one's goals in the face of difficulty and beliefs about one's own ability to be creative (goal orientation and beliefs); and task motivation.

27. As for the features of students' social environments that might incentivise or hinder creative thinking (described henceforth as 'social enablers'), the classroom culture, the educational approach of schools and wider education systems, and the broader cultural environment all represent distinct social environments for students. They can all influence the extent to which students value and invest in their own creative abilities, and can provide incentives or obstacles for engaging in creative thinking.

28. Finally, schools are arenas in which students' manifestations of creative thinking, either as individuals or as part of a group, can be observed and measured. Creative achievement and progress in the classroom can refer to forms of creative expression (i.e. communicating one's internal world and imagination through writing, drawing, music or other arts), knowledge creation (i.e. generating knowledge that is new to the group and understanding in a collaborative enquiry process), or creative problem-solving (i.e. finding creative solutions to a variety of problems across domains).

29. These distinct enablers of creative thinking in the classroom are strongly interconnected. Social enablers are inherently shaped by cultural norms, which in turn affect how students' individual enablers are developed and honed.

Individual enablers of creative thinking

Cognitive skills

30. Several authors have tried to identify the cognitive skills necessary to think creatively. Guilford's (1956[46]) conceptions of convergent thinking and divergent thinking have strongly influenced research in this area. Convergent thinking is generally defined as the ability to apply conventional and logical search, recognition and decision-making strategies to stored information, in order to produce an answer (Cropley, 2006[47]). By contrast, divergent thinking is defined as the ability to follow new approaches and produce original ideas by forming unexpected combinations from available information, and by applying abilities such as semantic flexibility and fluency of association, ideation and transformation (Cropley, 2006[47]). It has also been described as the ability to break out of performance scripts and search for different solutions, to try something counterintuitive when everything else fails, to look at problems from different angles, to approach tasks from a different starting point, and to construct new methods rather than following ready-made ones (Schank and Abelson, 1977[48]; Duncker, 1972[49]). In essence, divergent thinking brings forth answers that may never have existed before and that are often novel, unusual or surprising.

31. Creative thinking is often described in divergent thinking terms, and most assessments of creative thinking to-date have focused on measuring divergent thinking cognitive processes. However, the literature clearly highlights that convergent thinking cognitive processes, such as analytical and evaluative skills, are also important for creative production (Cropley, 2006[47]; Reiter-Palmon and Robinson, 2009[50]; Tanggard and Glaveanu, 2014[51]). For example, the ability to generate novel and valuable ideas may depend on the prior execution of other activities, such as successfully defining the problem space, or on 'late cycle' processing skills, such as evaluating the creative value of several possibilities or successfully assessing the extent to which a potential solution corresponds to the given task constraints (Runco, 1997[52]). Indeed Getzels and Csikszentmihalyi (1976[53]) found that art students' success in 'problem construction' was strongly correlated with measures of the originality and aesthetic value of their resulting paintings, and that these measures were furthermore linked to long-term artistic success.

32. Schools can promote the use of pedagogies that encourage the development of the cognitive skills and approaches inherent to the creative process (Beghetto and Kaufman, 2010[54]). For example, Mayer (1989[55]) demonstrated how learning strategies for forming mental representations can lead to improvements in students' creativity in science, mathematics and computing problems.

Domain readiness

33. Domain readiness conveys the idea that an individual requires some degree of pre-existing knowledge and experience within a particular domain in order to successfully produce creative work (Baer, 2016[56]). The assumption is that the more knowledge one possesses and the better one understands the relationships between pieces of information within a domain, the greater the likelihood one has of generating a creative idea (Hatano and Inagaki, 1986[57]; Schwartz, Bransford and Sears, 2005[58]).

34. However, this relationship may not be strictly linear, particularly in the case of 'little c' or everyday manifestations of creative thinking. While it is generally accepted that some degree of domain-relevant knowledge or skills is beneficial for creative thinking, the prior cultivation of established routines for deploying knowledge or skills may also present

a barrier for creative thinking, by resulting in fixation and a reluctance to think beyond those established routines.

35. Schools naturally have an important role to play in developing children's domain readiness (knowledge and experience) in a range of subject areas in which students can express their creative thinking.

Openness to experience and intellect

36. There is a vast literature dedicated to identifying the personality traits that characterise 'creative people'. Empirical studies examining the personality and behaviour of creative individuals typically employ questionnaire instruments and operationalise creativity as a relatively enduring and stable personality trait (Hennessey and Amabile, 2010[1]). These studies have shown that many creative people share a core set of tendencies, but particularly 'openness': both 'openness to experience' and 'openness to intellect' (although both variants are seen as comprising the larger 'openness' factor) (Amabile, 2012[59]; Batey and Furnham, 2006[60]; Feist, 1998[61]; Prabhu, Sutton and Sauser, 2008[62]; Sternberg and Lubart, 1991[41]; Sternberg and Lubart, 1995[42]).

37. Kaufman et al. (2009[31]) found that openness to experience was the only one of the 'Big Five'[3] personality dimensions that was significantly and positively correlated with creative achievements across all domains. The study was then repeated with Chinese participants, who recorded similar results (with the exception of creativity in the maths/science domain) (Werner et al., 2014[63]). McCrae (1987[64]) also found that divergent thinking was consistently associated with openness to experience, but not with the other remaining dimensions of personality. Meta-analyses of studies on creativity and personality have confirmed that openness to experience appears to be a common trait in creative achievers across domains, whereas other personality traits appear to interact with creativity only insofar as they benefit individuals within specific domains of endeavour (for example, 'conscientiousness' seems to enhance scientific creativity but detract from performance in the arts) (Batey and Furnham, 2006[60]; Feist, 1998[61]).

38. More specifically, 'openness to experience' refers to an individual's receptivity to novel ideas, imagination and fantasy (Berzonsky and Sullivan, 1992[65]). It has been suggested that its predictive value for creative achievements across domains is due to its "broad constellation of traits with cognitive (e.g. fantasy, imagination), affective (e.g. curiosity, intrinsic motivation) and behavioural manifestations (e.g. being adventurous, stepping outside of one's comfort zone, actively trying new things), all of which are related to creativity" (Werner et al., 2014[63]). Several scholars have further emphasised the importance of a sense of curiosity for successfully producing creative work (Chávez-Eakle, 2009[66]; Feist, 1998[61]; Guastello, 2009[67]; Kashdan and Fincham, 2002[68]).

39. 'Openness to intellect' is a related yet distinct trait that has also been shown to predict creative achievement. This construct refers to cognitive engagement with abstract and semantic information, primarily through reasoning (DeYoung, 2014[69]). In contrast to openness to experience, openness to intellect seems particularly correlated with scientific creativity (Kaufman et al., 2016[70]).

[3] Also referred to as the Five Factor Model of personality traits: Openness to experience; Conscientiousness; Extraversion; Agreeableness; and Neuroticism (see McCrae and Costa (1987[125])).

Goal orientation and creative self-beliefs

40. Persistence, perseverance and creative self-efficacy are all attitudes that have been shown to influence creativity by providing individuals with both a strong sense of goal orientation, and the belief that they can go on to achieve those goals.

41. Persistence – the act of single-mindedly continuing to invest effort towards one's goal in spite of difficulty – and perseverance – enduring and overcoming difficulty to achieve one's goal – are essential for creativity. Cropley (1990[71]) characterised creative individuals by "their willingness to expend effort", and Torrance (1988[72]) emphasised perseverance as one of the main traits of creative individuals. Amabile (1983[34]) argues that the ability to concentrate effort for long periods and to persevere in the face of frustration is an important component of creative capacity.

42. Creative self-efficacy refers to the beliefs that individuals have about their own ability to perform a task creatively (Beghetto and Karwowski, 2017[73]). Goal orientation and creative self-beliefs are closely linked: several researchers consider creative self-efficacy essential in determining whether an individual will sustain effort in the face of resistance (i.e. persist) and ultimately succeed (i.e. persevere) in performing tasks creatively (Bandura, 1997[74]). These beliefs can in turn be influenced by prior performance history, mood and the social environment in which a task is performed (Bandura, 1997[74]; Beghetto, 2006[75]).

43. Efforts to stimulate creative thinking in the classroom might therefore aim to strengthen students' beliefs in their creative abilities and their proficiency in self-regulatory attitudes and behaviours (including persistence and perseverance) (Davis and Rimm, 1985[76]).

Collaborative engagement

44. Contemporary research is increasingly looking beyond creative thinking as a purely individual construct and towards creative thinking as a collective endeavour, for example by examining the actions of teams in generating new knowledge (Thompson and Choi, 2005[77]; Prather, 2010[78]; Grivas and Puccio, 2012[79]; Scardamalia, 2002[80]). This particular understanding of creative thinking posits that creative work is the result of the interaction between an individual and their environment, including other individuals within that environment. Creative thinking and engagement is thus structured as a continuous cycle of "doing" (actions directed at the environment) and "undergoing" (taking in reactions of the environment) (Glaveanu et al., 2013[44]). Through collaborative engagement, teams can provide new answers to complex problems that are beyond the capabilities of any one person (Warhuus et al., 2017[81]).

45. Research on collaborative creative thinking shows that team members engage in a complex intentional, opportunistic, improvisational and emergent process, setting goals and monitoring progress as different members of the team assume leadership based on their own strengths. Being able to engage in dialogic and improvisational processes in particular creates the conditions for new ideas to emerge (Montuori, 2003[82]; Tsoukas, 2009[83]). Through collaboration, action is fused with idea creation and improvement, the reparation of weaknesses in ideas, and the discovery of new ways around dead ends.

46. The capacity to engage in collaborative work is an important driver of knowledge creation, also in a classroom context. Schools can provide a rich environment in which students can explore and build upon others' ideas in an iterative process, and thus collaboratively create new knowledge. Students need to learn how to get inspired by the

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ideas of others, and appreciate co-authorship and collective action (Starko, 2010[84]; Scardamalia, 2002[80]).

Task motivation

47. The role of task motivation as a driver of creative work has been well documented in research, namely in the works of Amabile (1997[85]; 2016[40]; 2010[1]; 1983[34]). The basic assumption is that individuals may possess the ideal constellation of components for high creative potential, and yet still not produce creative work if they are not sufficiently motivated to do so.

48. Motivation to be creative can be both intrinsic and extrinsic in nature. Individuals who experience intrinsic task motivation: find their work meaningful, engage in the task purely for reasons of enjoyment, self-interest or desire to be challenged; and are relatively insensitive to incentives, contingencies or other external pressures. Csikszentmihalyi (1996[21]) proposed that creative work is powerfully facilitated by the related experience of ‘flow’ because, in the state of flow, people “persist ... single-mindedly, disregarding hunger, fatigue, and discomfort” (Nakamura and Csikszentmihalyi, 2002[86]) precisely because they are fully engaged in a task for reasons inherent to the work itself. Conversely, extrinsic task motivation refers to the external incentives, goals or pressures that can motivate people to engage in a particular task.

49. In general, research has emphasised the conducive role of intrinsic task motivation and the detrimental effect of extrinsic task motivation on creative performance (Amabile, 2012[59]; Sternberg, 2006[43]). More recent theories, however, have acknowledged that extrinsic motivators such as pressures (e.g. deadlines) or rewards (e.g. incentives and recognition) can successfully motivate people to be or persist in their creative endeavours (Eisenberger and Shanock, 2003[87]; Amabile and Pratt, 2016[40]).

Social enablers of creative thinking

Cultural norms and expectations

50. Creative outputs are embedded within social contexts (Baer, 2016[56]; Csikszentmihalyi, 1996[21]), and these social contexts are inherently shaped by cultural norms and expectations. Cultural norms and expectations affect creative thinking as they can influence the skills and cognitive processes that individuals prioritise for development, the emergence of values that shape personality development, and the differences in performance expectations within a given society (Niu and Sternberg, 2003[88]; Wong and Niu, 2013[89]). Cultural norms can also encourage creative thinking in some situations and for some topics, but discourage it for others (Lubart, 1998[90]). Some studies have investigated the effect of cultural differences on measures of national creativity and innovation. In general, they conclude that only variations along the individualism/ collectivism axis of cultural difference have reliably demonstrated a significant impact on creative outputs (Rinne, Steel and Fairweather, 2013[91]; Ng, 2003[92]).

