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Socio-demographic and practice-oriented factors related to problem solving skills: A lifelong learning perspective

Abstract
This article explores the relative importance of different socio-demographic and practice-oriented factors that are related to proficiency in Problem Solving in Technology-Rich Environments (PSTRE) and by extension may be related to Complex Problem Solving (CPS). The empirical analysis focuses on the proficiency measurements of PSTRE made available by the Programme for the International Assessment of Adult Competencies (PIAAC), which may be relevant for gaining insight on some of the factors related to CPS. The purpose is to examine the relationship between the broad information processing experience that individuals gather in different contexts over the lifespan, and the chances to develop problem solving skills that adults receive in different socio-demographic profiles. Results reveal that socio-demographic factors such as age, education and immigration status as well as practice-oriented factors such as ICT use and reading practice at and outside work are strongly related to proficiency.

Keywords
Problem solving skills, PIAAC, skill formation, skill development, practice engagement theory

Introduction

It is widely recognized that continuing innovations and advances in the information and communications technology sector are, in combination with other technological developments, transforming modern societies and increasing the demand for skills that enable persons to change, to adapt to such innovations, and to integrate computers and other information communications technologies (ICTs) related tools into their daily lives and work. ICTs have become increasingly important as these continue to pervasively impact not only production and occupational structures pertaining to the world of work, but also modes of the provision of public and other services and consumption pertaining to the everyday lives of children, youths, and adults of all ages (OECD, 2013a). Such developments may demand higher individual proficiency to solve problems related to technology such as in the context of computers or the Internet (Autor & Price, 2013; Levy, 2010). The growing use and spread of ICTs relative to other technologies make it important to develop a broader understanding of the factors related to the formation of problem solving skills in technology-rich environments. Not least, the socio-demographic distribution of these skills and opportunities to develop and practice them is likely to have an increasing importance on the extent and distribution of a diverse range of economic and social outcomes.

This article explores the relative importance of different socio-demographic and practice-oriented factors that may affect individual proficiency in Problem Solving in Technology-Rich Environments (PSTRE). On the extent that such factors are related to PSTRE they may also be related to problem solving more generally. Further, on the extent that PSTRE and Complex Problem Solving (CPS) (a core focus of this special issue) are both related to problem solving, the findings also help to provide some insight on the broader factors that may be related to CPS. The first part of the article provides a brief overview of the link between the concepts of PSTRE as measured in PIAAC (the Programme for the International Assessment of Adult Competencies) and CPS. This is followed by a brief overview of the 2013 PIAAC (alternatively known as 2013 OECD Survey of Adult Skills) results for PSTRE, focusing on the extent of proficiency among adults in 18 countries. The PIAAC data

contain a direct measure of PSTRE proficiency along with a comprehensive set of background information. This allows for a unique exploration of a wide range of factors, which are plausibly linked to the development and maintenance of PSTRE. A multivariate analysis based on logistic regression is then presented to examine the relative importance of different socio-demographic and practice-oriented factors that may affect proficiency in PSTRE. Particular emphasis is placed on a variety of learning opportunities that an individual may experience in multiple contexts throughout a lifespan. This highlights the relationship between the broad information processing experience that individuals gather in different contexts over the lifespan, and the chances that adults with different socio-demographic profiles receive to develop problem solving skills over their lifespan.

The link between problem solving in technology-rich environments (PSTRE) and complex problem solving (CPS)

At their most basic, problems typically involve a situation in which a person cannot readily or routinely achieve a goal because of some obstacle or difficulty. One's ability to overcome or solve these difficulties involves complex and sophisticated human cognition (Newell & Simon, 1972). To solve a problem, one has to become aware of the problem and understand the problem ('problem finding'). Typically, individuals then have to engage in thinking and action so as to define sub goals and steps in which the problem can be tackled ('planning'). This is followed by action to reach sub goals and ultimately to solve the problem. Individuals usually monitor their progress and often must reconsider their understanding, sub goals and actions to resolve difficulties. The concepts of PSTRE and CPS both share elements of these core aspects to problem solving.

In PIAAC, PSTRE is defined as:

> "…using digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks. The first PIAAC problem-solving survey focuses on the abilities to solve problems for personal, work and civic purposes by setting up appropriate goals and plans, and accessing and making use of information through computers and computer networks." (OECD, 2012, p. 47)

As in CPS situations, PSTRE in PIAAC emphasizes the above mentioned cognitive dimensions which involve the mental structures and processes by which a person solves a problem. However, in PSTRE the context in which problems are situated and thus the type of problems addressed are much narrower since special emphasis is placed on the 'technology-rich' and 'information-rich' dimensions. In PIAAC, the focus is on the digital technologies through which problem solving is conducted including hardware devices (PSTRE in PIAAC is administered via a laptop), applications (simulated software) and functionalities (commands and functions, and representations such as text, graphics, etc.). By extension, the focus is also on 'information-rich' problems since digital technologies are primarily aimed at storing, processing, representing, and communicating symbolic information.

In both the PSTRE and CPS contexts, important elements of cognitive functioning relating to *fluid intelligence* or *cognitive mechanics* and *crystallized intelligence* or *cognitive pragmatics* can play an important role. The former refers to cognitive functioning such as attentional capacity, processing speed, reasoning, working memory capacity, and spatial ability, or alternatively the ability to learn or understand things independent of prior knowledge. The latter refers to cognitive functioning such as knowledge, skills and wisdom, or alternatively abilities that are acquired or learned through practice, repetition and social experiences (Cattell, 1971; Baltes, 1993). For example, in the stages of 'knowledge acquisition' and 'knowledge application' that are integral to CPS (Fischer et al., 2012), performance can be improved by a methodical, systematic and disciplined approach. This performance depends not only on so called Cattel-Horn-Carroll (CHC) type levels of cognitive strength that relate to *fluid reasoning* (see McGrew, 2009), but also non-CHC type levels of

personality traits such as discipline, ambition or perseverance, or other forms of *crystallized intelligence* or *cognitive pragmatics*. It may therefore be possible that CPS includes an element of learned or acquired cognitive strength resulting from those personality or social environments. The same could be said for the problem 'finding', 'planning' and 'solving' aspects relating to PSTRE.

