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Unpacking PIAAC's cognitive skills measurements through engagement with Bloom's taxonomy

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ABSTRACT

The Programme for International Assessment of Adult Skills (PIAAC) surveys people between the ages of 16 and 65 and includes an assessment of cognitive skills (literacy, numeracy and problem-solving in a technology-rich environment). In traditional educational psychology, Bloom's taxonomy on cognitive domains is perceived as a core reference in the field and distinguishes between Low, Medium and Higher Order cognitive skills. However, Bloom's work on the hierarchical nature of cognitive skills has not been referenced by the OECD in its PIAAC documentation. This paper demonstrates – through a text-based analysis of the PIAAC's definitions of skills levels – that the OECD's description of cognitive skills resembles keywords used by Bloom but does not explicitly define these through a hierarchical approach. Instead, high level cognitive skills are mainly characterised through the ability to apply cognitive strategies to unfamiliar contexts outside the adults' immediate life circumstances.

1. Introduction

The main purpose of this paper is to engage in a content analysis of the cognitive skills descriptors as featured in the OECD's Programme for the International Assessment of Adult Competencies (PIAAC). The theoretical framework selected for this analysis is the well-known Bloom taxonomy of cognitive domains. Providing a deeper understanding on the measurement of cognitive skills is important as these skills are perceived to be vital for adults to survive in the rapidly changing knowledge-based economy (Authors, 2020; Hanushek, Schwerdt, Wiederhold, & Woessmann, 2013; Hanushek & Woessman, 2015). Adults need to be sufficiently literate and numerate to cope with the demands of work, even if they are employed in elementary jobs. The fast introduction and development of a wide range of ICT tools at work and at home has also created the need for adults to engage with problem-solving in a technology rich environment (PS-TRE) (Authors, 2020; Frank & Castek, 2017; He, Borgonovi, & Paccagnella, 2021; OECD, 2009, OECD, 2015). Being proficient in these cognitive domains is supposed to be beneficial for the individual, but also for society as a whole as highly skilled adults are believed to make positive contributions to a country's research and development, industrial innovation and economic competitiveness (Feinstein, Budge, Vorhaus, & Duckworth, 2008l Gloster et al.; Hanushek & Woessman, 2015; Schuller, 2017). Guaranteeing basic cognitive skills for everyone will also help to reduce poverty, ill health, gender inequalities and is expected to boost social and civic participation.

The OECD, together with other leading international organisations such as the European Commission, UNESCO and the World Bank highly influence the current education and skills debates around the world (Dehmel, 2006; González-salamanca, Agudelo, & Salinas, 2020; Ioannidou, 2007; Lee, Thayer, & Madyun, 2008; Rubenson, 2011). The OECD's Programme for International Student Assessment (PISA), undertaken with 15-year old pupils, has highly influenced the debate on compulsory schooling systems, underpinned by country comparisons on outcomes of cognitive skills measurements in relation to literacy and numeracy (Gardinier, 2017; Sellar & Lingard, 2014; Seitzer, 2021). PIAAC focuses on these cognitive skills too but works with a sample between the ages of 16 and 65 (OECD, 2013).

While measurements of 'cognitive skills' are thus core within both PIAAC and PISA, it is needed to further unpack this term. Gierl (1997) stated nearly 25 years ago that Bloom's Taxonomy of Educational Objectives was widely used by cognitive literacy and numeracy test

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developers but not necessarily the most ideal model to use in these types of cognitive skills assessments. In recent years however, a number of studies have been published in which scholars compare cognitive test measurements to the Bloom taxonomy or in which Bloom has been used as a theoretical framework to interpret these test results (see for example Ramirez, 2017; Radmehr & Drake, 2019; Virranmäki, Valta-Hulkkonen, & Pellikka, 2020; Yaz & Kurnaz, 2020). While the OECD has worked with expert groups at the time of preparing for PIAAC, resulting into working papers on the conceptual frameworks on literacy, numeracy and problem-solving in technology-rich environments, their documentation on definitions of cognitive skills and strategies tends to be thin on references to the core academic literature (OECD, 2021). Bloom's taxonomy of cognitive domains remains a core theoretical tool introduced in pedagogical training across the world and several authors have specifically compared PISA to Bloom taxonomy (Bodin, 2005; Willms, 2013; Wasis, Sukarmin, & Prastiwi, 2017). Academic literature on the comparison between Bloom and PIAAC does not exist. The OECD working paper reporting on the PIAAC Literacy Expert Group in 2009 did not mention the Bloom taxonomy (OECD, 2009). The 2013 PIAAC Survey of Adult Skills Reader's Companion does not mention the name 'Bloom' once, while the term 'cognitive' is being used 99 times (OECD, 2013). Instead of explicitly referencing Bloom, the OECD constructed its own conceptual frameworks for the measurement of cognitive strategies, in case of PIAAC these are literacy, numeracy and problem-solving in technology-rich environments. An overview of PIAAC's conceptual framework on the measurement of skills can be found in Table 1. Proficiency levels of respondents are being expressed through a points system, ordinally ranking adults at Proficiency Levels from Below 1 to Level 5 for literacy and numeracy and from Below 1 to Level 3 for problem-solving in technology rich environments.

1.1. Objectives

Given the strong presence of Bloom in the literature on cognitive domains and the resemblance of key words in Table 1 to aspects of Bloom's taxonomy – discussed below –, it is a worthwhile exercise to analyse PIAAC skills descriptors to this work. Through the analyses presented in this paper, a number of gaps in the knowledge base will be filled. This study therefore addresses the following objectives.

The first objective relates to providing a more in-depth qualitative framework on what PIAAC is exactly measuring. Cognitive skill levels of adults are typically presented through an aggregated number referring to a calculated literacy and numeracy score or a standardised IQ-type indicator. These scores often lack detailed qualitative information on its underlying measurement (Hamilton, 2012; Ozga, 2012; O'Keeffe, 2017). It is important to raise awareness among researchers, policy makers and practitioners on what PIAAC is measuring.