Educational approaches

51. Cultural norms affect educational approaches, in particular the outcomes an education system values for its students and the content it prioritises in the curriculum. These approaches may, in some cases, result in a lack of encouragement or even the active discouragement of certain creative behaviours at school (Wong and Niu, 2013[89]). The investment theory of creativity argues that being creative is in large part a decision that

anyone can make yet few actually do because they find the social costs to be too high. Schools therefore play an important role in encouraging students' creative thinking by increasing the rewards and decreasing the social costs associated with it in the classroom (Sternberg, 2006[43]). For example, it has been argued that the pressures of standardisation and accountability in educational testing systems have reduced the room afforded to students for creative thinking in their school work (DeCoker, 2000[93]). Some researchers have even claimed that increasingly narrow educational approaches and assessment methods are at the root of a 'creaticide' affecting today's young people (Berliner, 2011[94]).

Classroom climate

52. Organisational research has demonstrated the effects of certain features of the working environment on the creativity of workers. Informal feedback, goal setting, positive challenges, teamwork, relative freedom in carrying out tasks, and appropriate recognition and encouragement to develop new ideas are all environmental enablers of creativity (Amabile, 2012[59]; Zhou and Su, 2010[95]). Conversely, harsh criticism of new ideas, emphasis on the status quo, low-risk attitudes among top management, and excessive time pressures are among the environmental factors that can inhibit creativity (Amabile, 2012[59]). It could be argued that the effects of similar environmental factors could also apply to creative thinking in the classroom.

53. With regards to schools specifically, Nickerson (2010[96]) provides a list of school practices that can stifle creative thinking: (1) perpetuating the idea that there is only one correct way to do a task and only one correct answer to a question; (2) cultivating attitudes of submission and fear of authority; (3) adhering to lesson plans at all costs; (4) promoting the belief that originality is a rare quality; (5) promoting beliefs in the compartmentalisation of knowledge; (6) discouraging curiosity and inquisitiveness; (7) and above all, never permitting learning and problem solving to be fun.

54. Teachers are more likely to focus on teaching creatively and developing learner creativity within school and policy environments that encourage innovation (and accept its associated risks) and that allow them to develop and express their own creativity. Teachers thus need to understand the importance of students' idea diversity, risk taking, and working with peers in order to accomplish difficult tasks. These approaches are all supported by teachers' beliefs that creative thinking competences are something that can be developed in the classroom, even if this development takes time.

55. Beghetto and Kaufman (2014[97]) propose that teachers should monitor implicit messages sent by the classroom environment as well as actively cultivating an environment that helps students learn how to take charge of their own creativity. For example, this could be achieved by encouraging higher levels of student agency in setting goals, monitoring progress, identifying promising ideas, and taking collective responsibility for contributing to productive, creative team work. Teachers should also help students to recognise how and when creative thinking is task appropriate.

56. Some educational researchers have explored different ways of teaching and learning that increase the likelihood of knowledge creation. The research shows that creative thinking can be successfully engendered through collaboration in knowledge-building communities, in other words, when schools operate as knowledge-creating organisations in which students are directly engaged in sustained, creative work with ideas (Scardamalia and Bereiter, 2006[98]; Scardamalia and Bereiter, 1999[99]). When knowledge creation becomes an intentional activity that is integral to classroom life – a

norm of engagement – students can contribute new ideas to their community and work towards continually improving those ideas (Scardamalia, 2002[80]).

57. Knowledge creation can also be promoted through ‘questions of wonderment’. Questions of wonderment describe the process of trying to understand the world and trigger students to put forth their ideas about different phenomena (Scardamalia and Bereiter, 1992[100]; Bereiter and Scardamalia, 2010[101]).

Creative engagement

58. The creativity of students’ products provides indicators of their capacity to think creatively, particularly in tasks where much of the creative thinking process is ‘invisible’. Students’ creative products can therefore be useful to determine whether their creative thinking process has been successful (Amabile, 1996[35]; Kaufman and Baer, 2012[102]).

59. Over the years, an impressive body of literature on the importance and analysis of creative products across a range of domains has emerged. According to accepted definitions within the literature, creative products are both novel and useful as defined within a particular social context. In the context of schools, creative engagement can take distinct ‘everyday’ forms: for example, through expressive activities of writing, drawing, music or other ‘arts’ subjects; the creation of new knowledge and understanding; or the generation of creative solutions to different types of open problems. These forms of creative engagement in the classroom are multi-disciplinary and extend beyond traditional subjects, such as art and science (Beghetto and Kaufman, 2010[54]; Sawyer, 2011[103]).

Creative expression

60. Creative expression consists of both verbal and non-verbal forms of creative engagement, in instances where individuals communicate their internal world and imagination to others. Verbal expression refers to the use of language, including both written and oral communication. Non-verbal expression includes not only drawing, painting, modelling and musical expression, but also expressive movement and performance, for example dance and drama.

Knowledge creation

61. Knowledge creation refers to the advancement of knowledge where the emphasis is placed on progress rather than achievement per se, for example by establishing improved conceptual ideas such as better explanations or theories. Knowledge creation is not only reserved for discoveries of historical importance, but can also occur at all levels of society and in all domains. Scardamalia and Bereiter (1999[99]) have elaborated parallels among the work of scientists, designers and young students in creating knowledge: for example, it can be helpful for all, regardless of domain, to reconstruct knowledge in order to interpret the findings of others and to make sense of existing theories.

Creative problem solving

62. Closely linked to knowledge creation is creative problem solving. Not all cases of problem solving require creative thinking: creative problem solving is a distinct class of problem solving characterised by novelty, unconventionality, persistence, and difficulty in problem formulation (Newell, Shaw and Simon, 1962[104]). Creative thinking becomes particularly necessary when students are challenged with problems outside of their realm

of expertise, and where the techniques with which they are familiar do not work (Nickerson, 1999[105]).

Implications for the design of the PISA 2021 creative thinking assessment

Focus and objectives of the PISA 2021 assessment of creative thinking

63. PISA 2021 focuses on the creative thinking processes that one can reasonably expect from 15-year-old students. It does not aim to single out exceptionally creative individuals, but rather to describe the extent to which students are capable of thinking creatively when searching for and expressing ideas, and how this capacity is related to teaching approaches, school activities and other features of education systems.

64. The main objective of PISA is to provide internationally comparable data on students' creative thinking competence that have clear implications for education policies and pedagogies. The creative thinking processes in question therefore need to be malleable through education; the different enablers of these thinking processes in the classroom context need to be clearly identified and related to performance in the assessment; the content domains covered in the assessment need to be closely related to subjects taught in common compulsory schooling; and the test tasks should resemble real activities in which students engage, both inside and outside of their classroom, so that the test has some predictive validity of creative achievement and progress in school and beyond.

65. Collecting information on the complex set of enablers of creative thinking in PISA is challenging yet achievable, at least in part. The PISA 2021 creative thinking assessment is composed of two parts: a test and a background questionnaire. The test provides information on the extent to which students are able to mobilise their creative thinking cognitive processes when working on tasks requiring the generation, evaluation and improvement of ideas. The background questionnaires complement this information with data on other enablers of students' creative thinking, including creative attitudes (openness, goal orientation and beliefs), perceptions of their school environment, and activities they participate in both inside and outside the classroom.

66. In the assessment some enablers of creative thinking are better covered than others. For example, while collaborative skills are a key enabler of knowledge creation in the classroom, students' capacities to engage in collaborative, creative thinking is not directly measured (although several test tasks ask the students to evaluate and improve the work of others) due to the organisational and technical difficulties of making students work together in PISA. Nonetheless, collaboration skills are recognised as an important individual enabler of creative thinking in the classroom in this framework, in the hopes of inspiring future assessments of creative thinking.

Domains of creative thinking included in PISA 2021

67. The literature suggests that the larger the number of domains included in an assessment of creative thinking, the better the coverage of the construct. However, certain practical and logistical constraints of PISA have had important implications for the possible domains included in the PISA 2021 assessment of creative thinking.

68. The first relates to the age of test-takers. Given that the PISA target population (15-year-old students) only has a limited amount of knowledge and experience in many domains, those selected as assessment domains need to be based on the knowledge and experiences that are common to most students around the world (such as drawing, writing

or problem-solving). The assessment domains (and related tasks) must also be reflective of the realistic manifestations of creative thinking that 15-year-olds can realise in this context.

69. A second constraint is the amount of available testing time. Under the current design of PISA assessments, students will take a one-hour creative thinking test. This means that the range of possible assessment domains must necessarily be limited, in order to ensure that a sufficient amount of data is collected in each domain. As PISA aims to provide comparable measures of performance at the country level, rather than at the individual level, it is possible to apply a rotated test design in which students take different combinations of tasks within domains (with some overlap). Nonetheless, ensuring the ability to produce reliable measures of country-level student performance by each domain requires that a sufficient amount of testing time be dedicated to the tasks within each domain, therefore limiting the number that can reasonably be covered in the assessment.

70. A third constraint is the necessity to implement the creative thinking test within the standard PISA testing platform. The PISA test is administered on standard desktop computers with no touch-screen capability and no internet connection. The platform currently supports a range of item types and response modes, including multiple choice, text entry, drag and drop, hot spots (clicking on areas within a text or image), a chat interface, and interactive charts and graphs. While it has been possible to include new functionalities to the platform during the development of this assessment, such as a drawing tool, both the choice of assessment domains and the design of the tasks had to take into due consideration the technical limitations of the platform.

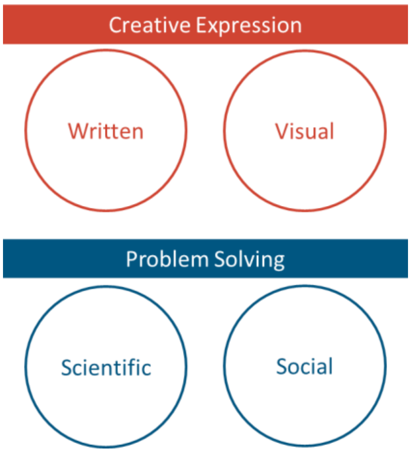
71. Taking these main constraints into account, and building upon the literature that discusses the different domains of creativity, the PISA 2021 creative thinking assessment focuses on two broad thematic content areas: ‘creative expression’ and ‘knowledge creation and creative problem solving’. ‘Creative expression’ refers to instances where creative thinking is involved in communicating one’s inner world to others. This thematic content area is further divided into the domains of ‘written expression’ and ‘visual expression’. Originality, aesthetics, imagination, and affective intention and response largely characterise creative engagement in these domains. By contrast, creative engagement in ‘knowledge creation and creative problem-solving’ involves a more functional employment of creative thinking that is related to the investigation of open questions or problems (where there is no single solution). It is divided into the domains of ‘scientific problem solving’ and ‘social problem solving’. In these domains, creative engagement is a means to a ‘better end’, and it can thus be characterised by generating solutions that are original, innovative, effective and efficient.

72. The four assessment domains represent a reasonable coverage of the creative thinking activities in which 15-year-olds typically engage, and reflect the nature of real world and everyday creative thinking. While they clearly do not exhaust all possible manifestations of creative thinking in school, they do provide a sufficiently diverse coverage of the construct of creative thinking as well as adequately respect the various logistical and technological constraints of the PISA 2021 assessment.

73. Finally, given that differences in cultural preferences for certain forms of creative engagement exist, as do differences in what is valued in education and in how subjects are taught across the world, we can expect some degree of variation in student performance across domains. By having students work on more than one domain, it will be possible to gain insights on country-level strengths and weakness by domain of creative thinking. The data may also uncover the differences in the extent to which students are encouraged to

search for their own solutions and ways to express their ideas, with important implications for how creative thinking in different domains should be taught in school.