Prior experience and knowledge may therefore be equally important in both the PSTRE and CPS contexts. With this as a backdrop, defining and studying problem solving can be seen to have followed three distinct branches (for a description of these branches, see Buchner, 1995). The North American branch (founded by Herbert A. Simon) focuses on problem solving as a process of building domain expertise. In Great Britain, the English branch focuses more on the mathematical and logical relationships to be discovered in problem solving processes (established by Donald Broadbent). The German branch (established by Dietrich Dörner) encompasses the interplay of the cognitive, motivational, and social components of problem solving processes. The perspective in this article, exploits the broader conceptualization of problem solving, which Dörner created, so as to acknowledge other factors that may affect problem solving, such as personality, experience over the individual life course, as well as societal aspects. Specifically, socio-demographic and practice-oriented conditions are seen as important factors related to the formation of problem solving skills.

Indeed, research on CPS has typically sought to understand the interplay among cognitive, motivational, personal, and social factors when complex, novel, dynamic, non-transparent tasks are solved. Often, the 'problem solving' is viewed as the interaction between three components: the problem solver, the task, and the environment (Frensch & Funke, 1995). This line of research has led to a number of factors being thought to affect or predict CPS performance, which are in varying degrees supported in both theoretical and empirical terms (Frensch & Funke, 1995; Wenke et al., 2005). These include *external factors* and *internal subject factors*.

The *external factors* relate to:

- problem structure (i.e. the structure, complexity, and transparency of the task) (Funke, 1995)
- problem context (i.e. the semantic embeddedness of a task, and whether or not the task is couched within a well-understood and familiar context) (Huber, 1995)
- environmental factors (i.e. the environment within which a solver operates, resources available for problem solving, feedback and feedback delay, expectations, cooperation, peer pressure, disturbances) (Brehmer, 1995).

The *internal subject factors* relate to:

- experience affecting the likelihood of successful problem solving and choice of strategies employed to solve problems (Krems, 1995; Süß, 1996)
- cognitive variables (i.e. background knowledge, monitoring and evaluation strategies, cognitive style, and general intelligence) (Beckmann & Guthke, 1995; Berry & Broadbent, 1995)
- domain-specific declarative knowledge and intelligence, especially reasoning (e.g. Funke, 1992; Funke & Frensch, 2007)
- implicit knowledge (e.g. Berry, 1991; Berry & Broadbent, 1995; Buchner et al., 1995) defined as performance advantages in the accomplishment of cognitive requirements, which are based on an unconscious use of previously perceived and unintentionally stored information (Meyer & Scholl, 2009)
- non-cognitive variables of personality and social factors such as self-confidence, perseverance, motivation, enjoyment (Dörner & Wearing, 1995).

However, much of the CPS related research from this perspective has emphasized the immediate environment or 'situation' and the social factors involved within this 'situation'. In contrast, the research enabled by the empirical evidence from the PIAAC data on PSTRE takes this further, to include the wider social and cultural factors or personal life histories that situate an individual within a particular situation.

PIAAC

The dataset

The following empirical analysis makes use of the 2013 PIAAC (alternatively known as the 2013 OECD Survey of Adult Skills) data, which were collected in a comparative manner across several OECD countries in 2012. See OECD (2013a; 2013b) for a detailed description of PIAAC, the methodology used and results. In brief, PIAAC is a large-scale co-operative effort undertaken by governments, national statistics agencies, research institutions and multi-lateral agencies. It is an international comparative assessment of key information processing skills that also collected comparable background information such as socio-demographic and practice-oriented factors related to skill use and skill formation. It is based on a unique combination of household survey methodologies (as in the case of Labour Force Surveys) and direct skill assessment methods. For each country that participated, large scale representative samples of adults aged 16 to 65 were drawn, and face to face interviews were conducted (for approximately 40 minutes) to collect information for the Background Questionnaire (BQ) before administering a test (approximately one hour in duration) to respondents.

The PSTRE proficiency measure

Also see OECD (2009; 2012) for a detailed description of how the PSTRE assessment framework was defined. The assessment framework, items and methods to derive a PSTRE scale were developed by an international team of experts in problem solving (OECD, 2012). A sample of items was administered to respondents in their home using a laptop. Two example test items were made available in OECD (2012, p. 53-55). Items were later scored as correct or incorrect and scaled using Item Response Theory (IRT) producing a score ranging from 0 to 500. Adults who did not have any experience using a computer or did not pass a core set of questions assessing basic knowledge of computers were not administered any PSTRE items and thus did not receive a PSTRE score. A discrete proficiency scale was defined which combined those that did not receive a score, as well as the proficiency levels corresponding to distinct intervals of proficiency scores spanning the 0 to 500 scale as follows (for more details, see OECD, 2013a):