The second objective focuses on a further discussion of the Bloom taxonomy. While his work remains a core fundamental source in the pedagogical and cognitive literature, it is not strongly visible in work on cognitive skills by leading international organisations such as the OECD. Our objective is to specifically zoom in on the common critique on the hierarchical nature of the Bloom taxonomy. This will be done through comparison of the Bloom taxonomy with PIAAC's approach to classifying cognitive skills through Proficiency Levels. Engaging in an in-depth investigation of the underlying meaning of the PIAAC direct skills measurements from a Bloom's perspective will give colleagues insights in how the theorisation of cognitive skills has developed in past decades.

Table 1
PIAAC's conceptual framework on cognitive strategies.

Literacy	Numeracy	PS-TRE
✓ evaluate and reflect ✓ integrate and interpret ✓ access and identify	✓ interpret, evaluate ✓ act upon, use ✓ identify, locate or access	✓ goal-setting and progress ✓ monitoring, planning, self-organising ✓ acquiring and evaluating information ✓ making use of information

Our third objective relates to enhancing policy and practice. Bloom's taxonomy was originally developed as a way to help instructors to achieve a range of educational objectives within their teaching practice. Based on analyses of PIAAC data, we know that a significant proportion of the adult population lacks proficiency in basic skills (Durda, Gauly, Buddeberg, Lechner, & Artelt, 2020; Lechner, Gauly, Miyamoto, & Wicht, 2021; Paccagnella, 2016). It is important that education scholars receive more in-depth information on the nature of the exact skills problems in order for to fine tune this area of research. Analysing skills descriptors will help to raise awareness of the OECD's understanding of literacy, numeracy and problem-solving skills.

The following research questions will be addressed in this paper:

1. To what extent are keywords in the PIAAC cognitive skills descriptors from Below Level 1 to Level 5 related to Bloom's taxonomy?
2. To what extent do PIAAC cognitive task scores for the strategies presented in Table 1 represent a hierarchical structure?

We start this paper by discussing PIAAC, followed by a summary and critique of the original and revised Bloom taxonomies on cognitive skills as published in the international literature. We will then turn to our methodological procedures and discuss the results of our analyses. The paper will end with a discussion and conclusion section in which we will also highlight limitations of our work as well as implications and recommendations for future work.

2. PIAAC: the OECD and the assessment of adult skills

The OECD is world-famous for its assessments of cognitive skills (OECD, 2013). While PISA has a much higher level of visibility in the public domain, PIAAC has received some public attention in previous years too (Cort, Larson, & Mariager-Anderson, 2014; Rubenson & Walker, 2014; Yasukawa, Hamilton, & Evans, 2017). In the past, various scholars have in fact been highly critical of the OECD's skills measurements and the way in which results of these surveys put unhealthy pressures on education systems. Academics have been critical about the research technical aspects of the surveys, including the need to be careful when comparing results between countries or subgroups (d'Agnese, 2018; Jerrim, 2016; Pokropek, Borgonovi, & McCormick). The OECD's work has often been criticised for being strongly work-related and for linking human capital to economic performance and financial gains in the neoliberal marketplace (Ball & Olmedo, 2013; Connell, 2013). In relation to adult skills, this fits into the discourse on lifelong learning for 'lifelong earning' and the transformation of the humanistic scope of adult education into 'human resource development in drag', especially visible since the mid-1990s and the start of the 21st Century (Boshier, 1998; Holford & Spolar, 2012).

PIAAC works with a Survey of Adult Skills, which includes a main component on direct assessment of three cognitive skills (literacy, numeracy and PS-TRE), which has been developed through expert groups on the different skills (OECD, 2013). Sample items can be consulted in the PIAAC's Reader Companion (OECD, 2013, p.17–36). As highlighted in Table 1 above, different cognitive strategies are being assessed according to PIAAC's conceptual framework: (1) access and identify, (2) integrate and interpret, (3) evaluate and reflect for *literacy*; (1) identify, locate or access, (2) act upon, use, (3) interpret, evaluate for *numeracy* and; (1) making use of information, (2) acquiring and evaluating information, (3) goal-setting and progress, (4) monitoring, planning, self-organising for *PS-TRE*. Results of the cognitive skills assessments are being expressed through numerical scales, ranging from below 1 till 5 for literacy and numeracy, and from below 1 to 3 for PS-TRE. Each respondent receives an aggregated score for these three cognitive skills, expressed through a set of 10 Plausible Values for increased accuracy of cognitive measurements. For literacy and numeracy, Level 3 is generally perceived as the minimum level adults should obtain in order for them to be able to cope with the demands of the 21st Century. Those at Level 2 or below are often referred to as low-skilled adults. The Reader's Companion outlines the different descriptors per level per skill, which will be discussed and analysed below (OECD, 2013).

The Survey of Adult Skills also collects information on the use of skills, both at home and at work, and respondents are asked to provide individual-level information as part of the background questionnaire. This includes the collection of typical socio-demographic and socio-economic variables such as gender, age, educational attainment and occupational status. Respondents are between the ages of 15 and 65 and the survey has so far been conducted in 39 countries. PIAAC has been implemented in order to follow up on previous OECD survey on adult skills, notably the International Adult Literacy Survey (IALS) and the Adult Literacy and Lifeskills Survey (ALL) (Desjardins, Rubenson, & Milana, 2006; Murray, Kirsch, & Jenkins, 1998; Paccagnella, 2016). A new cycle of data collection is being planned for 2022–2023. Over 30 countries have agreed to participate in this second cycle of PIAAC.