Figure 2. Proposed focus domains for the assessment



Written expression

74. Written work represents a natural means for creative expression both inside and outside of the school context, and creative writing is important for developing children's cognitive and communication skills (Tompkins, 1982[106]). Good creative writing requires logical consistency; creative writers ask the readers to understand and believe in their imagination, and this requires that they focus on details and continuity. For example, even stories that are based on fantasy, with monsters and space aliens, need to obey a certain set of rules of logic and to make sense within the universe the author has created.

75. Individuals engaged in creative writing reflect upon the craft and process of writing, define expectations for their work, and respond imaginatively to the text of others (Carter, 2001[107]). These processes can stimulate many new areas of intellectual and emotional development for students, deepening their understanding of themselves and of the world (Essex, 1996[108]). Moreover, creative writing does not only apply to works of fiction: engaging in non-fictional writing can also be creative, such as writing slogans and tag-lines, and these forms of creative written expression can help students to understand and master basic rules of effective communication they need for their life.

76. In the cognitive test, students will need to demonstrate a capacity to express their imagination in a written format, respecting the rules and conventions that make written communication understandable and appreciated for its originality by different audiences. Several test unit templates have been designed for the domain of written expression. Students are asked to: engage in open and imaginative writing (with constraints limiting the length of written text that human raters will need to evaluate); generate ideas for various written formats by considering different stimuli, such as cartoons without captions or fantasy illustrations; and make an original improvement to someone else’s written work (as provided in the task stimuli).

Visual expression

77. In the domain of visual expression, students explore, experiment and communicate ideas and their own experiences using a range of media, materials and processes (Irish

National Teacher Association (INTO), 2009[109]). Producing visual representations can help students to interpret both overt and subtle images and to develop a better understanding of how information, communication and design work in general. Creative visual expression has arguably become more important in recent years: with the ubiquity of desktop publishing, digital imaging and design software, nearly everyone will, at some point, be making visual communications that will affect either themselves or the wider public (think, for example, about the importance of the visual quality of a curriculum vitae).

78. The test unit templates designed in the domain of visual expression ask students to: engage in open visual design tasks, using a digital drawing tool; generate visual design ideas based on the scenario and stimuli provided in the unit (e.g. specific details to include, provision of certain drawing tools); and suggest or make original improvements to different forms of visual expression (as provided in the task stimuli), following given instructions or additional information.

Social problem solving

79. In their everyday life, students use creative thinking to tackle (inter-)personal, and social problems. Creative thinking in this context involves looking at the problem not just from a technical perspective but also from the social perspective, in other words trying to understand and address the needs of others to find solutions to central problems – be they at a personal, school, wider community or global level. Creative thinking in this domain depends on the students' ability to empathise with and evaluate the needs of a specific group, recognise patterns, and construct ideas that have emotional meaning, as well as propose innovative yet functional solutions (Brown and Wyatt, 2010[110]).

80. The test unit templates designed in the domain of social problem solving ask students to: engage in open problem-solving tasks with a social focus, either individually or in simulated collaborative scenarios; generate ideas for solutions to social problems, based on a given scenario; and suggest original improvements to problem solutions (as provided in the task stimuli).

Scientific problem solving

81. Creative thinking in science can manifest itself in various ways: in the conception of new ideas that contribute to advancing scientific knowledge; in the conception of experiments to probe hypotheses; in the development of scientific ideas or inventions applied to particular domains of practical interest; or in the novel implementation of plans and blueprints for scientific/ engineering activities (Moravcsik, 1981[111]). Students can demonstrate creative thinking as they engage in inquiry sessions during which they explore, manipulate and experiment with materials in any way they choose (Hoover, 1994[112]).

82. Creative thinking in science is closely related to scientific inquiry skills, yet several characteristics of this test fundamentally differentiate it from other assessments of mathematics and science. First, this assessment focuses on the generation of new ideas, rather than on the application of taught knowledge. Secondly, the originality of students' approaches and solutions are credited (provided that responses are valid). The third difference is the use of open problems that have multiple possible solutions and where there is no clear optimal solution. Lastly, the this assessment focuses on students' processes of creative thinking in scientific contexts – i.e. the ways in which students go about solving open problems and searching for original ideas– rather than their ability to produce a 'right' or 'most optimal' solution.

83. The test unit templates in the scientific problem solving domains cover these different aspects of creative thinking in various scientific contexts. In general, students are asked to: engage in open problem solving tasks in a scientific context; generate ideas for hypotheses or solutions to problems of a scientific nature, based on the given scenario; and suggest original improvements to experiments or problem solutions (as provided in the task stimuli). Possible units might present students with observations on a scientific phenomenon and ask the student to formulate different research questions or hypotheses to explain the phenomenon; others might ask students to invent something in a laboratory environment, utilising different tools. Units with a more mathematics focus could require students to develop different methods to demonstrate a given property of data or geometrical figures, or might ask students to make as many valid inferences as possible from a given set of data. Alternatively, units might present students with an open engineering problem that requires an innovative solution, or presents a system that can be made more efficient or effective.

84. Interactive simulations and games are particularly appropriate modes for assessing creative thinking in scientific problem solving because such environments provide immediate feedback to students on their choices and actions; observing how students react to this feedback can provide relevant measures of their capacity to engage in the process of failure and discovery that often characterises scientific innovation.

85. The importance of domain readiness is clearly an issue that inevitably arises with most tasks that can be imagined in this domain. Originality has little value without validity (i.e. appropriateness), and validity in turn requires at least some level of background knowledge or understanding of basic scientific principles. Moreover, finding scientific tasks that are equally demanding with regards to the level of background knowledge necessary, across all countries and groups of students, is challenging. This issue could be mitigated by incorporating learning supports, such as short tutorials, that adequately cover the base knowledge necessary to complete the task. Another alternative is to design tasks that obey scientific rules, but for which all students would have very limited experience.

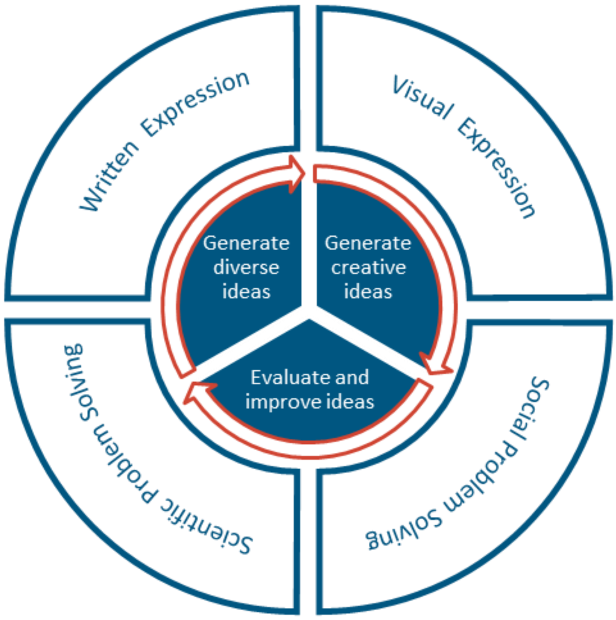
Competency model of creative thinking

86. Figure 3 outlines the competency model for the PISA 2021 creative thinking test. The competency model deconstructs creative thinking into three facets for measurement purposes: ‘generate diverse ideas’, ‘generate creative ideas’, and ‘evaluate and improve ideas’.

87. The test measures creative thinking by asking students to engage productively in the cognitive processes of idea generation (the generation of diverse or creative ideas respectively) and idea evaluation and improvement. It therefore does not only look at the divergent cognitive processes of creative thinking (the ability to generate diverse or creative ideas); students are also asked to evaluate other people's ideas and develop and suggest original improvements to those ideas.

88. ‘Ideas’ in the context of the PISA assessment can take many forms: for example a story, a drawing, a solution to a social problem, or a research question concerning a scientific phenomenon. The test units provide a meaningful context and sufficiently open tasks in which students can prove their capacity to produce multiple ideas and think outside of the box. The test units will be assembled in such a way that the test provides, as a whole and at the population level, an adequate coverage of all the facets of creative thinking. However, not every unit within the test provides points of observation for all of the facets of the competency model.

Figure 3. Competency model for the PISA test of creative thinking



89. The skills demanded by the cognitive processes of idea generation and idea evaluation and improvement are partly defined by context. For example, although composing a poem and considering viable scientific hypotheses to explore in a laboratory can both be conceived as acts of creative idea generation, the actual cognitive and domain-relevant skills an individual needs to successfully think creatively in these two activities are somewhat different and can rely on a different set of domain knowledge and experience. In written expression, idea generation generally involves the writer identifying a memory probe based on the topic of the writing and using this probe to explore long-term memory (Bereiter and Scardamalia, 1987[113]). In a scientific setting, idea generation mainly originates from an inquiry process that involves formulating new questions and carrying out experiments in order to collect evidence concerning those questions (Getzels and Csikszentmihalyi, 1967[114]).

90. Similarly, idea evaluation and selection can involve distinctive cognitive skills, domain knowledge and experience across different creative domains. For example, creative written expression requires revision based on an effort to achieve clarity and coherence, and address audience needs (Bereiter and Scardamalia, 1987[113]); in a scientific context, evaluation entails verifying that a solution is effective and is feasible.

91. The balanced coverage of four domains will make it possible to investigate the extent to which students who are proficient in one area of creative thinking can also demonstrate proficiency in others.

Generate diverse ideas

92. A common indicator of someone's capacity to think creatively is the number of ideas he or she is able to generate, often termed ideational fluency. In fact, ideational fluency has long been the most-used measure for assessing an individual's potential for creative work. However, more than the simple generation of many ideas, which all may be very similar to one another, it is the diversity of those ideas, or ideational flexibility, that

truly demonstrates creative thinking and the ability to avoid functional fixedness in the idea generation process (Amabile, 1983[34]).

93. In the measurement of idea generation, those ideas offered in distinctly different categories should be weighted more than those that fall within the same category (Guilford, 1956[46]). For example in a hypothetical task asking students to list possible uses for a piece of paper, a student who suggests "writing, making a funnel, cutting paper dolls, using as insulation" (four distinct categories of use) shows a higher level of skill in idea generation than a student who suggests "writing, scribbling, printing and drawing" (all in the same category, i.e. paper as a canvas).

94. The facet 'generate diverse ideas' of the creative thinking test focuses on students' capacities to think flexibly across domains: for example, by providing different solutions for a problem, writing different story ideas, or creating different ways to visually represent an idea. In tasks relating to this facet, students are presented with an open scenario and instructed to provide two or three answers that are different from one another. It should be noted that the measure of the diversity of students' ideas is contingent upon the responses being appropriate with respect to the specific task.

Generate creative ideas

95. Creative thinking begins with an intention and ends with a tangible product or idea. Despite the differences that exist in the conceptual and empirical research on creativity, the literature generally agrees that creative outputs are both novel and useful.

96. However, this new-and-useful criteria for measuring creative ideas nonetheless requires further qualification. Firstly, there is uncertainty in the literature about whether 'new' means completely unique or only pre-eminent, or whether creative outputs need only be new for the creator or for society at large (Batey and Furnham, 2006[115]). Clearly, measuring 15-year-olds' creative ideas against the criteria of total uniqueness and society's positive judgement in PISA is inappropriate. In this context, the related and often cited criterion of 'originality' for measuring novelty is a useful concept to measure creative ideas. Defined by (Guilford, 1950[116]) as "statistical infrequency", this criterion encompasses the qualities of newness, remoteness, novelty or unusualness, and refers to deviance from patterns observed within the population at hand. Essentially it poses the question, *how frequent is this kind of response?* In the PISA assessment, originality is thus relative to a reference point: the responses of other students who complete the same task.