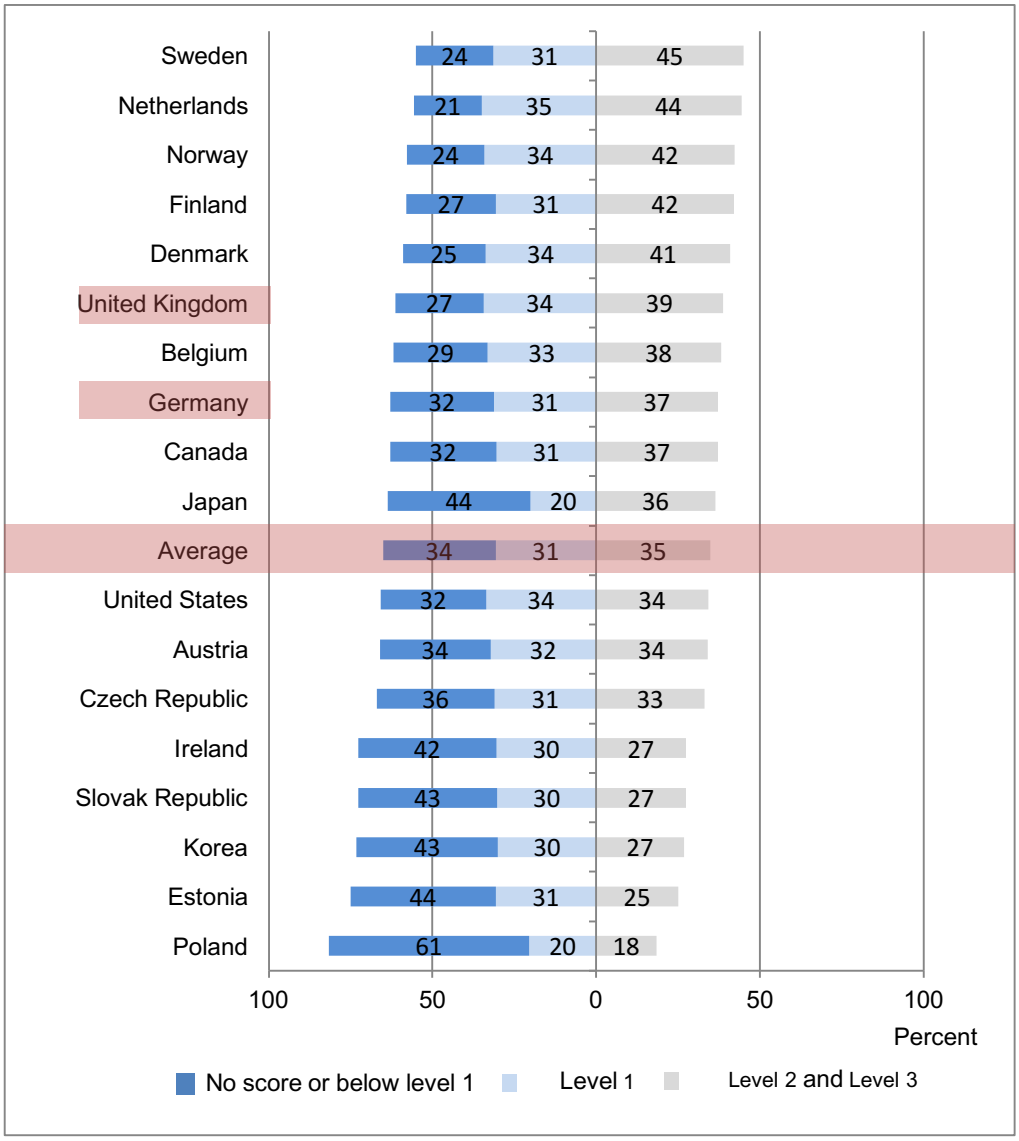
- No score – adults who did not have any experience using computers or did not pass a core set of questions assessing basic knowledge of computers (e.g. pointing and clicking using a mouse) did not receive a score. Separately, adults with language difficulties, or learning or mental disabilities (referred to as literacy-related non-response), and those who experienced technical problems with the computer used for the survey did not receive a score. A number of adults also opted out of the Computer Based Assessment (CBA) because they did not feel comfortable or want to do it. Analyses performed by the Educational Testing Service suggested that while most persons who opted out of the CBA had some experience with computers, it was limited, indicating a possibly very low level of proficiency.
- Below Level 1 – adults scoring at this level are only likely to be able to solve computer-related problems at the most rudimentary level. Few steps are required and they involve no inferential reasoning, or transforming of information.
- Level 1 – adults scoring at this level are able to use widely available and familiar technology applications such as email software or a web browser. PSTRE tasks at this level only require simple forms of reasoning such as assigning items to categories. There is no need to contrast or integrate information.

- Level 2 – adults scoring at this level can use generic and more specific technology applications. PSTRE tasks at this level involve multiple steps and require inferential reasoning. Distractors may be present and the contrasting and integration of information may be required.
- Level 3 – adults scoring at this level can use similar technologies as those at Level 2, and they can perform similar tasks as those at Level 2 but at a more advanced level. That is, steps can be more numerous and complicated and there can be unexpected outcomes.

The extent of proficiency in PSTRE across OECD countries

The distribution of PSTRE skills by level of proficiency among the 18 countries in PIAAC that fielded the PSTRE domain are reported in OECD (2013, p. 87) for adults aged 16 to 65. Similar, results are reported here in Figure 1 but for the adult population aged 25 to 65 who were employed during the 12 months preceding the survey. This exclusion is done so that practices at work and at home can be compared in the analysis to be presented below, and also to exclude most students still in their initial cycle of studies or in transition to the labour market.

Figure 1. Percent of adults aged 25 to 65 who were employed during the 12 months preceding the survey at each level of proficiency on the PSTRE scale



Source: Own calculations based on 2013 OECD Survey of Adult Skills database.
Note: Adults who opted of the CBA are included in the 'no score or below Level 1' category.

Very few adults scored at Level 3 ranging from about 3-8% depending on the country, so results are combined for Levels 2 and 3. Additionally, many adults received no score for a variety of reasons (i.e. opted out of the computer based assessment, had no computer experience, or failed the ICT core test) as mentioned above. Receiving no score or scoring below Level 1 is combined in Figure 1, since these individuals are likely to reflect very low levels of proficiency.

The most revealing finding that can be distilled from Figure 1 is that only a minority of employed adults aged 25 to 65 attain Levels 2 or 3 on the PSTRE scale, ranging from a high of 45% in Sweden to a low of 18% in Poland. Those remaining received either no score for a variety of reasons or they scored at or below Level 1. On average across all of these countries, about a third received no score or scored below Level 1, a third scored at Level 1, and the remaining third scored at Level 2 or above. The Nordic countries along with the Netherlands display the highest proportion of working adults with proficiency at Levels 2 or 3. The UK (England and Northern Ireland only) follow along with Belgium (Flanders only), Germany, Canada and Japan, all displaying a greater proportion at Levels 2 or 3 than the 35% average across countries. The proportion of US employed adults scoring at Levels 2 or 3 is just below the average at 34%.