3. Bloom's taxonomy of cognitive domains

The term 'cognitive skills' is often used in a rather vague way and asks for further unpacking, especially in relation to highly influential OECD work. While generally known as the Bloom taxonomy, the original work on this 'Taxonomy on Educational Objectives' was constructed as a co-operation between Bloom and his colleagues Engelhart, Furst, Hill and Krathwohl in 1956 (Bloom, 1956). Their work focused on (1) cognitive, (2) affective and (3) sensory domains and was originally developed to help educators construct and revise their curricula, assessment methods and pedagogical activities. For the purpose of this paper, we solely focus on the cognitive domain, in accordance with the focus of PIAAC. As can be seen from Table 2, Bloom and colleagues defined cognitive skills as a *hierarchical* construct which starts with the development of Low Order Thinking Skills. These can then be further refined to Medium and High Order Cognitive Skills. Revised taxonomies have been published, notably by Anderson, one of Bloom's former students, together with Krathwohl, who was also part of the original Bloom team (Anderson & Krathwohl, 2001). Their 2001 revised taxonomy transformed the 'nouns' used in the original Bloom taxonomy into 'verbs'. While 'evaluation' was included as the highest order thinking skill by Bloom (1956), the two highest order thinking skills 'evaluation' and 'synthesis' were swopped around and renamed as 'evaluate' and 'create'. Looking into the taxonomies in Table 2, 'knowledge', or 'remembering', have been defined as the basic Low Order Thinking Skill. 'Comprehension' or 'understanding' are also Lower Level Thinking Skills, based on the capacity to remember. At the medium level, 'applying' and 'analysing' are skills to be gained after skills in remembering and understanding have been mastered. At the highest level, people need to be able to 'evaluate' and 'create' new ideas or outcomes based on their previously gained abilities to remember, understand, apply and analyse new information. The nature of knowledge in the original Bloom's taxonomy can be rather factual but can also be from a theoretical-conceptual level or be subject-specific in nature, for example understanding subject-specific techniques. While the original and revised core taxonomy consist of single words, synonyms have been added on in order to further expand the meaning of the different cognitive domains. Examples of these synonyms have also been included in Table 2. In our analysis, we will work with both the keywords of the taxonomies, as well as with their synonyms.

Table 2
Original and revised Bloom taxonomy with synonyms.

	Bloom (1956)	Anderson and Krathwohl (2001)	Synonyms
High Order 1	Evaluation	Create	Designing, constructing, planning, inventing, devising, making
High Order 2	Synthesis	Evaluate	Checking, hypothesising, critiquing, experimenting, judging, testing, detecting, monitoring
Medium Order 1	Analysis	Analyse	Comparing, organising, deconstructing, attributing, outlining, finding, structuring, integrating
Medium Order 2	Application	Apply	Implementing, carrying out, using, executing
Low Order 1	Comprehension	Understand	Interpreting, summarising, inferring, paraphrasing, classifying, comparing, explaining, exemplifying
Low Order 2	Knowledge	Remember	Recognising, listing, describing, identifying, retrieving, naming, locating, finding

While widely used by educational psychologists, pedagogues and practitioners, one core critique of the Bloom taxonomies is that they are sequential and hierarchical – from Low to Medium to High – prompting the question how far these different levels of cognitive skills can be developed and taught in a parallel mode (Kreitzer & Madaus, 1994; Spencer, 2008). Soozandehfar and Adeli (2016) argue that different levels of proficiency can potentially occur within similar types of cognitive strategies. As an example, they discuss the difference between evaluating information at the novice versus expert level. While the original and revised Bloom taxonomies see evaluation as a Higher Order Thinking Skills, it might thus be possible that this type of skills represent more modest cognitive skill levels in PIAAC. Providing an answer to this question is a core aim of this paper.

4. Research procedures

To answer the first research question, a text-based content analysis has been undertaken on the descriptors of the PIAAC direct skills measurement levels, engaging in a qualitative enquiry (Atkinson & Coffey, 2004; Bowen, 2009; Rapley, 2007). The PIAAC's Reader Companion includes information on the concepts of literacy, numeracy and PS-TRE, as well as descriptors for the different cognitive measurement 'levels' (OECD, 2013). These range from Below Level 1–5 for literacy and numeracy, and from Below Level 1–3 for PS-TRE. These levels correspond to a range of 'points' earned through completion of cognitive skills tasks with more points referring to higher levels of cognitive skills. The analysis is thus able to reveal how far the OECD cognitive skill levels resembles the Bloom's hierarchical levels, distinguishing between Low, Medium and Higher Order Thinking Skills. The type of analysis conducted as part of this research is thus a 'directed' content analysis as it uses an existing theoretical framework – the Bloom taxonomy – as its starting point against which the text is being coded (Hsieh & Shannon, 2005).

Given the open access availability of the literacy, numeracy and PS-TRE definitions and descriptors in OECD's work, a qualitative text analysis has been chosen as a cost-effective and efficient investigation method (Bowen, 2009). Text analyses have been undertaken on the literacy, numeracy and PS-TRE descriptors through marking nouns and verbs present in the original and revised Bloom taxonomy, including its synonyms (see Table 2). The analyses have been undertaken manually, based on a pen and paper approach highlighting keywords on printed versions of the PIAAC descriptors with text markers in the first instance. The analysis was primarily conducted by the first author of the paper and has been double checked by the second author in order to enhance its reliability.

In the descriptor tables below, these Bloom keywords/synonyms (e.

g. use, understand, …) have been marks in **bold**. In accordance to information presented in Table 1, the labels HOT, MOT and LOT have been used to define between Bloom's High, Medium and Low Order Thinking. This information is being supplemented to the keywords in bold. Numbers 1 and 2 have been used as well, similarly to information in Table 2. Negatively worded instances have been labelled through NOT.