97. Secondly, there is also the issue of whether the new-and-useful definition of creative ideas applies uniformly across domains. The requirement of novelty may be less appropriate for some scientific endeavours, where the efficiency, feasibility and effectiveness of advancements in knowledge or solutions to problems provide greater value than novelty, just as a requirement of usefulness may be less essential for creative engagement in the arts (Batey and Furnham, 2006[117]). These differences in the meaning and relative value of 'usefulness/relevance' and 'originality' across domains need to be taken into account in the test design: for example, it is important to provide to students a clear justification for searching for an original scientific explanation when not-original explanations might be more plausible.

98. In the PISA test, the facet 'generate creative ideas' focuses on students' capacities to search for appropriate and original ideas across different domains (e.g. an original story idea, an original way to communicate an idea in visual form, or an original solution to a social or scientific problem). In other words, students are asked to provide an appropriate,

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task-relevant response that other people might not have thought of. The appropriateness criteria means that the response must comply with the basic requirements of the task, respect the task constraints (if present), and reflect a minimum level of usefulness in the response. This is to ensure that students are truly thinking creatively (i.e. generating ideas that are both original and of use) rather than making random associations (i.e. producing original ideas of no use with respect to the task context). In tasks relating to this facet, students are presented with an open scenario and asked to elaborate, in some detail, one original idea.

Evaluate and improve ideas

99. Successfully engaging in creative thinking is not simply characterized by producing something new by deviating from the usual, but also something that works for its intended purpose; a creative output therefore generates "effective surprise" (Bruner, 1979[118]). Evaluative cognitive processes support the production of novel ideas that are at the same time adequate, efficient and effective (Cropley, 2006[47]). They may serve to remediate deficiencies in ideas, and often lead to further iterations of idea generation or the reshaping of initial ideas to improve the creative outcome. Evaluation and iteration are thus at the heart of the creative thinking process. The capacity to identify and provide feedback on the strengths and weaknesses of others' ideas is also an essential part of any collective effort of knowledge creation.

100. The facet 'evaluate and improve ideas' of the test focuses on students' capacities to evaluate limitations in given ideas and find original ways to improve them. In order to reduce problems of dependency across items, students are not asked to iterate upon their own ideas but rather to change or continue someone else's work. In tasks relating to this facet, students are presented with an open scenario and asked to suggest an original improvement for the given idea. Similarly to tasks in the other facets, any measure of 'evaluate and improve ideas' is contingent upon the appropriateness of a student's response. In these tasks, an appropriate response must be an original improvement. An 'original improvement' is defined as a change that preserves the essence of the idea presented in the task but that incorporates original elements, thus incorporating both elements of new-and-useful that characterise creative ideas.

Table 1. Possible ways to measure creative thinking facets across domains

	Expressive (written and visual domains)		Knowledge creation and problem solving (scientific and social domains)	
	Written	***Visual***	***Social***	***Scientific***
Generate diverse ideas	The student writes different captions, titles or story ideas for a given stimulus (e.g. cartoon or comic strip, picture or illustration), which suggest a different interpretation of the stimulus.	The student combines given shapes or stamps in multiple ways to produce distinct visual products (e.g. logo or customisation designs), or the student visually represents data in different ways (e.g. infographics).	The student finds multiple, different solutions to a social problems (e.g. water shortage), which rely on different actors, instruments or methods to achieve the desired outcome.	The student develops multiple, different mathematical methods to solve an open problem (e.g. most consistent player on a team); or the student generates multiple, different hypotheses or experiment ideas to investigate an observation (e.g. animals that suddenly become aggressive).
Generate creative ideas	The student produces an original title for some artwork that is somehow related to the art.	The student produces an original poster for a school exhibition that effectively conveys the theme of the exhibition.	The student can think of an original strategy to effectively market a product (where effective simply requires that the strategy, if implemented properly, could result in increased awareness of the product among the target audience).	The student generates an effective and original solution to an engineering problem (where effective simply requires that the solution, if properly implemented, could represent a possible solution to the problem).
Evaluate and improve ideas	The student makes an original improvement to a title for some artwork in light of new information (e.g. the artist's inspiration behind the illustration), where the student retains elements of the given title but incorporates elements relating to the artist's inspiration in an original way.	The student makes an original improvement to a poster for an exhibition, where the student retains the images included in the given poster but makes a clearer connection to the theme of the exhibition in an original way.	The student makes an original improvement to a suggested solution (e.g. reducing the amount of household waste), where the student's solution effectively (i.e. if properly implemented, could represent a possible solution) builds upon the given solution in an original way.	The student makes an original improvement to a suggested experiment (e.g. testing properties of materials), where the student's response is a valid and original experiment idea and builds upon the given experiment.

Distribution of tasks, response format and scoring methods in the cognitive test

Distribution of tasks

101. According to the current PISA assessment design, students who take the creative thinking assessment will spend one hour on creative thinking items with the remaining hour assigned to mathematics, reading and scientific literacy items. Creative thinking items are organized into 30-minute sections or 'clusters'. Each cluster includes test units that vary in terms of the facets that are measured (generate diverse ideas, generate creative ideas, and evaluate and improve ideas), the domain (written expression, visual expression, social problem solving, or scientific problem solving) and unit duration (guidelines of 5 to 15 minutes). The clusters are placed in multiple computer-based test formats according to a rotated test design.

102. The desired balance, by percentage of items, among the facets of creative thinking is shown in Table 2. These weightings reflect a consensus view among the experts consulted during the drafting of this assessment framework.

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Table 2. Desired distribution of items, by facets of the competency model

Facet	Percentage of testing time
Generate diverse ideas	40%
Generate creative ideas	30%
Evaluate and improve ideas	30%

103. The assessment aims to achieve a good balance between units that situate creative thinking within the two thematic content areas and the four domains. Table 3 shows the desired distribution of items, by domain, in the PISA 2021 creative thinking assessment.

Table 3. Desired distribution of items, by thematic content area and domain

Thematic content area	Domain	Percentage of total items
Creative expression	Written expression	25%
	Visual expression	25%
Knowledge creation and problem solving	Social problem solving	25%
	Scientific problem solving	25%

Response types

104. The items used to assess the creative thinking facets identified in this framework consist of the following different types of responses:

- Constructed-response tasks: these typically call for a written response, ranging from a few words (e.g. cartoon caption or scientific hypothesis) to a short text (e.g. creative ending to a story or explanation of a design idea). Some constructed-response items call for a visual response (e.g. designing a poster or combining a set of given shapes) that is supported by a simple drawing editor tool.
- Interactive simulation-based tasks: these tasks simulate lab-type environments in which students can engage in scientific enquiry or game-type environments in which students complete a level. In these tasks, students receive immediate automated feedback on their actions.
- Simple and complex multiple-choice: these tasks call for answers that are based on the choice of one option among many (e.g. selecting a previously suggested idea as opposed to generating a new idea), and drag-and-drop responses (e.g. categorising ideas).

105. The distribution of tasks by type of response differs across the four domains of creative thinking.

106. A series of potential test units were designed, developed and assembled within the PISA testing platform. The test units that progress to the final pool of units for the field trial (FT) have been selected from this series of potential units with the support of country reviewers and the Expert Group based on (but not limited to) the following key criteria:

- The representation of concepts key to creative thinking (e.g. competency model, domains) as identified in the framework;
- The range of tasks that can accurately discriminate proficiency;
- The appropriateness and variety of the task types;

- The ability to produce reliable coding and scoring guides for the selected units;
- The familiarity and relevance of topics to all students, independent of their country and socio-cultural context;
- Their performance in the cognitive labs and validation studies.

Scoring of the tasks

107. Constructed-response types corresponding to each facet of the competency model follow the same format, and thus the same coding procedure. However, given that the precise form of responses (e.g. a title, a solution, a design) will differ by domain and by task, so will the specific criteria for assessing the diversity and originality of responses. The coding guide that has been developed provide a detailed explanation of the specific criteria within each step of the coding procedure, relative to the task in question, as well as example responses to help orient the coders and increase consistency across coders.

108. However, scoring challenges are greater for this assessment than for any other PISA domains, and are intrinsically related to the nature of this domain. The use of open-ended tasks means that automated and human scoring methods that are applicable to all the participating countries, cultures and languages represented in PISA must be developed. It is therefore helpful to discuss these scoring challenges and the multiple ways that exist to mitigate them.

Scoring methods for 'generate diverse ideas' items

109. Every item corresponding to the facet 'generate diverse ideas' results in a list of two or three responses for coding. These responses can vary in form: for example the students can be asked to suggest ideas for titles, logos, solutions to a social problem, or ideas for an experiment.

110. There are two steps in the coding procedure for these items. First, the coder must identify whether a student's responses are 'appropriate'. Appropriate responses are understandable with respect to the specific task form, and relevant with respect to the specific task content. This means, for example, eliminating text entries that have no meaning (e.g. random typing) or do not respect the task form (e.g. a title is suggested instead of a story idea), or entries that are totally unrelated to the task (e.g. the entry 'eat more cherry pies' in response to a task asking students to suggest ideas for saving water).

111. Second, the coder must establish whether the responses are 'sufficiently different' from one another. The coding guide provides examples of responses that belong to different categories (e.g. two story ideas whose plot is sufficiently different, or two different approaches to solving a social problem). The specific criteria delimiting whether two entries are equivalent or sufficiently different will be as objective and as inclusive of different response types as possible. For example in a written expression item where students are asked to suggest different titles, the criteria for determining sufficient difference between responses might be 'using words that convey a different meaning (i.e. not synonyms)'; in a visual expression item where students are asked to create a company logo, the criteria might simply be 'combining different shapes to generate a different image'. For several tasks in the social and scientific problem solving domains, it will be possible to list pre-defined 'categories' of distinct responses to orient the raters and to which students' ideas can be assigned (for example in a task asking students to suggest ways to save water, 'take short showers' or 'take a bath with little water' would belong to same category).

112. Full credit is assigned where all the responses required in the task are both appropriate and different from each other. Partial credit is assigned in tasks requiring students to provide three responses, and where two or three responses are appropriate but only two are different from each other. No credit is assigned in all other cases.

Scoring methods for 'generate creative ideas' items

113. Every item corresponding to the facet 'generate creative ideas' results in a single response for coding. These responses may also vary in form: for example a short story idea, a t-shirt design, a solution to a social problem or a scientific research question.

114. There are three steps in the coding procedure for these items. The first step in the coding process mirrors that of the coding of 'generate diverse ideas' items. First, the coder must identify whether the response is 'appropriate', whereby appropriate responses are understandable with respect to the specific task form and they are relevant with respect to the specific task content.

115. The coder must then establish whether the response is original. In general, an original response is a relatively uncommon one amongst those in the entire pool of responses. There is a two-step approach for determining the originality of responses. Responses are original if they refer to an unconventional theme with respect to the task prompt (for example, the response conveys an original idea association in the choice of a title for an illustration, or suggests an uncommon type of solution for a social problem). A list of the most conventional themes for each task is included in the coding guide; if an appropriate response does not correspond to one of the conventional topics listed, then it is coded as original. If the topic of the response is conventional (i.e. included in the list of most conventional themes in the coding guide), however, it may still be considered original in the next step of the coding process if it incorporates an original approach (for example, a conventional solution for a scientific problem that is enhanced by some original features, or a design that uses common images but presents them in an original way). The coding guide provides contextualised explanations and examples of original approaches for each task.

116. This twofold criterion for establishing originality ensures that originality in both the conception (i.e. the 'theme') of the idea and in the realisation of the idea (i.e. the approach) are taken into account when establishing if a response significantly deviates from common ones. The list of conventional themes and the examples of original approaches included in the coding guide is based on an analysis of the patterns of genuine student responses gathered in the validation studies. These lists will be further updated after an analysis of samples of responses from the Field Trial to ensure that they reflect conventional responses across students in the different participating countries.