Results for Finland, Germany, Norway and the UK are highlighted in Figure 1 since these countries are used as examples to examine the socio-demographic and practice-oriented factors related to attaining proficiency Levels 2 or 3 on the PSTRE scale. These countries were chosen to reflect three distinct types of political economies which are thought to be related to the formation of human capital: socio democratic (Finland and Norway), conservative (Germany) and market liberal (UK) (see Iversen & Stephens, 2008).

Socio-demographic and practice-oriented factors related to proficiency in PSTRE

As discussed above, while the CPS research literature has mostly focused on understanding the situated cognition of individuals as they attempt to solve problems, the PIAAC data allows a focus on the question of who has opportunities to practice and develop problem solving in different situations and over the lifespan. In this sense, socio-demographic characteristics are seen as potentially important factors that influence the PSTRE proficiency of adults by affecting the opportunity of adults to practice and develop PSTRE. The focus of the analysis is on identifying who at the population level is likely to display lower and higher levels of proficiency in PSTRE. In so doing, the analysis focuses on socio-demographic and practice-oriented factors. Thus the focus is on the problem solver, the opportunity structure of different groups of problem solvers, and on their experiences in different contexts that might be relevant to developing PSTRE proficiency. PSTRE is a particularly important skill because it can help adults to process information and accumulate knowledge via continued learning over a lifespan (OECD, 2009), and thus it may play a pivotal role in realizing life chances and further developing skills.

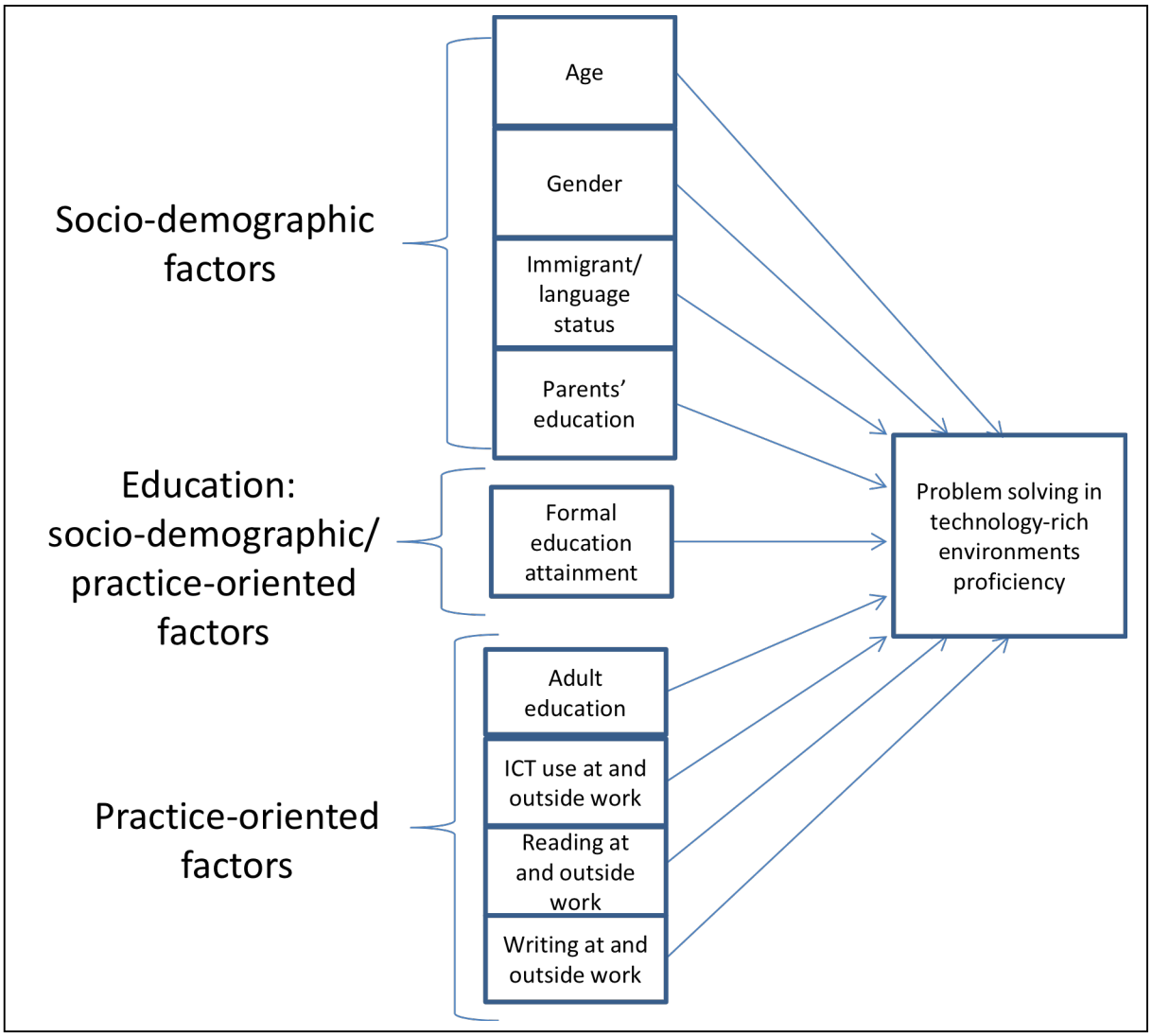
The PIAAC database is advantageous from this latter perspective because it allows for a broad perspective of the interplay between socio-demographic and practice oriented factors and PSTRE proficiency at the population level. In particular, the representative nature of the data at the population level reduces selection biases associated with studying particular groups or settings such as workers in specific industries or 'situations'. By extension, this permits a broad perspective of different life experiences vis-à-vis information processing skills such as those relevant to problem solving in the context of technology-rich environments. Moreover, the advantage of PIAAC is that the information it provides is comparable across a diverse range of countries.