Taking into account the core criticism in relation to the hierarchical nature of the Bloom taxonomy, an additional layer of coding was included to indicate the complexity and familiarity of cognitive skills tasks in relation to the *life context* of the adults. Critics argue that cognitive strategies can be used in parallel to each other at varying levels of proficiency. To control for this aspect in the analyses, additional elements of complexity have been underlined in the text and are also part of the text-based analysis. This procedure fits with PIAACs focus on defining higher levels of proficiency as being able to complete tasks that include 'distracting information' which makes cognitive operations more complex (OECD, 2013).

To answer the second research question, scores of individual test items on literacy, numeracy and PS-TRE have been analysed according to their cognitive strategies. Information on these test items, their corresponding scores and cognitive strategies have been extracted from the PIAAC's Reader Companion and included into SPSS. Descriptive analyses have been undertaken on the items to reveal whether the distribution of scores on the diverse cognitive strategies represented a hierarchical or more parallel construct.

5. Results

5.1. Literacy

PIAAC's Survey of Adult Skills Reader Companion describes that adults need to undertake three types of cognitive strategies in responding to the literacy assessment component (OECD, 2013): (1) 'access and identify', (2) 'integrate and interpret' and (3) 'evaluate and reflect'. At first sight, linking these strategies back to the Bloom taxonomies, they seem to draw on High Order Thinking Skills, notably 'evaluate', Medium Order Thinking Skills such as being able to integrate information and Low Order Thinking Skills to be able to identify and locate information.

Within the assessment, adults are asked to undertake a range of literacy tasks. Each of these tasks refers to a specific difficulty score and relates to one of the three specific cognitive strategies mentioned above. The context of the tasks relates to education and training, personal, work-related or community-related contexts. Based on a combination of tasks, adults receive a final literacy score which can range from below 176 points for 'Below Level 1' to over 376 points for 'Level 5'.

Fig. 1 presents the three PIAAC cognitive strategies for literacy and indicates the proportion of items measuring a specific Proficiency Level. A total of 57 literacy test items were presented in the PIAAC Reader's Companion, 31 of which measured 'access and identify', 17 that measured 'integrate and interpret' and nine that measured 'evaluated and reflect. Access and Identify would be categorised in the Bloom taxonomies as a Lower Order Thinking Skill, however, a PIAAC task measuring this strategy has been designed at Level 4. Equally, test items measuring the cognitive strategy Evaluate & Reflect – seen as High Order Thinking Skill by Bloom – have been to reflect lower proficiency levels. While the Access and Identify strategy is more present among test items at the lower proficiency levels, it is clear that PIAAC skills strategies are more used in a parallel than hierarchical way.

Exploring the content of the literacy skill descriptors coded in Table 3 – from Below Level 1 to Level 5 –, it is clear that *'Below Level 1'* focuses on the cognitive strategy for adults to locate information in the text, which links back to 'Low Order Thinking 2' in the Bloom taxonomies. Furthermore, the descriptor of this level indicates that 'Low Order Thinking' skills in relation to understanding, or 'Medium Order Thinking' skills in using or applying information is *not* needed at this level. Exploring the words underlined in the descriptor, it is clear that the focus is on basic, non-complex tasks.

Low Order Thinking skills remain the focus of *'Level 1'*. Bloom's focus on 'knowledge' and the synonym of 'recognising' information are important here, combined with the information provided in the descriptor that this information remains from a basic and familiar level, without added levels of complexity.

This level of complexity slightly increases at *'Level 2'*. Adults need to be able to engage with inferences, defined as Lower Order Thinking 1, comparable to understanding and comprehension in the Bloom taxonomies, although at a low level. This indicates building further on the skill to 'remember' or 'locate information' in order to proceed onto understanding this information. The focus on the need to 'compare and contrast' different types of information moves the cognitive strategy to be applied away from simple 'understanding' to engaging in an analytical task, defined as 'analysis' or 'analyse' in the Bloom taxonomies, and thus a Medium Order Thinking skill.

The descriptor at *'Level 3'* contains many terms referring to Low Order Thinking Skills, but clearly states that the texts adults have to work with become longer, more complex and contain more information than needed to answer the questions. The respondent thus needs to engage in an analytical task to distinguish between competing levels of

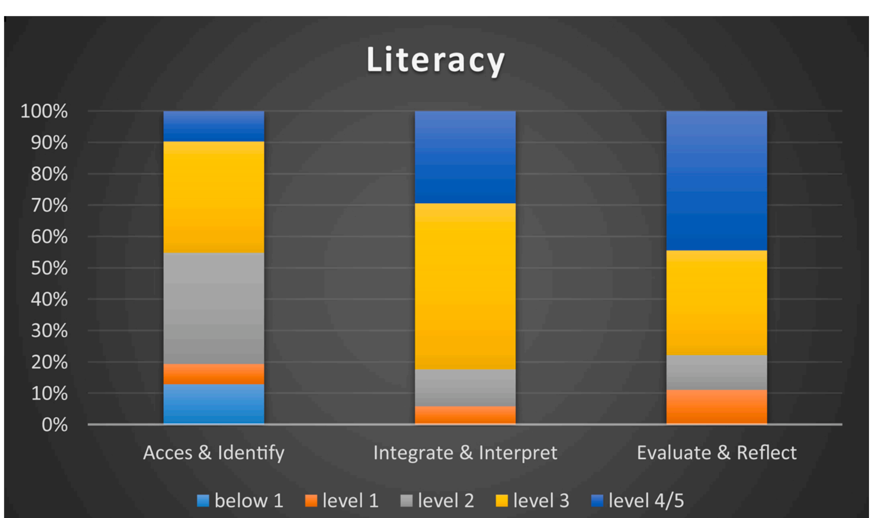

Fig. 1. Distribution of literacy test strategies by proficiency level.

Table 3
PIAAC literacy and numeracy descriptors by proficiency level.

