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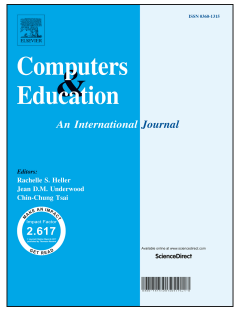

What makes the difference – PIAAC as a resource for understanding the problem-solving skills of Europe's higher-education adults

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What makes the difference – PIAAC as a resource for understanding the problem-solving skills of Europe's higher-education adults

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Abstract. The ever-evolving technological landscape is challenging adults' problem-solving skills. The central goal of higher education (HE) is to guarantee a high level of know-how, which is in line with the changing demands of technology at work and in everyday life. This study builds on European data from the Programme for the International Assessment of Adult Competencies (PIAAC) to understand adults' (N=53,407) skills for solving problems in technology-rich environments. The study provides insight into the socio-demographic, work-related, and everyday factors that are associated with a strong and a weak problem-solving performance. The results indicate that HE adults stand out from adults with other educational backgrounds. Having a higher education degree is related with strong problem-solving skills. Still, it is rather surprising that only 15% of HE adults are strong problem-solvers and that as many as 35% can be considered weak problem-solvers. Since this century requires citizens to possess more and more skills to resolve problems in technology-rich environments, this study identifies the indicators for problem-solving skills differences. Namely, this article presents the models that predict problem-solving performance on the basis of theoretical assumptions as well as empirical support. Our results indicate that HE adults' strong or weak performance seems to be associated with socio-demographic factors (especially age, gender, parental education, and native speaking skills), as well as work-related and everyday-life factors. The models presented in this study may be helpful when developing HE practices and new approaches to foster HE adults' problem-solving skills to meet the needs of technological advancement at work and in everyday life.

Keywords: Problem-solving, Technology-rich environments, Higher education, Large-scale assessment – PIAAC; Work-based and everyday life learning

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1. Introduction

New environments and new tools are challenging adults' problem-solving skills in technology rich environments (TRE). The development of tools (such as digital games), together with social media environments and Web2.0 applications, has revolutionized people's work (e.g. Harteis, 2018), everyday life, and living environments. As a direct result of this development, in today's digital world, the competencies to be mastered include problem-solving skills in a technology-rich environment (TRE). At the same time, a central goal of higher-education (HE) is to ensure that the students have the skills to meet this changing demands of technology at work and in everyday life (e.g. Noble & Billett, 2017; van Deursen, van Dijk, & Klooster, 2015). Our study grounds on a notion that we must first understand the core demands of technological development and the related problem-solving skills in TRE. Second, we must understand the extent to which adults with HE backgrounds are currently able to solve these problems within TRE. With this grounding, it is possible to estimate if and how well HE in different European countries corresponds to work-life needs and how it should (and could) be enhanced. To begin, we shortly describe, (i) pedagogical development in HE, and (ii) (technology influenced) changes in society, both in terms of working life as well as adults' personal lives.

The current research-based pedagogical development trends in HE largely acknowledge the diverse role that technology is playing in the development of teaching and learning. In general, the HE system in Europe has been based on the idea that students' problem-solving skills in TRE are assumed to develop via teaching and learning in these settings. In these technology rich environment, students need to define problems, search and select reliable sources of information, and synthesize and process the information into a coherent body of knowledge. This will involve higher-order thinking, conceived as intentional processes to solve authentic problems (Lindblom-Ylänne, Haarala-Muhonen, Postareff, & Hailikari, 2017).

In addition to this focus on enhanced problem-solving requirements, new tools, environments and applications are often suggested as promising ways for shaping HE practices (for an overview, see Hsu, Ching, & Grabowski, 2014). Novel tools, environments and applications may appear to be especially useful to prepare students for future work environments, which are characterized by an increasing demand for advanced skills to analyze information and solve complex problems in inter-professional groups (Tynjälä, Häkkinen & Hämäläinen, 2014). Despite the potential, it should be noted that most of the studies so far have focused on the specific HE context for a relatively short time. For example, the focus has been on the educational use of technology (e.g. how technologies and/or pedagogical approaches in TRE can be harnessed to enhance the learning of specific skills and/or contents (Gielen & De Wever, 2015; Noroozi, Weinberger, Biemans, Mulder & Chizari, 2012). Actually, hardly anything is known about HE students' development in problem-solving skills and processes over time. Furthermore, according to Kirkwood and colleagues (2014) relatively little is known about what kind of general skills and competences technology-enhanced learning and teaching practices are actually enhanced in TRE. This study is one attempt to fill this gap and we are interested in understanding how HE background is associated with strong and weak problem-solving performance in TRE.