The model

Figure 2 summarizes a multivariate model, which presumes a causal structure that may underlay PSTRE proficiency. The purpose of the model is to disentangle the influences of various factors and to estimate the relative importance of different factors, which may contribute to the development of PSTRE proficiency. In so doing, causal directions among the factors are hypothesized. These are merely hypotheses advanced on the basis of theory and previous research that are discussed when presenting the results. The findings do not in themselves prove or disprove the hypotheses, but provide reasonable support for or against the potential role of different factors.

The model first considers socio-demographic factors that are not influenced or changeable such as the parents' education level, immigrant and language status, and age, whereby these factors can significantly affect learning experiences, attitudes, behaviours, opportunities, and choices. These are labelled as 'socio-demographic' factors. Next, education is considered, which has a clearly dual status as both a socio-demographic and practice-oriented factor. It is a socio-demographic marker since it is often fixed at an earlier stage of life and influences a wide range of subsequent life experiences, yet it is also practice-oriented since it is directly involved in the development of information processing skills and in turn PSTRE related skills such as ICT and problem solving skills. A set of practice-oriented factors occurring at or outside work are considered next. These implicitly occur at a later time and thus differ distinctly from the (fixed) socio-demographic factors. These behaviours are potentially recurrent over the lifespan of individuals as they can occur on a daily, weekly or monthly basis, or not at all. It is important to note, however, that because PIAAC is a cross-sectional survey, some of the inherent reciprocal and dynamic relationships among the factors considered cannot be taken into account. For example, the cumulative effect of continued learning in adulthood on PSTRE proficiency cannot be accounted for, perhaps leading to an underestimation of the relative effect of the job and other literacy related factors occurring in adulthood.

Figure 2. Simple model depicting socio-demographic and practice-oriented factors hypothesized to have an impact on the development of problem solving proficiency (in technology-rich environments)



Source: Authors.

Descriptive statistics for socio-demographic and practice-oriented factors included in the model

Table 1 outlines all of the independent variables included in the analysis including gender, age, immigrant and language status, parents' education, formal education attainment, participation in adult education in last 12 months, ICT use at work, ICT use outside work, reading at work and reading outside work. The ICT use and reading at and outside work variables are based on more than one question from the background questionnaire and were combined into an index using Item Response Theory (IRT). The method and results for deriving these scales are described in more detail in OECD (2013b). Additionally, low use refers to the bottom third of the distribution of the index, while medium-low and medium-high use refer to the middle third of the distribution and high use refers to the top third of the distribution. Those who never used ICTs or never read are combined with the 'low use' category. The proportion of adults aged 25-65 who score at either Level 1 or below, or Level 2 or above is provided in Table 1 for each category of each independent variable. The sample sizes for each country after the above mentioned exclusions are also provided.

Table 1. Percent of adults at high (Level 2/3) and low levels (Level 1 or below or no score) of proficiency on the PSTRE scale, by various socio-demographic and practice-oriented categories

	Finland		Germany		Norway		UK	
	Level 1 or below or no score	Level 2/3	Level 1 or below or no score	Level 2/3	Level 1 or below or no score	Level 2/3	Level 1 or below or no score	Level 2/3
Age								
25-34	30	69	42	55	38	59	45	53
35-44	42	55	50	31	44	51	54	43
45-54	58	32	64	29	59	36	62	32
55-65	68	12	73	19	69	17	65	25
Gender								
Women	50	42	60	33	54	39	59	36
Men	49	43	54	41	49	45	55	41
Immigration/language status								
Native-born/native language	48	43	54	41	49	45	55	40
Native-born/foreign language	45	51	69	24	39	55	62	34
Foreign-born/foreign language	66	18	77	13	68	25	67	27
Parents' education								
Less than upper secondary	61	25	80	9	64	23	75	18
Upper secondary	43	52	59	36	53	42	50	47
Higher than upper secondary	33	66	44	52	38	60	37	61
Education								
Less than upper secondary	67	13	76	11	68	16	78	13
Upper secondary	57	31	65	29	59	34	63	33
Professional degree	51	43	49	46	49	48	60	36
BA, MA, research degree	31	68	37	61	37	61	34	65
Adult education participation								
Yes	46	48	49	47	48	49	51	46
No	59	26	68	24	60	27	68	26
ICT use at work								
Low or no use	62	15	74	13	67	14	79	11
Medium-low use	60	30	67	30	64	26	72	23
Medium-high use	50	47	49	48	55	43	59	39
High use	33	65	36	63	36	63	36	63
ICT use at home								
Low or no use	62	14	68	15	65	13	75	15
Medium-low use	56	37	61	37	60	35	58	38
Medium-high use	45	53	50	49	49	48	48	50
High use	34	64	40	60	40	58	40	59
Reading at work								
Low or no use	60	25	72	17	64	22	72	20
Medium-low use	51	40	58	38	56	37	55	41
Medium-high use	45	48	46	50	48	48	50	48
High use	44	52	46	51	45	53	46	52
Reading at home								
Low or no use	65	17	75	15	64	19	72	19
Medium-low use	56	35	57	36	59	34	60	35
Medium-high use	44	49	51	34	50	45	52	46
High use	42	53	49	48	45	51	47	50
Sample size	3468		3459		3332		5407	

Source: Own calculations based on 2013 OECD Survey of Adult Skills database.

Note: Adults who opted out of the CBA are not included in the category 'Level 1 or below or no score'. Thus columns 'Level 1 or below or no score' and 'Level 2/3' do not sum to 100% - the difference reflects those who opted out of the CBA.