	Literacy	Numeracy
Below level 1 Below 176 points	The tasks at this level require the respondent to read *brief* texts on *familiar* topics to **locate (LOT2)** a *single piece* of specific information. There is *seldom any competing information* in the text and the requested information is *identical* in form to information in the question or directive. The respondent may be required to **locate (LOT2)** information in *short continuous* texts. However, in this case, the information can be **located (LOT2)** as if the text was *non-continuous* in format. Only *basic* vocabulary knowledge is required, and the reader is *not required* to **understand (LOT1-NOT**) the structure of sentences or paragraphs or make **use (MOT2-NOT)** of other text features. Tasks below Level 1 do not make use of any features specific to digital texts.	Tasks at this level require the respondents to **carry out (MOT2)** *simple* processes such as counting, sorting, performing basic arithmetic operations with whole numbers or money, or **recognising (LOT2)** *common* spatial representations in *concrete, familiar* contexts where the mathematical content is *explicit* with little or no text or distractors.
Level 1 176 to less than 226 points	Most of the tasks at this level require the respondent to read *relatively short* digital or print *continuous, non-continuous, or mixed* texts to **locate (LOT2)** a *single piece* of information that is *identical* to or *synonymous* with the information given in the question or directive. Some tasks, such as those involving non-continuous texts, may require the respondent to enter personal information onto a document. *Little, if any, competing* information is present. Some tasks may require *simple* cycling through more than one piece of information. **Knowledge (LOT2)** and skill in **recognising (LOT2)** *basic* vocabulary determining the meaning of sentences, and reading paragraphs of text is expected.	Tasks at this level require the respondent to **carry out (MOT2)** *basic* mathematical processes in *common, concrete* contexts where the mathematical content is *explicit* with *little* text and *minimal* distractors. Tasks usually require *one-step or simple* processes involving counting; sorting; performing *basic* arithmetic operations; **understanding (LOT1)** *simple* percentages such as 50%; and **locating (LOT2)** and **identifying (LOT2)** elements of *simple or common* graphical or spatial representations.
Level 2 226 to less than 276 points	At this level, the medium of texts may be digital or printed, and texts may comprise *continuous, non-continuous, or mixed types* . Tasks at this level require respondents to *make matches* between the text and information, and may require **paraphrasing (LOT1)** or *low-level* **inferences (LOT1).** Some *competing* pieces of information may be present. Some tasks require the respondent to • cycle through or **integrate (MOT1)** two or more pieces of information based on criteria; • **compare (MOT1)** and *contrast* or reason about information requested in the question; or • navigate within digital texts to access-and-**identify (LOT2)** information from *various parts* of a document.	Tasks at this level require respondents to **identify (LOT2)** and act on mathematical information and ideas embedded in a range of *common* contexts where the mathematical content is fairly *explicit* or visual with relatively *few distractors*. Tasks tend to require the **application (MOT2)** of *two or more steps* or processes involving calculation with whole numbers and common decimals, percentages and fractions; *simple* measurement and spatial representation; estimation; and **interpretation (LOT1)** of relatively *simple* data and statistics in texts, tables and graphs.
Level 3 276 to less than 326 points	Texts at this level are often *dense or lengthy*, and include *continuous, non-continuous, mixed, or multiple pages* of text. **Understanding (LOT1)** text and rhetorical structures become more central to successfully completing tasks, especially navigating *complex* digital texts. Tasks require the respondent to **identify (LOT2), interpret (LOT1), or evaluate (HOT2)** one or more pieces of information, and often require *varying levels* of **inference (LOT1).** Many tasks require the respondent to construct meaning across larger chunks of text or perform *multi-step* operations in order to **identify (LOT2)** and formulate responses. Often tasks also demand that the respondent *disregard irrelevant or inappropriate* content to answer accurately. *Competing information* is often present, but it is not more prominent than the correct information.	Tasks at this level require the respondent to **understand (LOT1)** mathematical information that may be *less explicit*, embedded in contexts that are *not always familiar* and represented in more *complex* ways. Tasks require *several steps* and may involve the choice of problem-solving strategies and relevant processes. Tasks tend to require the **application (MOT2)** of number sense and spatial sense; **recognising (MOT2)** and working with mathematical relationships, patterns, and proportions expressed in verbal or numerical form; and **interpretation (LOT1)** and *basic* **analysis (MOT1)** of data and statistics in texts, tables and graphs.
Level 4 326 to less than 376 points	Tasks at this level often require respondents to perform *multiple-step* operations to **integrate (MOT1), interpret (LOT1), or synthesise (HOT1)** information from *complex or lengthy continuous, non-continuous, mixed, or multiple* type texts. *Complex* **inferences (LOT1)** and **application (MOT2)** of background **knowledge (LOT2)** may be needed to perform the task successfully. Many tasks require **identifying (LOT2)** and **understanding (LOT2)** one or more specific, non-central idea(s) in the text in order to **interpret (LOT1)** or **evaluate (HOT2)** subtle evidence-claim or persuasive discourse relationships. *Conditional* information is frequently present in tasks at this level and must be taken into consideration by the respondent. *Competing* information is present and sometimes seemingly as prominent as correct information.	Tasks at this level require the respondent to **understand (LOT1)** a *broad range* of mathematical information that may be *complex, abstract* or embedded in *unfamiliar* contexts. These tasks involve undertaking *multiple steps* and choosing relevant problem-solving strategies and processes. Tasks tend to require **analysis (MOT1)** and more *complex* reasoning about quantities and data; statistics and chance; spatial relationships; and change, proportions and formulas. Tasks at this level may also require **understanding (LOT1)** arguments or communicating well-reasoned explanations for answers or choices.
Level 5 Equal or higher than 376 points	At this level, tasks may require the respondent to search for and **integrate (MOT1)** information across *multiple, dense texts*; **construct syntheses (HOT1)** of *similar and contrasting* ideas or points of view; or **evaluate (HOT2)** evidence based arguments. **Application (MOT2)** and **evaluation (HOT2)** of logical and conceptual models of ideas may be required to accomplish tasks. **Evaluating (HOT2)**	Tasks at this level require the respondent to **understand (LOT1)** *complex* representations and abstract and formal mathematical and statistical ideas, possibly embedded in *complex* texts. Respondents may have to **integrate (MOT1)** *multiple* types of mathematical information where considerable translation or **interpretation (MOT1)** is required; draw **inferences**