117. While this approach to scoring originality may provide less granularity than a five or ten point scale, thus failing to allow the most original responses to stand out, it has a clear advantage of not being affected by culturally-sensitive grading styles that favour middle points or extremes. Full credit is assigned where the response is both appropriate and original. Partial credit is assigned where the response is appropriate only, and no credit is assigned in all other cases

Scoring methods for 'evaluate and improve ideas' items

118. Every item corresponding to the facet 'evaluate and improve ideas' results in a single response for coding. These items generally require students to make changes to or

adapt a given idea in an original way. Once again, responses may vary in form: for example an alternative story ending idea, an improved design, an idea for making a social event more interesting or a way to make a technological invention more useful or innovative.

119. There are three steps in the coding procedure for these items. First, the coder must identify whether the response is appropriate. In general, a response is appropriate if it is understandable with respect to the specific task form and it represents an improvement or possible continuation of the idea presented in the stimulus. The appropriateness criteria for items measuring this facet is thus strengthened (the response must not simply be relevant but also constitute an improvement) in order to measure the type of creative thinking that results in the betterment of ideas. The coding guide provides explanations and examples of what types of responses constitute an improvement, with respect to the specific context of the task.

120. The coder must then establish whether the response is an original improvement. This steps in the coding process thus mirrors those of the coding process of ‘generate creative ideas’ items where, in general, an original improvement is a relatively uncommon one amongst those in the entire pool of responses (for example, the response suggests an original experiment step in order to gather more evidence about an observed phenomenon, or suggests an uncommon variation of a logo design). A list of the most conventional iterations or improvement for each task is included in the coding guide; if an improvement does not correspond to the conventional ones listed, then it is coded as original. As for ‘generate creative ideas’, raters can code a response as original if the type of improvement is conventional (for example, the student suggests to add images to a webpage), but the approach he/she implements or the description of the idea contains original elements (the images that the student suggests to include are original).

121. Full credit is assigned where the response is both appropriate and an original improvement. Partial credit is assigned where the response is appropriate only. No credit is assigned in all other cases.

Inter-rater reliability

122. The inclusion of open tasks and responses by its very nature generates a risk to the reliability of scoring. Given that reliability and comparability of scoring are a primary objective of PISA assessments, it will thus be important to verify that the coding approaches outlined in this framework actually work. Multiple validation steps and empirical checks before the Main Study are expected to significantly reduce this risk.

123. The success of these scoring approaches clearly depends on the quality of the coding rubrics produced and in particular on a rigorous process of verification to ensure that the rubrics are not culturally biased. Country raters will therefore be asked to provide feedback on the content and language used in the coding guide and rubrics. Secondly, and according to practice that is already established in PISA, ‘within-country inter-rater reliability’ is measured during the Field Trial by having multiple raters code a set of randomly selected 100 responses for each human-coded item. The evaluation of ‘across-country inter-rater reliability’ is achieved by asking English-speaking raters in different countries to code a set of 10 anchor responses selected from responses to each human-coded item of real students in different countries. For the PISA assessment of Creative Thinking, a first verification of inter-rater reliability will be done as part of the validation exercises that precede the Field Trial and additional studies for measuring reliability will be considered.

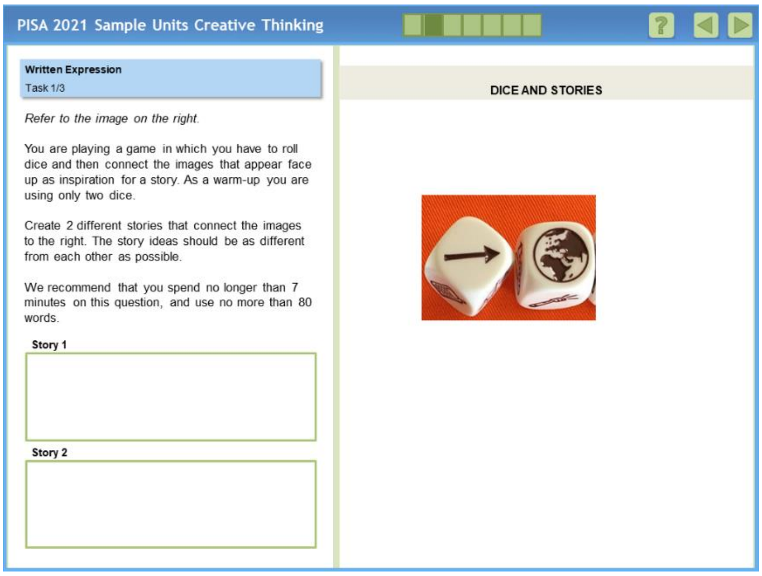
124. In particular, research for this assessment will consider to ask all raters involved in the Field Trial – and not only the English-speaking ones – to rate a number of translated, anchor responses. This would reveal whether there are systematic differences across countries in the ‘leniency’ of ratings and make it possible to estimate the effect of these differences on the final scores. Both the gains in terms of reliability, and the consequences in terms of costs for countries, will be evaluated before engaging in these additional exercises.

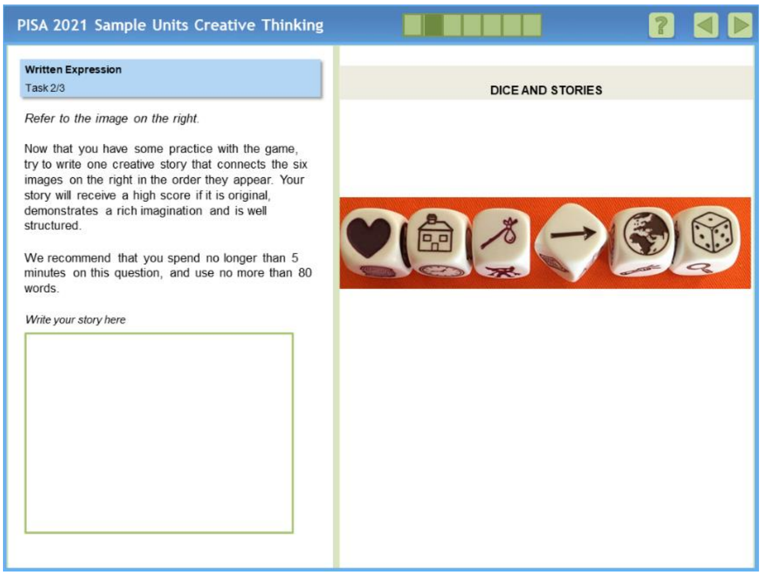
Example units and scoring methods in the cognitive test

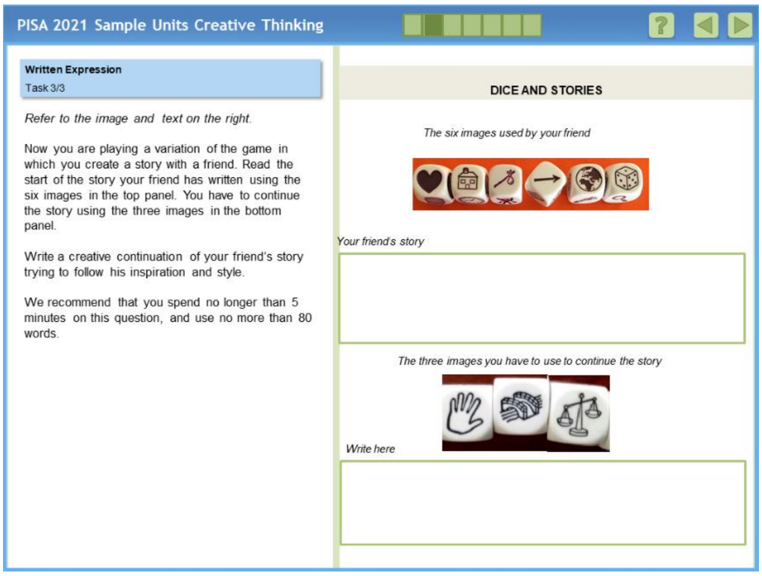
Unit model in written expression

125. Figure 4 presents an example unit in the written expression domain. The unit is sequenced into three tasks designed to provide data on the three facets of creative thinking as defined in the competency model. This unit does not demand high levels of prior knowledge, but performance can be influenced by students’ verbal abilities.

Figure 4. Examples of tasks in a written expression unit







126. In the first task, students are asked to think of two different short story ideas based on the images on the dice. This item thus provides information for the facet 'generate diverse ideas'. Variations of this task template can use different types of stimuli (e.g. images, titles, a photo), as the difficulty of the task is likely to be affected by the stimuli characteristics, such as the degree of abstractness of a title or image or the contextual familiarity of a photo. Ideas are 'appropriate' in this task if they represent a story idea (i.e. one or more extended sentences outlining a possible plot) and if they reference, in some way, both of the images shown in the stimulus. Students demonstrate that they can generate diverse ideas by suggesting appropriate stories that are sufficiently different from one another (as described in the earlier section on scoring). Two stories that recount the same plot with only a few words changed for synonyms would not be considered sufficiently different (e.g. 'the arrow does a tour of the earth' and 'the arrow flies around the planet').

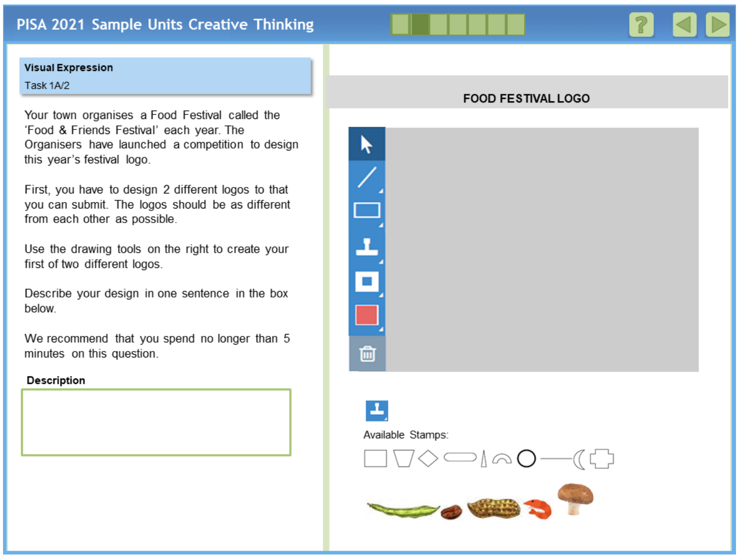
127. The second task of the unit provides information for the 'generate creative ideas' facet. Students are asked to write a creative story, this time referring to six stimuli images. For this task, 'appropriate' ideas represent a story idea (i.e. one or more extended sentences outlining a possible plot) and reference, in some way, all of the images in the order in which they appear, as shown in the stimulus. To determine 'originality', the coders will refer to the task-specific coding guide to determine whether the student's response is considered unconventional, either in theme or approach. Examples of conventional response themes for this item could be: (1) the story is about a heart that starts travelling; (2) the story is about a person looking for love and leaving their house; (3) the story is about someone who does not feel happy at home and decides to leave. If a student's response can be categorised within a conventional story theme, then it can nonetheless be considered original if it employs an unconventional approach (the plot includes original details or has unexpected twists).

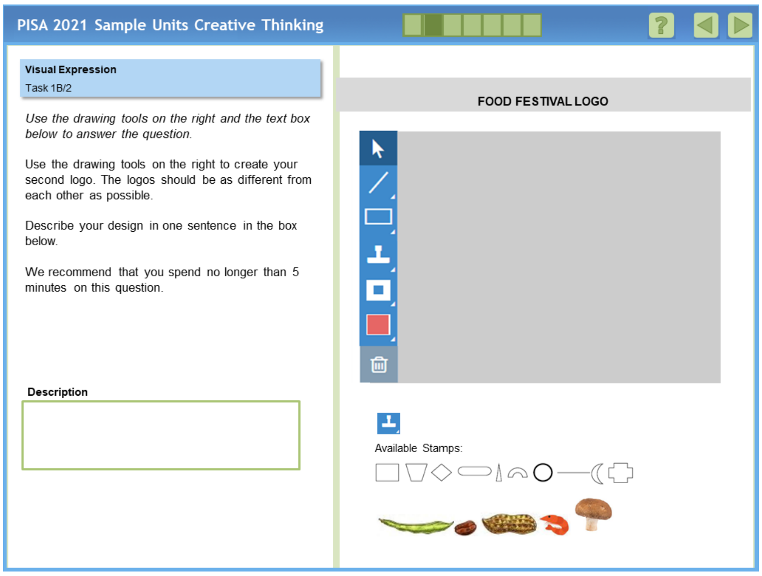
128. In the final task of the unit, students are provided with an additional stimuli and asked to continue the story of a friend. This task will generate data for the 'evaluate and improve ideas' facet, and will be scored according to whether the student's response successfully integrates the additional information provided (i.e. the three new images) into a coherent and original story continuation. Students will receive full credit if their story continuation is appropriate (i.e. makes a connection to the additional three images provided and makes a coherent reference to the friend's initial story) and describes an unconventional plot continuation. Similarly to Task 2, a student's response can be unconventional in either its theme and its response. Students will receive partial credit if their story is appropriate only.