Empirical results of the relationship between socio-demographic and practice-oriented factors and proficiency in PSTRE

Logistic regression was used to estimate the odds of adults aged 25 to 65 scoring at Levels 2 or 3 on the PSTRE scale. The dependent variable is a dichotomous variable indicating whether an individual has scored at Level 2 or 3, or not. The purpose is to find a reasonable model to describe the relationship between scoring at higher levels on the PSTRE scale and a set of socio-demographic characteristics and practice-oriented behaviours (as outlined above). The parameters that are estimated are a logit transformation of the probability of scoring higher, which maximize the likelihood of observing higher scores at Level 2 or 3. Table 2 outlines the empirical results of the model by reporting the odds ratios. Odds ratios greater than one reflect greater chances of an event occurring (i.e. scoring at Level 2 or 3) for a particular group relative to the reference group, while those with a value of less one reflect lower chances (Hosmer & Lemeshow, 1989). Results are based on a block entry model that excluded variables with high multicollinearity. For example, writing practices were excluded due to high collinearity with reading practices.

Table 2. Odds ratios showing the likelihood of scoring at Level 2/3 on the PSTRE scale, by various socio-demographic and practice-oriented factors

	Finland		Germany		Norway		UK	
	Odds ratio	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value
Age								
25-34	13.4	***	5.2	***	8.4	***	3.2	***
35-44	7.8	***	3.7	***	5.1	***	2.4	***
45-54	3.1	***	1.7	***	2.9	***	1.9	***
55-65 (reference)	1.0		1.0		1.0		1.0	
Gender								
Women	0.9		0.7	***	0.7	***	0.6	***
Men (reference)	1.0		1.0		1.0		1.0	
Immigration/language status								
Native-born/native language	6.0	**	3.8	***	4.0	***	2.8	***
Native-born/foreign language	5.6	**	2.6	**	3.3	**	1.0	
Foreign-born/foreign language (reference)	1.0		1.0		1.0		1.0	
Parents' education								
Less than upper secondary (reference)	1.0		1.0		1.0		1.0	
Upper secondary	1.5	***	2.6	***	1.3	*	2.2	***
Higher than upper secondary	2.0	***	3.0	***	1.7	***	2.4	***
Education								
Less than upper secondary (reference)	1.0		1.0		1.0		1.0	
Upper secondary	1.3		1.2		1.8	**	1.9	***
Professional degree	2.5	***	1.8	*	2.6	***	1.2	
BA, MA, research degree	3.3	***	2.6	***	3.5	***	3.4	***
Adult education participation								
Yes	1.0		1.2		1.3	*	1.4	**
No (reference)	1.0		1.0		1.0		1.0	
ICT use at work								
Low or no use (reference)	1.0		1.0		1.0		1.0	
Medium-low use	1.4		1.4	*	1.6	**	1.8	**
Medium-high use	2.5	***	2.3	***	2.6	***	3.0	***
High use	5.1	***	3.7	***	5.3	***	5.8	***
ICT use at home								
Low or no use (reference)	1.0		1.0		1.0		1.0	
Medium-low use	1.7	***	1.6	***	1.8	***	2.4	***
Medium-high use	2.1	***	1.9	***	2.1	***	2.7	***
High use	2.7	***	2.5	***	2.4	***	2.8	***
Reading at work								
Low or no use (reference)	1.0		1.0		1.0		1.0	
Medium-low use	1.0		1.1		1.0		1.1	
Medium-high use	0.8		1.1		0.9		0.9	
High use	0.6	**	0.8		0.7		0.7	*
Reading at home								
Low or no use (reference)	1.0		1.0		1.0		1.0	
Medium-low use	1.4	*	2.1	***	1.0		1.2	
Medium-high use	2.0	***	2.1	***	1.4		1.9	***
High use	2.1	***	1.9	***	1.4	*	1.4	*

Source: Own calculations based on 2013 OECD Survey of Adult Skills database.
Notes: *$p < .05$, **$p < .01$, ***$p < .001$. Adults who opted out of the CBA are excluded from the analysis.

Discussion of results

As can be seen from Table 2, with the exception of gender, socio-demographic characteristics display a strong relationship to PSTRE proficiency.

There are no strong theoretical expectations regarding the possible impact of gender on PSTRE proficiency, except perhaps on the extent to which attitudes to digital technologies vary by gender. Girls and women have in the past been found to be less interested in computers and technology than boys and men (see Shashaani, 1997). Empirical evidence now suggests that gender differences in computer use, skills, and attitudes have in many respects narrowed, particularly among younger cohorts (see United States Census Bureau, 2013; Eurostat, 2013). Nevertheless, results in Table 2 suggest that gender differences in PSTRE proficiency do exist in Germany and the UK. Discrimination or gender selection into systematically different occupations may thus continue to have an impact through practice-oriented effects in some countries.

Not surprisingly, age is strongly related to PSTRE proficiency (OECD, 2013a). Generally, older age groups tend to have much lower average levels of skill proficiency in PSTRE than younger adults. Like other socio-demographic variables, age can be a marker of practice, exposure and familiarity with different situations. However, this applies in particular to the age factor with respect to practice, exposure, and familiarity with computers and the Internet, since many adults born before approximately 1970 or even later did not grow up using these technologies. There are some striking differences among the countries that were considered. In Germany, Norway and Finland, the odds for the age group 25–34 years are about five times higher than the odds for the age group 55–65 years. These results are similar across the countries and unsurprising. But in the Nordic countries, the odds for a slightly older group of young adults aged 35–44 years to score at Levels 2 or 3 are also about five times higher than the odds for age group 55–65 years. For comparison, odds for the age group 35–44 years in Germany and the UK to score at Levels 2 or 3 are only about three times higher than for older adults. Nordic mid-agers into their 40s appear to display higher PSTRE proficiency than in other regions. Why might this be the case? It is difficult to think that a specific age group in the Nordic countries should have that much higher cognitive performance over their Southern peers for reasons other than that they have been exposed to computer technology-rich environments earlier and longer, and are therefore more capable of operating it than their German and British counterparts. This age observation supports the idea that exposure and training generates proficiency.