(*continued on next page*)

Table 3 (*continued*)

	Literacy	Numeracy
	reliability of evidentiary sources and *selecting* key information is frequently a requirement. Tasks often require respondents to be aware of *subtle, rhetorical cues* and to make *high-level* **inferences (LOT1)** or **use (MOT2)** specialised background **knowledge (LOT2)**.	**(LOT1)**; develop or work with mathematical arguments or models; and justify, **evaluate (HOT2)** and *critically reflect* upon solutions or choices.

information, which refers to Medium Order Thinking skills in the Bloom taxonomies. The term 'evaluation' also gets mentioned here for the first time, labelled as the Highest Order Thinking skill in the original Bloom taxonomy. The OECD states that Level 3 should be achieved by all adults in order to survive in the knowledge-based economy. Knowing and understanding basic information is thus not enough. Adults need to be encouraged to engage in 'analytical thinking' and being able to 'compare and contrast' different pieces of information in a meaningful way, which they might understand separately, but not necessarily in relation to each other.

Keywords in the descriptor at *'Level 4'* combine Low, Medium and High Order Thinking skills. This indicates that the Lower Order Thinking Skills remain important, but that adults are expected to do more with them, like 'applying and evaluating' information, which are Medium and High Order Thinking skills according to Bloom. The level of tasks has now also clearly moved away from digesting a single piece of information towards a much longer and complex texts in which adults need to use their thinking skills in multiple steps in order to complete tasks. Building on a range of Low, Medium and High Order thinking skills is also the case at 'Level 5'. Adults operating at this level are not only able to 'locate and understand' information, but they are also proficient in 'applying and evaluating' long and complex texts. This makes them proficient across all cognitive domains as specified in the Bloom taxonomies.

5.2. Numeracy

Test tasks in relation to the PIAAC's numeracy assessment start from three underpinning cognitive strategies. These are 'identify, locate or access' (3 test items), 'act upon or use' (34 test items) and 'interpret, evaluate/analyse' (19 test items). Similar to the tasks in relation to numeracy, each of them is being linked to a difficulty score and a specific cognitive domain. Based on information in the PIAAC's Reader's Companion, and outlined in Fig. 2, it seems that most tasks fell in the cognitive skills strategy 'act upon or use' (34 out of 56 test items). From a Bloom's perspective, this would be labelled as a Medium Order Thinking Skill that relates to 'applying'. However, tasks referring to this cognitive domain broadly vary in their level of difficulty, ranging from 155 to 348 points. An even wider spread is visible for tasks underpinned by the cognitive strategy 'interpret, evaluate', which are terms used by Bloom as Medium and High Order Thinking Skills. A limited number of test items were used to measure 'identify, locate and access' and these referred to skills below Level 3, which is in accordance with Bloom's focus on Low Order Thinking Skills, and is thus an indication of hierarchical thinking. However, the other two cognitive strategies seem more designed as parallel constructs.

Looking into the specific Level descriptors for numeracy as coded in Table 2, it is clear that in relation to *'below Level 1'*, there is again use of words like 'simple' and 'familiar'. The focus is on being able to 'recognise' common numerical representations, which relates to the Low Order Thinking skill of 'remembering' and 'knowledge' in the Bloom taxonomies. While there is a focus on 'application' as a Medium Order Thinking skill as well, this is clearly mentioned in relation to its non-complex and simple level.

At *'Level 1'*, the focus remains on Low Order Thinking skills, such as 'recognising' knowledge and being able to 'identify' information. While application is being mentioned again through the words 'carry out', it is linked again to non-complex, basic and simple level. As such, Level 1 remains mostly at the cognitive domain drawing on Low Order Thinking skills as specified by Bloom.

At *'Level 2'*, the focus on Low Order Thinking skills is being uplifted through adding on the Medium Order Thinking skill of 'application', for which adults now need to be able to work with tasks that require multiple steps to be undertaken. The focus on application as a thinking skill higher than low order thinking skills like remembering and understanding, as evident in Bloom taxonomies starts coming through at this level.

Complexity of thinking also increases at *'Level 3'* as the context of the tasks become less familiar and less explicit, and thus requires extra 'analysis', 'application' and 'recognition' from the adult. These refer to cognitive skills which are situated at the Medium level in the Bloom taxonomies.

The range of mathematical information becomes even more complex and unfamiliar at *'Level 4'*, which keeps on combining cognitive skills strategies of Low and Medium level according to the Bloom taxonomies,