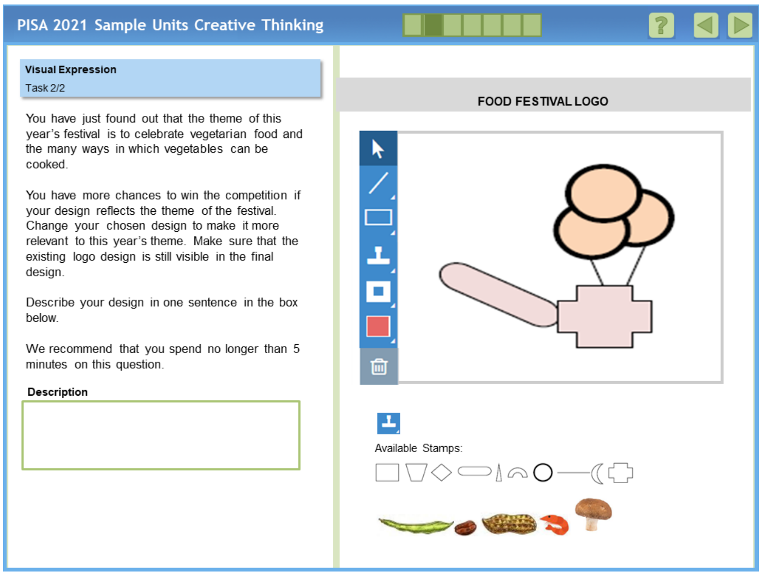
Unit model in visual expression

129. Figure 5 presents an example unit in the visual expression domain. The unit is sequenced into two tasks that provide information on each two of the three facets of creative thinking according to the competency model. The virtual drawing tools provided in the platform have been simplified as much as possible to limit dependency on digital drawing skills, while nonetheless offering sufficient capability to allow students to produce variation in their responses.

Figure 5. Examples of tasks in a visual expression unit







130. The unit revolves around a scenario in which students are asked to apply their creative visual imagination by designing logos for a local food festival. In the first task, students are asked to create three unique designs for the festival organisers to consider using as a potential logo. This task thus generates evidence for the facet 'generate diverse ideas'. Students are provided with some basic information about the theme of the festival, and are given a set of simple graphic tools (e.g. basic shapes, stamps) that they can use to create their designs. Each design space is accompanied by a text entry space in which students can briefly explain their design. Design ideas are 'appropriate' in this task if they resemble a coherent logo that makes a connection to the theme of food. Coders can refer to students' explanations of their designs in cases where the coherence or relevance of the design is ambiguous or not immediately obvious. Students demonstrate that they can produce 'different' design ideas either by incorporating different visual elements into each design, or by using different combinations of the shapes or stamps provided in the drawing tool. Detailed scoring rubrics will provide examples of clearly distinct design solutions for this task, informed by sample responses gathered in the cognitive labs, validation studies

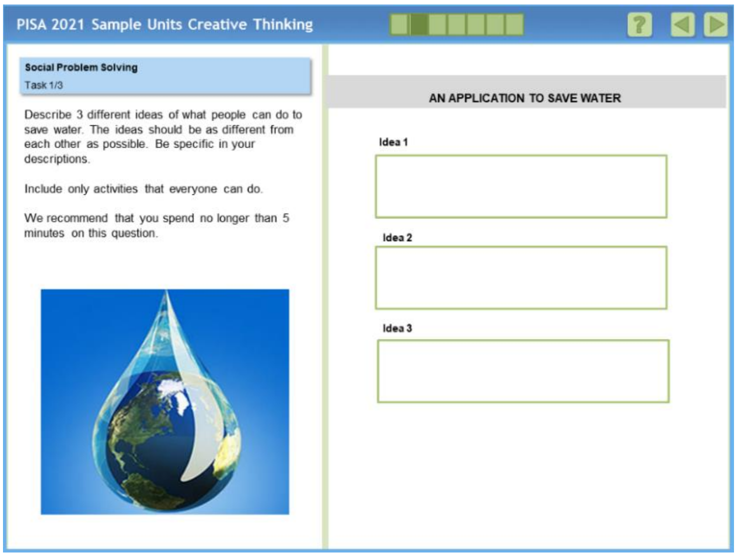
and the Field Trial, to further help orient the coders. Full credit is awarded where students produce three appropriate and different designs; partial credit is awarded where students only produce two designs that are different to each other.

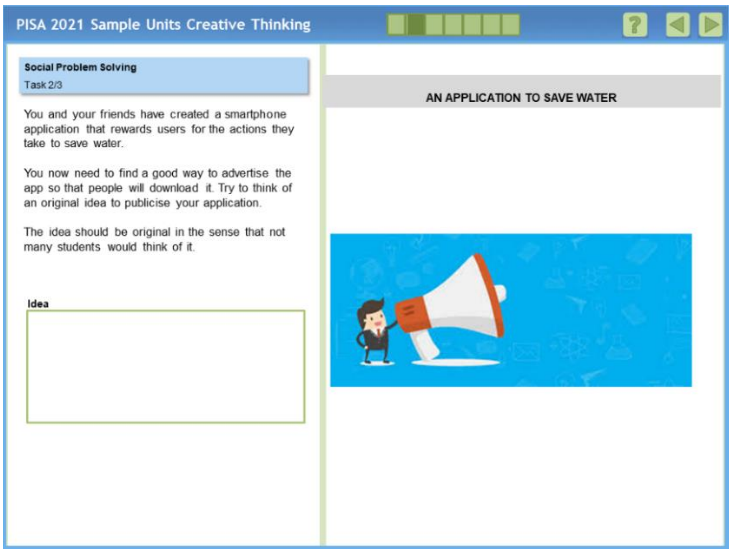
131. The second and final task of the unit asks students to make an original improvement to a given logo design. The task provides students with some additional information about the theme of the festival (i.e. it is a vegetarian food festival) and asks them to improve the chosen logo design in a way that better reflects this new information. This task thus generates data for the facet 'evaluate and improve ideas'. An improved (i.e. 'appropriate') logo design in this task resembles a coherent logo and makes a clear connection to the new theme of vegetarian food, yet at least partially retains the initial elements of the given logo. To obtain full credit, the response must also be an original improvement. Coders will be provided with lists of conventional improvements, based on the observation of real student responses.

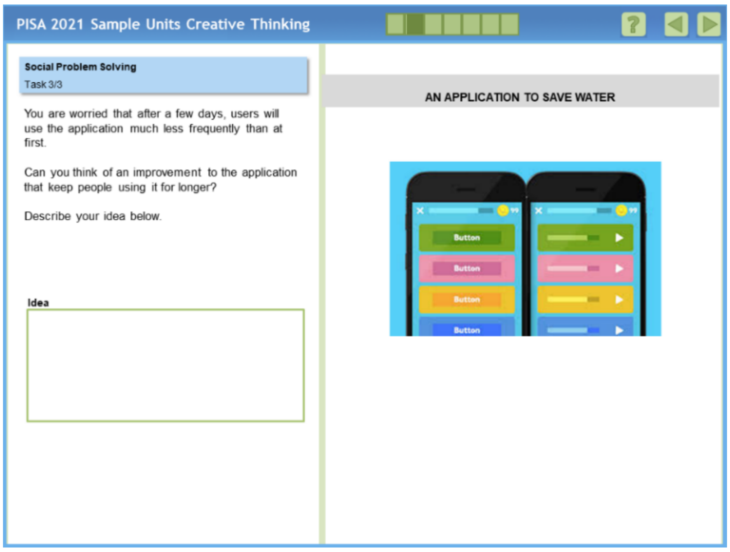
Unit model in social problem solving

132. Figure 6 presents an example unit in the social problem solving domain. In the example, students engage in three tasks that address the social problem of saving water. The choice of social problem used in the unit scenarios within the social problem solving domain is clearly paramount in test design considerations, as it is likely to influence the difficulty of the units. Saving water or reducing wasteful consumption of water is a topic of which many students across the world are familiar, and one that is often addressed in school. While prior knowledge of the issue can probably influence a student's ability to generate diverse and creative solutions for this unit, the relationship between prior knowledge and creative thinking proficiency is not so obvious: for example, prior knowledge might prompt responses that are effective, but may conversely reduce the originality of responses. The test developers have made efforts to ensure that there is a variety of issues presented within the social problem solving domain in order to mitigate any effects of domain readiness over the aggregate population.

Figure 6. Example of tasks in a social problem solving unit







133. The first task asks students to think of three different ways that individuals can save water in their households. This task thus generates information for the facet ‘generate diverse ideas’. Ideas are ‘appropriate’ in this task if they represent a coherent suggestion for a solution and if the suggested solution, if properly implemented, can contribute to saving water in households. Coders will be instructed not to consider the degree of efficiency and effectiveness of students’ responses, beyond the criteria for appropriateness stated above, in order to reduce the influence of domain readiness in the scoring (for both the students and the coders alike). In other words, if a solution might work in some way to save water consumption in households, then the idea should be considered appropriate, regardless of whether other solutions might be more effective or efficient. In order for ideas to be ‘different’, they must employ either a different method, tool or actor in their implementation. The coding guide will contain a comprehensive list of possible categories of solutions to which responses can be assigned; responses within the same category are not considered different.

134. The second task of the unit gathers information for the facet ‘generate creative ideas’. It presents the idea of creating a smartphone application that rewards users for the

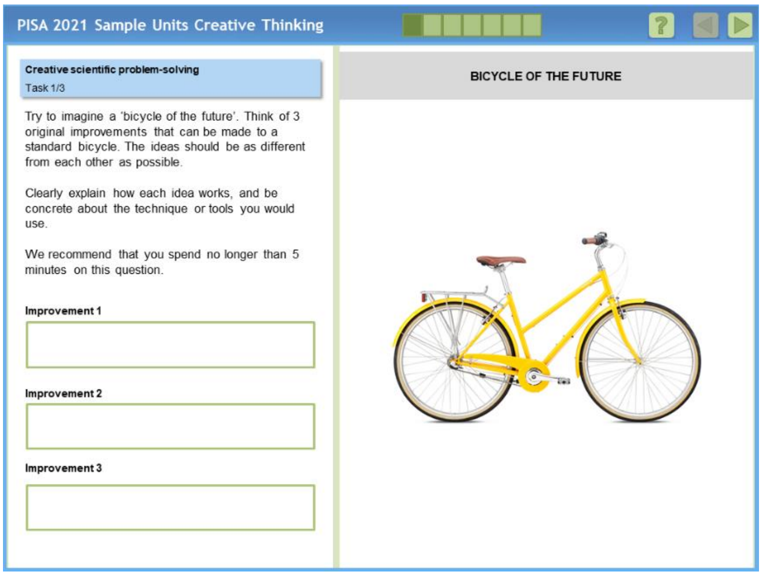
actions that they take to save water, and asks students to suggest a creative way to advertise the application to potential users. An ‘appropriate’ idea in this task is one that resembles a coherent suggestion for an advertisement strategy and one that, if properly implemented, might successfully work to advertise the application. To determine ‘originality’, the coders will refer to the task-specific coding guide to determine whether the student’s response is considered unconventional, either in its theme or approach. Examples of conventional response themes for this item could be: (1) put up posters or billboards that advertise the app; or (2) run a TV advert that shows the negative effects of drought and the application. If a student’s response can be categorised within these conventional themes, then it can nonetheless be considered original if it employs an unconventional approach. Examples of unconventional approaches are providing in the coding guide.