Language of origin and birth place can be important in securing opportunities to develop PSTRE, although this is expected to vary substantially by country. Proficiency in a language is naturally related to performance in the skills needed to process information; therefore, whether the person's native tongue differs from the language of the assessment needs to be taken into account. Separately, foreign-born status can be disadvantageous in terms of securing opportunities for learning and development. Indeed, results reveal that foreign-born adults with a foreign-language as their mother tongue (i.e. first-generation immigrants) are disadvantaged in their PSTRE proficiency compared to native-born adults with native-language status. Depending on the country, the latter have about three to six times the odds of scoring at Levels 2 or 3 compared to immigrants. Similarly, native-born adults with a native-language that is foreign (i.e. second-generation immigrants) are disadvantaged, although generally less than the first generation immigrants. This implies reduced chances for both first and second generation immigrants to experience opportunities to develop proficiency.

Parents' education, often taken as a proxy of socioeconomic status, can be a key factor in developing PSTRE as it has been found, for example, in relation to other skills such as language skills (see Fernald et al., 2013). This variable reflects the educative climate of the home during childhood and is, thus, directly involved in the development of information processing skills including PSTRE, not to mention the access and availability of computers and Internet in the home. Indirectly, the home background can influence life chances and access to nourishing environments over the entire

lifespan. Results confirm a strong relationship between parents' education and proficiency in all four of the countries considered. The relationship is strongest in Germany, where adults with at least one parent who attained higher education display over three times the odds of scoring at Levels 2 or 3 relative to adults with no parent who attained upper secondary education. This is followed closely by the UK, whereas the relationship is slightly weaker in the Finland and Norway.

As expected, educational attainment displays a strong association with proficiency. With the exception of Germany, adults with at least higher education have odds of scoring at Levels 2 or 3 that are three times higher than those who did not attain upper secondary. Only in Germany is the relationship between the parents' education and proficiency stronger than the adult person's own relationship between education and proficiency. This is an indication of the strong correlation between parents' education and the personal level of educational attainment in Germany.

While the above socio-demographic characteristics act as markers of the broader opportunities to develop PSTRE proficiency, the adjusted model also takes account of specific practice-oriented factors. Indeed, continued adult learning, whether formal (adult education and training) or informal (self-learning and as a by-product of engaging in a variety of contexts), can also have an impact. The extent of influence, however, will be conditioned by the extent to which the learning actually involves information processing, problem solving and computers. This is not necessarily the case in all instances, although some adult education programmes may be designed particularly with the aim of improving basic and computer related skills. Even in these situations, however, the evidence of success in improving the skills and practices of adult learners is inconclusive (Sheehan-Holt & Smith, 2000). The results here reveal that having participated in adult education and training in the 12 months preceding the survey displays a small positive association to PSTRE proficiency in all countries, although this is not significant in Finland. The weak association is due to many factors, one being that education is a strong predictor of further adult learning.

From a theoretical point of view, individuals acquire proficiency in different skills through participation in relevant practices, as described for example by practice engagement theory (Reder, 1994). According to this theory and in the context of literacy skills, it has been suggested that those who engage more in literacy practice both at work and at home will enhance or at least maintain their literacy skills. This implies that reading in daily life (outside of work) may be just as important. In line with this rationale, ICT use, independent of socio-demographic profile, is strongly associated with proficiency in PSTRE. In all four countries, high usage of ICT at home or at work doubles or quintuples the odds of being proficient in PSTRE relative to those who use ICT very little. This supports the idea that exposure and practice with ICT increases proficiency. However, it could be and most likely is also true the other way around: ICT proficiency leads to more usage of ICT at home and at work. So the association is clear, the causality is not.

ICT use at work appears to bare a stronger association to proficiency in PSTRE than ICT use at home in Norway, Finland and the UK, whereas they are about equal in strength in Germany. In the UK, in fact, ICT use at work is among the strongest factors relating to proficiency. This suggests that work life in the UK plays a particularly strong role for adults in terms of gaining experience with computers. Overall, the results suggest that everyday experience and exposure to ICT are likely to play a strong role in driving proficiency.

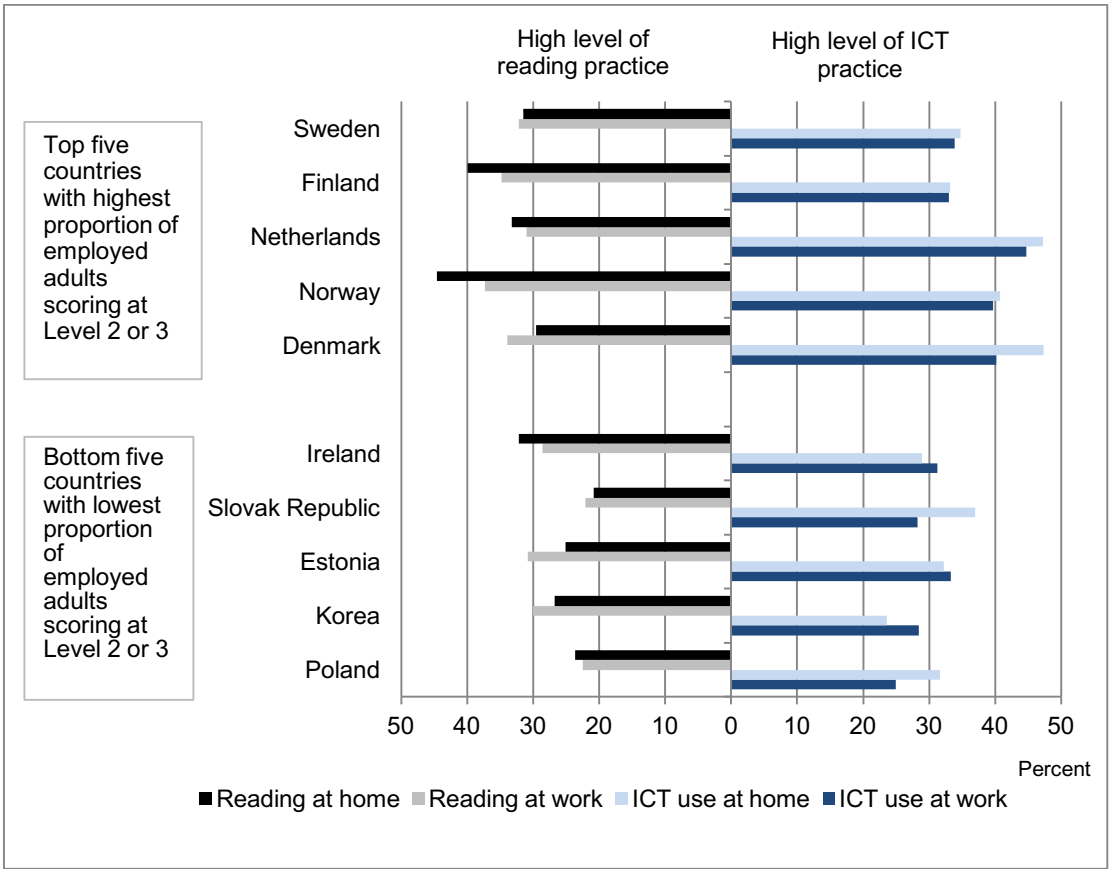
Even the practice of information processing related skills, which are not necessarily directly related to ICT use, such as reading, appear to be substantively related to PSTRE proficiency. In all four countries the frequency and variety of reading at home display an independent and positive relationship to PSTRE proficiency. Reading at work does not display a strong relationship in the