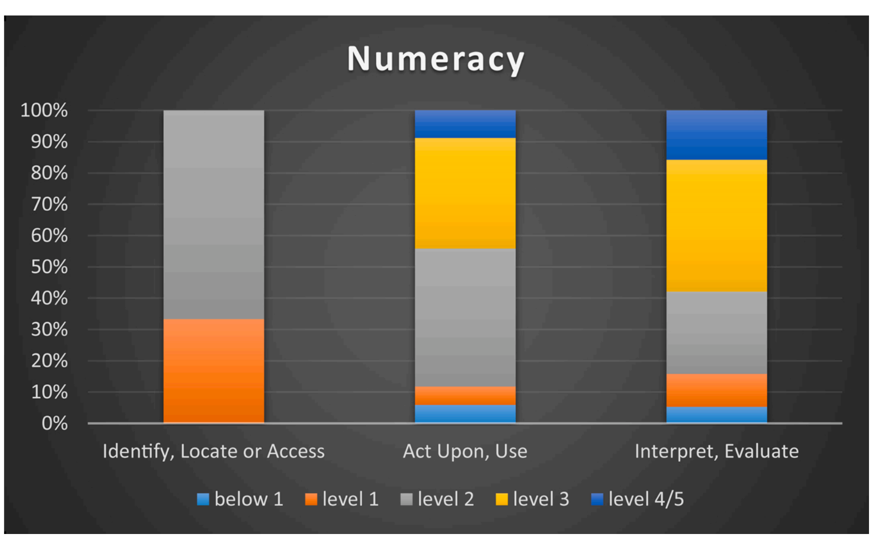

Fig. 2. Distribution of numeracy test strategies by proficiency level.

such as 'analysing' and 'understanding'.

The mentioning of High Order Thinking skills is clearly included in the descriptor of '*Level 5*', as it focusses on the need to 'evaluate' and critically justify solutions or choices made by the adult. This ability to engage in high order thinking skills builds further on a range of Low and Medium Order Thinking skills, including 'understanding', 'integrating' and making 'interpretations'. The ability to 'evaluate' information in order to reach solutions has clearly been defined as a High Order Thinking skill in the Bloom taxonomies.

5.3. Problem solving in technology rich environments

In contrast to literacy and numeracy, PS-TRE is expressed from 'Below Level 1' to 'Level 3'. Underlying cognitive strategies have been defined as 'setting goals and monitoring progress', 'selecting and evaluating information', 'organising and transforming information' and 'using information'. According to the PIAAC's Reader Companion, most tasks required the use of a combination of cognitive strategies (OECD, 2013). As can be seen from Fig. 3, these strategies represent a more parallel structure instead of a hierarchical one in the Bloom sense.

Analysing the descriptors (see Table 4), it is clear that at all levels, explanations start with sentences that include the word 'use', indicating some sort of application, a Medium Order Thinking skill according to the Bloom taxonomies. However, the complexity of application clearly differs. At *'Below level 1'*, other keywords in the descriptor include 'generic' and 'explicit', indicating the non-complex nature of tasks to be executed. This focus on the familiar non-complex nature of tasks is also clearly underlined at *'Level 1'*, with clear mentioning of 'no need' to deal with Medium Order Thinking skills such as 'contrasting' and 'integrating'. The more complex ability of 'applying' information becomes visible within the descriptive at '*Level 2*'. The need for 'integrating' and inferential thinking needs to be combined with the Higher Order Thinking skill of 'evaluating' information. Contexts become less familiar and there is a need to undertake multiple steps to achieve the desired outcome. Also at *'Level 3'*, the highest level in relation to PS-TRE, 'application' is from a more complex level. Adults operating at this level are able to 'integrate' different types of information, to make 'inferences' and to critically 'evaluate' this information. Evaluation skills are also being required to achieve the desired solution, which is also a High Order Thinking skill in the Bloom taxonomies.

6. Discussion and Conclusion

Having investigated PIAAC's cognitive skills descriptors and corresponding test items based on information available in the Survey of Adults Skills Reader's Companion, it became clear that the OECD defined a range of cognitive strategies adults need to use a range of cognitive strategies to successfully complete sets of tasks with varying levels of difficulties (OECD, 2013). From Figs. 1–3, it has become clear that tasks to be undertaken as part of the survey, drawing on these different cognitive strategies as presented in Table 1, widely varied in difficulty. In relation to literacy, low level tasks were more likely to lean on the 'access an identify' strategy (e.g. tasks accounting for 75 points), and in relation to numeracy, the most difficult task did *not* relate to 'identify, locate or access' (e.g. no tasks higher than 267 points). But otherwise, there seemed to be a strong mix between the highest scoring tasks and cognitive strategies. The highest scoring tasks in relation to PS-TRE (370 points) combined all four cognitive strategies. At first sight, reflecting on the Bloom taxonomies (see Anderson & Krathwohl, 2001; Bloom, 1956), it might feel confusing to have tasks that seem to draw upon typical high order level thinking skills, such as 'evaluating' to account for low to medium level proficiency scores. Having analysed and coded the specific skill level descriptors, it seems Low Order Thinking skills are indeed more common among the levels Below 1, 1 and 2, and that Medium and Higher Order Thinking skills are gradually being introduced. However, apart from the focus on the cognitive strategy, a major indicator of difficulty seems to arise at the level of the information provided to the respondent. At the lower literacy, numeracy and PS-TRE skill levels, terms used in the descriptor were 'common', 'familiar' and 'simple'. The reflection on the complexity level of information gradually changed into 'uncommon', 'non-familiar' and 'complex'. As such, being able to access and identify information in a text to measure literacy is not simply a matter of applying a Low Order Thinking skill, it is also a matter of being able to cope with the difficulty of the nature of the task. For example, 'recognising' – a Low Order Thinking skill – one's own name on a straightforward document will be easier for most people than to identify a difficult mathematical equation in a lengthy and unfamiliar text. This finding brings us back to the criticisms formulated towards the Bloom taxonomies, in which cognitive skills are seen as hierarchical and building on each other, instead of being used parallel to each other (Kreitzer and Madaus, 1994; Spencer, 2008). In PIAAC, it seems cognitive strategies are more likely to be used parallel to each other.