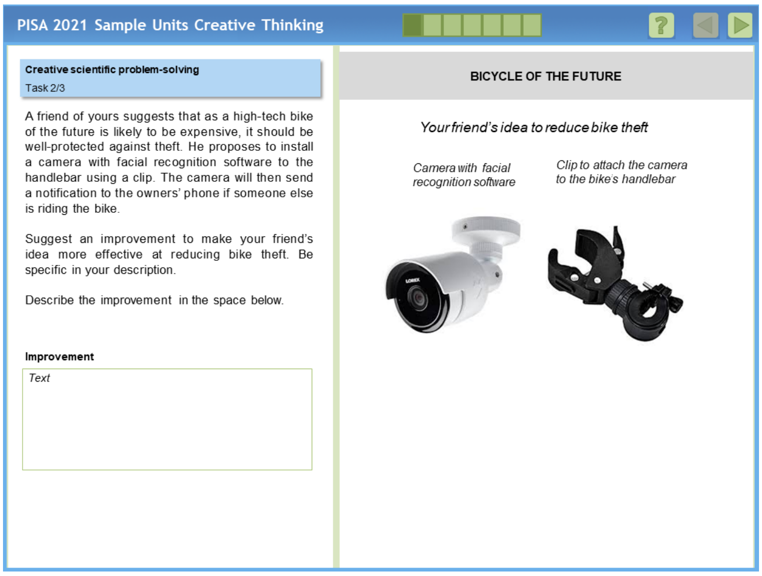
135. The final task of this unit asks students to suggest an original improvement to the application that addresses the particular issue of poor user retention (people quickly stop using the application after downloading it). This task will generate evidence for the ‘evaluate and improve ideas’ facet of the competency model. Students should understand that they need to provide incentives for users to keep using the application; an ‘appropriate’ idea for this item therefore must represent a coherent suggestion for a solution that, if properly implemented, improves the application by providing an additional incentive for users to continue using it. The originality of the improvement will be determined on the basis of whether the suggested improvement is conventional in either its theme or approach.

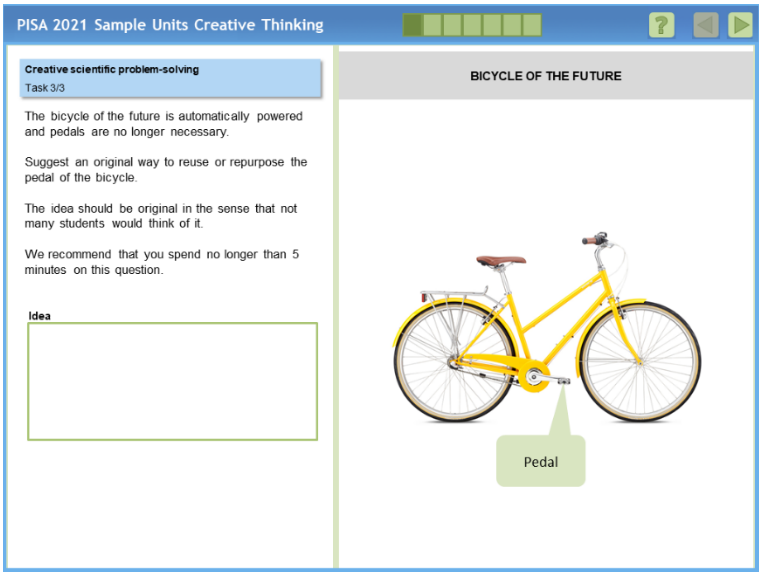
Unit model in scientific problem solving

136. Figure 7 presents an example of a test unit in the scientific problem solving domain. The unit is centred on a scenario in which students are asked to make engineering innovations to a standard bicycle. This unit offers the opportunity for students to be creative as it requires finding (non-prescribed) solutions to an open-problem, as opposed to finding a single-solution that is typical of close-ended problems.

Figure 7. Example of template for a scientific problem unit







137. The first task of the unit asks students to describe three innovative ways that bicycles might change in the future. This task generates evidence for the facet 'generate diverse ideas' of the competency model. Ideas are 'appropriate' in this task if they represent a coherent suggestion for a way that bicycles might change, and if the suggested solution, if properly implemented, still maintains the essence of a bicycle (i.e. a transportation device for a single individual). Coders will be instructed not to consider the degree of efficiency and effectiveness of students' responses, beyond the criteria for appropriateness stated above, in order to reduce the influence of domain readiness in the scoring (for both the students and the coders alike). In order for ideas to be 'different', they must suggest a different variation to the standard bike, for example replacing different elements.

138. In the second task of the unit, students are presented with a friends' suggestion for an anti-theft device and asked to think of an original way to improve their suggestion. This task generates information for the facet 'evaluate and improve ideas' of the competency model. The student should be able to evaluate that the friend's idea is flawed for at least

two reasons: it would be easy for a thief to remove the camera from the bicycle, and that the notification sent to the individual's mobile will likely be too late to stop the thief. An 'appropriate' idea for this item therefore must represent a coherent suggestion for a solution that, if properly implemented, improves the anti-theft device by addressing the weaknesses in the friend's suggestion. The originality of the improvement will be determined on the basis of whether the suggested improvement is conventional.

139. The third and final task of the unit asks students to suggest a creative way that the pedals on the bicycle can be used for a different purpose, now bicycles can be automatically powered. This item generates information for the facet 'generate creative ideas' of the competency model. An 'appropriate' idea in this item refers to any idea that resembles a coherent suggestion that, if implemented properly, might result in a new use for the pedals. The originality of the student's response depends on whether the response is conventional. Examples of conventional response themes for this item might include: (1) use the pedal as a hook (e.g. attach to the wall and hang a coat off of it); (2) use the pedals as a door handle; (3) use the two pedals as limb extensions (e.g. to pick something up off a high shelf/off the floor).

Design considerations and opportunities for additional indicators based on process data.

140. While the test focuses on producing reliable indicators of students' idea generation, evaluation and improvement capacities, other factors that are not the primary focus of the assessment are nonetheless likely to influence performance in the creative thinking test to some degree. Given the limited testing time allocated to the PISA assessment of creative thinking, the test unit and item design needed to focus on developing test material capable of generating sufficient evidence for the individual facets of the competency model. However, the test design has also taken into consideration possible ways to account for the importance of other drivers and mediators of creative thinking performance, in particular the extent to which performance depends on domain- and task-specific knowledge and experience, and engagement with the task (a proxy for task motivation). Accounting for the impact of these variables on performance increases the validity of the claims derived from the test scores, the interpretation of the test scores, and ultimately, the utility of the assessment results.

Accounting for domain and task-specific knowledge

141. Domain- and task-specific knowledge and experience are key enablers of creative thinking across domains. In order to create a valid and reliable assessment of creative thinking, the test items need to be relevant to what students learn and do either inside or outside of schools; it would not be meaningful to design a test with highly abstract tasks where background knowledge plays no role whatsoever. However it is also important to ensure that test taker's background knowledge is not the primary driver of performance in items. This may be the case, for example, if a task scenario is overly complex, causing students to refrain from attempting to be creative because they do not understand what they are expected or able to do.

142. Integrating learning resources into the task design would present another way to reduce the impact of background knowledge on performance. This could take the form of short tutorials at the beginning of tasks, or easy-to-access help functions. Moreover, it might be possible to infer some level of students' prior knowledge and experience from their interactions with these integrated task tools or simply with the test environment more

generally. For example, certain types of mouse movement during drawing tasks might suggest the test taker has little or no prior experience in drawing with a computer mouse. The test design could furthermore consider including questions aimed at identifying students who may have insufficient knowledge of the task topic (e.g. no knowledge of basic electricity principles in a scientific task asking students to build electric circuits) or insufficient experience with the test tools (e.g. no previous experience in drawing on a computer) to be able to successfully engage with the test material

Accounting for engagement with the task (task motivation)

143. Given the emphasis on motivation as a key driver of creative thinking in various componential theories of creativity, the effect of task engagement and motivation on student performance in the creative thinking test is likely to be substantial. The effect of task motivation is clear across all domains of creative engagement: in the scientific domain, task engagement supports creative thinking because it stimulates the exploration of how things work and the willingness to persist before a solution or discovery begins to emerge (Mansfield and Busse, 1981[119]); it also supports the activation of imagination and the fluent execution of creative writing tasks, and an extensive literature demonstrates that interest in and enjoyment of writing for its own sake positively influences creative engagement in writing (Amabile, 1985[120]); in the domain of social problem solving, the ability to find effective and novel solutions is tied to the curiosity of knowing more about a given problem or other people's needs, paired with a sense that one can make a difference by proposing new ideas and perspectives. Ignoring these mechanisms might result in scores of creative thinking that do not reflect true creative thinking potential simply because students were unmotivated or uninterested in the test.

144. As applied to other experiences where individuals interact with technology – such as gaming, web searching, online shopping, or taking a test on a computer – engagement has been conceptualised as a process comprised of four distinct stages: point of engagement, period of sustained engagement, disengagement and reengagement (O'Brien and Toms, 2008[121]).

145. One way to operationalise this concept within PISA is to develop measures of the students' activity level on the task. For example, one could hypothesise that students who use all the time available or recommended for completing a task (or who engage in optional work once they have completed the minimum output required) demonstrate greater task engagement. Some experimental and validation work is needed to assess the reliability of such measures of student engagement, especially as time-on-task data is not always straightforward to interpret; for example, less time spent on a task might also reflect, in some cases, the speed of intellectual work.

Design features to encourage students' exploratory skills and trial and error

146. Almost by definition, the end result of the creative thinking process is not necessarily known from the outset. Test takers should therefore be encouraged to explore all of the resources available to them within their work environment, as is the case for creative engagement in real life. For example in the arts, exploration can include searching for usable materials and tools, and sources of inspiration. Scientists also use exploration to observe the environment or a given phenomenon through multiple tools, in order to identify patterns and relationships among variables and to identify unexpected occurrences.

147. Tasks in the PISA assessment of creative thinking allow students to explore possibilities by creating multiple versions of the same product, by asking students open

questions with no single or prescribed answer, and by providing students with certain tools to aid their work (e.g. different graphic tools, such as stamps, shapes and free drawing capabilities). Similarly, some scientific tasks are situated within simulation-based units where students, through their interactions with the online environment, can experiment with different tools in order to identify patterns, underlying models, and relationships between variables.

148. In all of the test units and tasks, it must be easy for test takers to try things out and then backtrack when unsuccessful or wanting to quickly try alternative options (e.g. an easy-to-use 'undo' capability in the drawing tool). It is especially important that tools be "self-revealing" so that it is clear what test takers are able to do in the test environment. Finally, interactive tools should be fun to use: if students focus too much of their efforts on how to use the tools, then they will have less cognitive resources available to dedicate to the processes of creative thinking.

149. It will be relevant to analyse how students' creative thinking performance is related to their exploratory skills. In a similar method to establishing measures for student engagement, indicators for student exploratory skills could be derived by interpreting the telemetry from their behaviours on the computer platform. One can, for example, deduce that a student who tries using a larger number of different tools or who spends more time exploring different functions and properties of the digital environment, shows a higher engagement in exploratory processes.

150. Given that these process data on students' interactions with the testing environments are harder to analyse and interpret, the competency model does not include exploratory skills. Process data on students' exploration will, however, be produced and made available for the units to the public, to encourage research on students' exploratory and trial-and-error strategies in open, computer-based tasks.