adjusted model because reading at work and ICT use at work are strongly correlated. If ICT use at work is removed from the analysis, then reading at work comes out as one of the strongest factors relating to PSTRE proficiency. These findings are similar to previous studies which found that literacy practice is associated with higher literacy skills (OECD & HRDC, 1997; OECD & Statistics Canada, 2000; Rubenson, 1987; Meissner, 1971). The variety of print contents and literacy related contexts are also important. Some research shows that reading a wide variety of content is linked to higher levels of literacy proficiency (e.g. Smith, 1996). While this theory and research is specific to literacy skills, it is likely to extend to the development and sustenance of a wide range of skills including PSTRE.

Confirming the link between ICT and reading practices and proficiency in PSTRE, Figure 3 contrasts the top five countries that feature the highest proportion of employed adults scoring at Levels 2 or 3 (Sweden, the Netherlands, Norway, Finland, Denmark) with the bottom five countries that feature the lowest proportion of employed adults scoring at Levels 2 or 3 (Ireland, Slovak Republic, Korea, Estonia, Poland). In nearly all cases, the top five countries feature higher average levels of ICT use at home and at work than the bottom five countries (right panels). Causality cannot be confirmed, but the similar link between reading practice and PSTRE proficiency (left panel) suggests that opportunities for cognitive practice play an important role in developing problem solving skills.

While a similar pattern can be observed for practice-oriented behaviours at home and at work, those at work are particularly important because working life plays a significant role in the continued development of skills more generally. Research suggests that work environments involving knowledge practice and literacy engagement provide a nurturing environment to develop or maintain cognitive abilities such as literacy and other cognitive skills (Desjardins, 2003; OECD & Statistics Canada, 2005). ICT use and opportunities to develop PSTRE in the workplace may thus become increasingly related to cognitive development over the lifespan of workers.

Figure 3. Proportion of adults aged 25–65 years, employed during 12 months preceding the survey, using ICTs and reading at work and at home, by top and bottom five countries with the proportion of adults scoring at Levels 2 or 3 on the PSTRE scale



Source: Own calculations based on 2013 OECD Survey of Adult Skills database.

Conclusion

A lot of in-depth research into the factors affecting CPS has revealed a range of factors that relate to CPS proficiency, but little research has been able to address the wider socio-demographic factors related to CPS or problem solving more generally. By implication, while CPS research is advanced it has been narrowly focused on individuals and some micro-social relations. Much less research has been done in the context macro-social relations.

While PSTRE and CPS are indeed different, they both relate to core aspects of problem solving processes. On the extent PSTRE and CPS relate to problem solving more generally and to each other, the availability of PSTRE within PIAAC has enabled a different and broader perspective in approaching the study of factors related to problem solving skills, and has allowed for some insight on the broader factors that may also be related to CPS.

The measurements of PSTRE skills in the PIAAC data are not longitudinal and therefore cannot conclusively confirm that problem solving skills are generated by broader opportunities, experiences, and practices during adulthood, though it makes sense intuitively, and data from PIAAC provide some good evidence to suggest this is the case:

- Adults with disadvantaged socio-demographic characteristics, such as those with first and second generation immigrant status, or whose parents' did not complete upper secondary education, are found to be more likely to display lower proficiency, even after adjusting for their level of education and other practice-oriented factors.
- Finnish and Norwegian adults of the age group 35–44 years are far more technology-proficient than Germans and British of the same age group, suggesting that they have had more opportunities to maintain or develop their proficiency, possibly when they were younger 10–20 years ago. At the same time, it is possible that their opportunities for practicing problem solving in technology-rich environments have remained or become broader in that period of time relative to those in other countries.
- Independent of education and other socio-demographic characteristics that act as a marker of different experiences, ICT use both at work and at home is strongly related to proficiency.
- Additionally, persons who read more at home are more technology proficient than others.

Whether the observed results of the significance of practice and exposure to problem solving in technology rich environments can be transferred to CPS, ultimately depends on how strongly CPS relates to practice. To be sure, on the extent that practice and exposure to problem solving during adulthood helps to develop and sustain skills related to solving problems, practice and exposure become a critical socio-economic point of leverage with which to foster social inclusion in a modernizing society. Fostering practice in problem solving, whether PSTRE, CPS or otherwise, may thus be a particularly important focal point of public and business policy intervention via education and work place design.

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