PIAACs focus on complexity seems an important one. In order to be successful in the knowledge-intensive 21st Century, it is not enough for adults to be able to understand basic information that applies to their own familiar context. It is important that they are able to transfer their knowledge and understanding of certain aspects in relation to literacy,

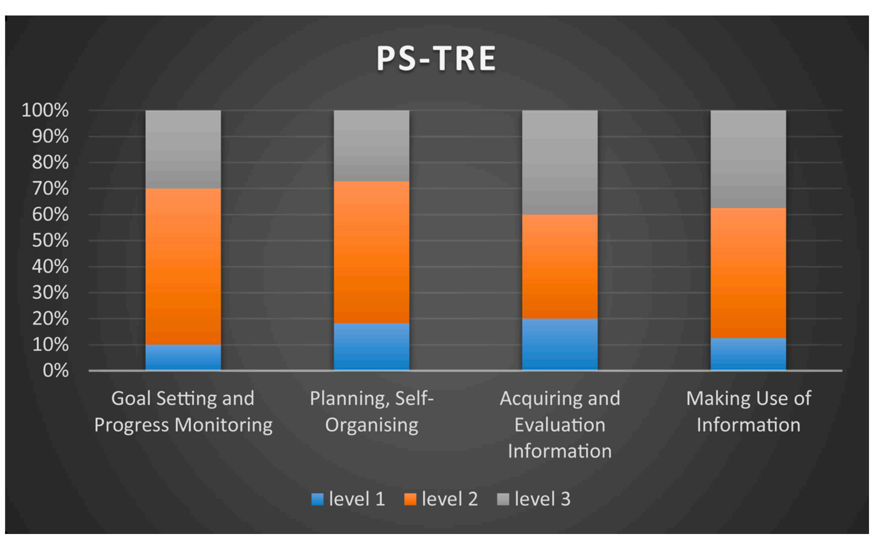

Fig. 3. Distribution of PS-TRE test strategies by proficiency level.

Table 4
PIAAC PS-TRE descriptors by proficiency level.

Below level 1 Below 241 points	Tasks are based on *well-defined* problems involving the **use (MOT2)** of only one function within a generic interface to meet *one explicit* criterion without any categorical, **inferential (LOT2)** reasoning or transforming of information. *Few steps* are required and *no sub goal* has to be generated.
Level 1 241 to less than 291 points	At this level, tasks typically require the **use (MOT2)** of *widely available* and *familiar* technology applications, such as e-mail software or a web browser. There is *little or no* navigation required to access the information or commands required to solve the problem. The problem may be solved regardless of the respondent's awareness and **use (MOT2)** of specific tools and functions (e.g. a sort function). The tasks involve *few steps* and a *minimal* number of operators. At the cognitive level, the respondent can readily **infer (LOT2)** the goal from the task statement; problem resolution requires the respondent to **apply (MOT2)** *explicit* criteria; and there are *few monitoring* demands (e.g. the respondent does not have to check whether he or she has used the appropriate procedure or made progress towards the solution). **Identifying (LOT2)** contents and operators can be done through *simple* match. Only *simple* forms of reasoning, such as assigning items to categories, are required; there is *no need* to **contrast (MOT1-NOT)** or **integrate (MOT1-NOT)** information.
Level 2 291 to less than 341 points	At this level, tasks typically require the **use (MOT2)** of both *generic* and more *specific* technology applications. For instance, the respondent may have to **make use (MOT2)** of a novel online form. Some navigation *across* pages and **applications (MOT2)** is required to solve the problem. The **use (MOT2)** of tools (e.g. a sort function) can facilitate the resolution of the problem. The task may involve *multiple* steps and operators. The goal of the problem may have to be defined by the respondent, though the criteria to be met are *explicit*. There are *higher* monitoring demands. Some *unexpected* outcomes or impasses may appear. The task may require **evaluating (HOT2)** the relevance of a set of items to discard distractors. Some **integration (MOT1)** and **inferential (LOT1)** reasoning may be needed.
Level 3 Equal to or higher than 341 points	At this level, tasks typically require the **use (MOT2)** of both *generic* and more *specific* technology applications. Some navigation *across* pages and **applications (MOT2)** is required to solve the problem. The **use (MOT2)** of tools (e.g. a sort function) is required to make progress towards the solution. The task may involve *multiple* steps and operators. The goal of the problem may have to be defined by the respondent, and the criteria to be met *may or may not be explicit*. There are typically *high* monitoring demands. *Unexpected* outcomes and impasses are likely to occur. The task may require **evaluating (HOT2)** the relevance and reliability of information in order to *discard distractors*. **Integration (MOT1)** and **inferential (LOT1)** reasoning may be needed to a *large extent*.

numeracy and PS-TRE towards other non-familiar contexts. This reasoning relates to the idea that in a rapidly changing society, it is important to develop transferrable skills that can be used in a variety of contexts on top of task specific skills in one specific setting (Hanushek & Woessman, 2015).

The results of this directed content text-based analysis have indicated that PIAAC's descriptors of cognitive skills somehow resembles the hierarchy in keywords as present in the Bloom's taxonomy. This is our answer to Research Question 1. However, tasks underpinning the different proficiency levels combine different cognitive strategies at varying non-hierarchical levels of difficulty. This result, and the answer to Research Question 2, indicates that the OECD's conceptualisation does not tend to be in line with Bloom's thinking. In their view, in order to develop a highly skilled population, it will be important to start teaching skills using simple familiar examples to people lives contexts, and to gradually let them apply and analyse these skills into more complex and less familiar contexts. These insights are useful to further understand the differences in conceptualisation of cognitive skills, as highlighted as one of the objectives of our study above. The limitation of this study is that is has been undertaken as a text-based analysis only. Future research in unpacking the conceptualisation of skills and its measurement could be supplemented by in-depth interviews with test developers and members of the OECD working groups who designed the conceptual frameworks for PIAAC. Referring to another objective of this paper, this is also intended to help policy makers and practitioners across the world to enhance the skills development of the wider population. As pointed out above, this is important to keep pace of the rapidly changing knowledge economy.

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