Test development and validation of the cognitive test

Ensuring appropriate coverage of the construct and cross-cultural validity

151. Test developers must take into account the test administration and format standards, as well as consider cultural and linguistic issues such as construct equivalence, when designing test materials for large scale international assessments. In psychometric terms, test bias describes the notion that test scores based on the same items measure different traits and characteristics for different groups.

152. In the PISA 2021 creative thinking assessment, such weaknesses might stem from the possible challenges of formally determining a priori: (a) the similarity of the creative thinking competence being measured across cultures, in terms of the conceptualisation, operationalisation, dimensionality, and targeted behaviours of the construct; (b) students' familiarity with the item format, in terms of the required response (e.g. in interactive simulation-based tasks); and (c) problematic item content, with respect to the level of necessary prior knowledge, the interpretation of task instructions, and the clarity of the stimuli provided (e.g. the use of colloquialisms or images). Failure to investigate these aspects through validation exercises almost certainly leads to the introduction of test bias and ultimately, to structural and measurement non-equivalence across the groups under study (Van de Vijver and Leung, 2011[122]).

153. This section highlights the critical importance of multi-faceted equivalence, outlines a recommended series of assessment design and psychometric analytic stages that

can result in rigorously adapted assessment tasks and scales, both within and across national groups (International Test Commission, 2017[123]), and describes the specific validation exercises in which the OECD Secretariat and the test development contractor have engaged during the development process of the PISA creative thinking assessment.

Validation and cross-cultural comparability of the assessment material

154. To ensure the valid assessment of creative thinking, the proper coverage of the creative thinking proficiency ranges in all the participating countries, and to account for possible inter-country and sub-group differences, the following procedures have or will be applied throughout the test development cycle:

1) *Cross-cultural face validity reviews:* ensuring that the construct under assessment is understood in the same way across linguistic and cultural groups. Individuals who are experts in the measurement of creative thinking, and who are familiar with the cultural groups being tested, have engaged in several cycles of review of the assessment framework and test material in order to evaluate the legitimacy of the construct across cultural and linguistic groups. This enabled the cultural and linguistic characteristics irrelevant to creative thinking to be identified during the early stages of the assessment development process. All participating countries have also engaged in several cycles of review of the test materials to help identify items that may be likely to suffer from cross-cultural bias.
2) *Cognitive laboratories:* observing how individuals of the target test population interact with and understand the test materials and expectations. Experienced testing professionals have been engaged to conduct cognitive laboratory exercises with students in three countries. In the format of thinking-out-loud exercises, students around the age of the PISA population were asked to respond to the cognitive and non-cognitive questions, explain their thought processes in answering and point out any difficulties or misunderstandings in the instructions or stimulus material. Further details hereon are provided in a separate document [EDU/PISA/GB(2019)8].
3) *Small-scale validation exercises:* conducting validation exercises in parallel to the overall test development process in order to observe how the current test materials function under test conditions. An analysis of the genuine student data can indicate items that do not perform as intended, and can inform evidence-based improvements to the test material including the coding guide. The purpose and methodology of the validation exercises conducted by the OECD Secretariat and the PISA contractors are detailed in the dedicated section in the separate paper on validation exercises for the PISA 2021 creative thinking test [EDU/PISA/GB(2019)8].
4) *Translatability reviews:* assessing potential issues of translatability, for example in the task scenarios or prompts. The OECD Secretariat works closely with the experts and contractors involved in the development of the test material to ensure that all assessment content can be sufficiently translated into the many languages of the PISA main study. An appropriate translation should represent a balanced adaptation of linguistic and cultural considerations associated with each language group. This process requires a solid understanding of the creative thinking competence and the assessment construction. Linguistic quality assurance mechanisms ensure that all specificities of the construct are taken into account.

5) *Field Trial:* administering the assessment to large, representative samples of the target population. This crucial phase in the test development process provides the opportunity to conduct a full-scale construct and assessment validation exercise prior to the Main Study. It will be undertaken in all participating countries and used to exclude, through a statistical analysis, the test items that demonstrate insufficient cross-cultural validity. The data analyses address the issue of construct and score validity and reliability, within and across countries, in addition to differential item functioning. Multi-group equivalence, measurement equivalence, and structural equivalence analyses are typically performed on the data. Multi-group confirmatory factor analysis (MGCFA), differential item functioning (DIF) proposed by the Item Response Theory (IRT), and multidimensional scaling (MDS) are among the valuable ways of assessing measurement invariance. Due to the operational timeline in PISA, it is not possible to include new items in the test after this phase, and no substantial modifications can be made to existing test items, i.e. poorly performing items will be removed from the test item pool to ensure a proper coverage of the construct.

155. In summary, this approach to validation and cross-cultural comparability addresses construct equivalence in addition to linguistic equivalence. This approach uses a committee method: groups of construct and large-scale assessment experts work both separately and together to determine the extent to which concepts, words, expressions and tools are culturally, psychologically and linguistically equivalent in the target languages.

Scaling and reporting proficiency in the cognitive test

156. To communicate the results of the PISA assessment, it is necessary to develop proficiency scales that are clearly interpretable in educational policy terms. The main goal of scaling and reporting is to inform stakeholders in each country about the performance of their students in creative thinking, as defined in this framework.

157. Generally, results of the PISA assessments are reported through a single, uni-dimensional scale. The advantage of this reporting method is that all test material is geared towards producing one single figure. This means that the scale is based on a large number of responses, and thus is highly reliable for the purposes of assessing differences across countries or sub-populations of students.

158. An alternative approach to producing one single scale would is to derive multiple indicators that can present a differentiated profile of strengths and weaknesses in student performance in each country. Sub-scales can be either calculated using the estimated parameters for the overall scale (thus assuming a one-factor/dimension solution) or can be calibrated separately (in which case, a total score can be obtained by aggregating the scores for each scale). Other methods do not produce a single, summary scale, but rather separate scores for each factor or dimension.

159. Sub-scales represent one way to expand on the set of information that is provided to stakeholders. PISA already produces sub-scales for the main domain in each cycle, for example when describing student competences in different areas of mathematics. One advantage of this approach is that sub-scales allow policy makers to better understand the focus of remediation activities and changes in the curriculum. However, without enough testing time, it might be not possible to produce multiple scales that are sufficiently reliable and that are meaningfully differentiated from the overall scale. It is for this reason that subscales were not produced in PISA for the minor domains in past cycles.

160. The PISA 2021 creative thinking assessment faces this trade-off between reporting a larger set of indicators in order to better inform policymakers about students' strengths and weaknesses, and ensuring that each reported indicator is reliably measured. Over successive iterations, the Expert Group has decided to simplify the competency model to reduce the challenge of reliably measuring a large set of related but distinct abilities (i.e. the complex set of cognitive, metacognitive and behavioural characteristics that constitute the individual enablers of creative thinking. The majority of the test items focus on idea generation. However, given that this assessment has not been implemented before, it is not yet possible to conclude that the data should be reported according to one single scale.

161. Multi-dimensional reporting can be more appropriate if the different facets and domains of the competency model represent clearly distinct factors: for example, it is possible that many students might have a high level of proficiency in evaluating and improving ideas, but are less capable of generating multiple, diverse ideas. Despite attempts to minimise the effect of background knowledge and domain readiness in the design of the test units, it is also possible that student performance might not be strongly correlated across the different domains of the assessment: for example, some students might be highly successful in generating diverse and original solutions to a social problem, but might struggle when they have to visually communicate an idea in a creative way. If students like some type of tasks (creating a visual product) but not others (developing an idea for a scientific experiment) this would reduce the observed correlations among items that are mapped to different domains.

162. A critical first step in the analysis of the creative thinking test results will be to assess whether the data can be represented by a model assuming uni-dimensionality, are better described through sub-scales, or indeed they require a more complex, multi-dimensional model. The validation study has provided a first set of real data to explore the dimensionality of the construct, although the results cannot be considered as conclusive evidence given the small size of the sample. More reliable information on dimensionality will be available after the Field Trial.

163. The analyses of the validation studies and the Field Trial should verify whether the units and items have been designed in a way that replicates the assumptions of the model, such as the items in the same domain should be more correlated with one another than items across different domains, and equally the correlation between items in the same content area (expressive, creative problem solving) should be higher than the correlation across items in the different content areas. The actual magnitude of these correlations will be the first indication of the most appropriate reporting method. The measured reliability of the sub-scales/sub-scores that can be produced will be the second element that will orient subsequent decisions on the direction of the reporting.

164. Not presuming the uni-dimensionality of the construct has implications on the method of selecting items for the PISA main study. Under a strong assumption of uni-dimensionality, the items that do not load onto the main factor will be discarded from the test item pool. For this assessment however, it is important to recognise that, theoretically, students can perform better as creative thinkers in some domains or some tasks than in others, and thus items that do not load onto the main factor might contain some relevant information about test takers strengths and weaknesses that should be used for reporting. In the process of selecting items for the main study, it will be important to maintain a good balance in the coverage of the different domains.

165. The analysis of field trial data will also put a strong emphasis on assessing the comparability of the results across countries. Given the influence of cultural background

on the evaluation and expression of creative work, it is possible that country-item interactions will be larger for this assessment than in other PISA domains. The analysis will provide information that can evaluate whether country-item interactions are related to the instruments' design and scoring methods (and could thus be mitigated through a careful selection of the units and items for the main study, and through an improvement of the coding guide) or whether they provide genuine evidence of cultural differences in creative thinking.

166. In addition to these summary indicators/scales, the reporting of this assessment will put a greater emphasis on international comparisons at the task-level (therefore releasing at least four units to the public, one in each of the four domains). In several units, task-specific information on students' strategies, exploratory skills and engagement can be captured through process data. These depictions are powerful as they can be linked back to pedagogical approaches for developing cognitive and metacognitive competences and supporting positive attitudes towards creative thinking.

Defining content for the PISA background questionnaires

167. In addition to the creative thinking test, the PISA assessment will gather self-reported information from students, teachers and school principals through the use of questionnaires.

168. According to this framework, creative thinking is enabled by the combination of various different individual components, and is influenced by contextual factors (see Figure 1). The questionnaires will therefore be used to extract information on those enablers and drivers that are not directly assessed in the cognitive test of creative thinking.

Curiosity and exploration

169. The student questionnaire will provide information about individuals' curiosity, openness to new experiences, and their disposition for exploration. Questionnaire scales on openness can be informed by the extensive literature on the relationship between personality and creativity, as well as the existing inventory of self-report personality measures that have been used in previous empirical studies of the 'creative person'.

Creative self-efficacy

170. The student questionnaire will also gather information on the extent to which students believe in their creative abilities. A scale on creative self-efficacy will measure students' general confidence in their own ability to think creatively, as well as their beliefs about being able think creatively in different domains.

Beliefs about creativity

171. One scale in the student questionnaire would explore what young people believe about creativity. The items will ask the students whether creativity can be trained or is an innate characteristics, whether creative expression is possible only in the arts, whether being creative is inherently a good thing in all contexts, and whether they hold other beliefs that can influence their motivation to learn to be creative.

Creative activities in the classroom and school

172. One or more questions in the student questionnaire will ask students about the activities that they participate in at school which, in turn, may contribute to their domain readiness in and dispositions towards different creative domains. For example students could be asked about the type of activities they are regularly asked to perform at school (e.g. painting, poetry, creative writing, doing experiments, debating social problems, tinkering and design…) as well as collecting information on students' out-of-school experiences. The school and teacher questionnaire will also include information on the inclusion of creative activities in the curriculum and in extracurricular time.

Social environment

173. Information on students' social environment will be collected in the student, teacher and school principal questionnaires. Questionnaire items will gather information on student/teacher interactions (e.g. whether students believe that free expression in the classroom is encouraged, or if students believe that teachers take seriously the ideas and proposals that they put forward) and the wider school ethos. These items can provide further information on the role of extrinsic motivation on student creative performance (e.g. students' perception of discipline, of time pressures or assessment).

174. Additional questions may also cover information on other relevant social environments for 15-years-old students, such as the family and the peer network.

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