The requirements in an ever-evolving, technology-intensive working life are fluid and constantly transforming. Over the last five years, major breakthroughs have been made in artificial intelligence technologies, which have been applied in real-life work situations across several fields (Hämäläinen, Lanz, & Koskinen, 2018). Furthermore, workplace structures (Cartwright, 2017), the so-called human clouds that match employers with freelancers (Zincir & Tunç, 2016), and workplace monitoring (Cantor, 2016) are becoming increasingly common and are changing how we work. Even though change has been rapid, it has not happened instantly. Already in 2001, the Organisation for Economic Co-operation and Development

(OECD) estimated that knowledge workers comprised the fastest-growing occupational group of employees in both the European Union and the USA between 1992 and 1999 (López-Bassols, 2002; Scarpetta, Hemmings, Tressel, & Woo, 2002). Nowadays, people increasingly work in TRE, and economists have indicated a high return to the labour market on competencies concerning information and communication technology (ICT; Dolton & Makepeace, 2004). The machinery used in workplaces has also undergone radical structural change (Frey et al., 2016; Goos, 2013). It is predicted that, over the next two decades, 47% of the jobs in the United States of America (USA) could be susceptible to computerisation (Frey & Osborne, 2013). Millard (2017) claimed that, by 2025, between 40 million and 75 million of the current jobs might be jeopardised worldwide. All these changes signal that, in future work contexts, workers will need to fill various technological positions, and problem-solving skills will play a crucial role. It is evident that we need to understand workers' skills to deal with future work requirements and technological settings.

Beyond the workplace, everyday living in this century requires citizens to have more and more skills to solve problems in TRE. The Internet and related applications are often used for leisure activities, such as taking a bus or train, inviting people to a party, or making appointments with physicians. Increasingly, we must resolve issues when interacting with these technologies. Valtonen, Dillon, Hacklin, and Väisänen (2010) argued that the enhanced use of the Internet for leisure activities may offer worthwhile opportunities for learning in everyday life. Previous research on Finnish adults (with vocational education backgrounds) indicated that skills used outside the workplace might contribute to problem-solving skills in TRE (Hämäläinen, De Wever, Malin, & Cincinnato, 2015), demonstrating that problem-solving skills are stimulated not only through education or work-related tasks but also through activities in everyday life. Furthermore, a study by van Deursen and colleagues (2015) showed that adults' educational backgrounds seem to be associated with how technologies are used in everyday life, and education seems to be an important predictor of the types of activities in which people engage in TRE settings (see also, Howard, Rainie, & Jones, 2001).

Many assumptions have been made about how HE can prepare people for a working and everyday life of the future, but theoretical elaboration is lacking, as is empirical, large-scale research on the skills that adults with HE backgrounds possess. Lawn (2013) proposed that it is possible to profit from the knowledge gathered from large-scale assessments by extracting indicators that predict adults' skills. Before the Programme for the International Assessment of Adult Competencies (PIAAC), however, no international, large-scale assessment data on adults' skills had been available, and it was a disincentive for this kind of research. Led by the OECD (OECD, 2013a), PIAAC—the most comprehensive study of adult skills ever undertaken—offers novel possibilities to investigate adults' skills and the associations between skills and educational backgrounds. PIAAC is a large-scale, ongoing programme employed by 25 countries around the globe. It monitors performance in literacy, numeracy, and problem-solving in TRE. PIAAC data is one response towards understanding the competencies of individuals and populations as it focuses on accessing, integrating, managing, evaluating, and constructing information about adults' skills by using the technologies of the information age (Schleicher, 2008). Inspired by PIAAC data, our previous studies have focused on investigating the associations between adults' problem-solving skills in TRE and vocational education backgrounds in Europe (Hämäläinen et al., 2014, 2015; Hämäläinen, De Wever, Nissinen, & Cincinnato, 2017). Thus far, similar empirical studies have not examined the relationship between problem-solving skills in TRE and HE backgrounds on a European scale. This study aims to fill this research gap.

2. Aim and research questions

This study builds on PIAAC data on problem-solving in TRE. Within PIAAC, data have been gathered among adults in 21 countries (not all the countries that took part in the PIAAC assessment collected data on problem-solving). For this particular study, we focused on 13 European countries that participated in the problem-solving in TRE part of the PIAAC assessment and were among the first countries to be full members of the European Higher Education Area (EHEA), meaning they have been involved in the Bologna process since 1999. This study aimed to analyse the level of HE adults' problem-solving skills in TRE and how these skills relate to work and non-work variables. We focused on basic skills that 16- to 65-year-old adults with HE have regarding problem-solving in TRE. The first aim was to identify adults with HE that can be considered 'weak performers', 'moderate performers', and 'strong performers' when it comes to analysing their problem-solving skills. Due to the changing needs of workplaces and everyday life, especially with relation to problem-solving skills, the second aim was to investigate which factors in adults' backgrounds are related to their strong, or respectively weak, problem-solving skills. Therefore, the following research questions guided our study:

RQ1: What is the level and distribution of problem-solving skills in TRE for adults with HE?

Based on earlier empirical evidence (Desjardins & Ederer, 2015; Hämäläinen et al., 2015), we assume that the level of HE adults' skills is significantly higher than that of adults with a lower educational level.

RQ 2: Which factors are associated with strong, or respectively weak, problem-solving in TRE for adults with a HE degree?

Studies on adults with vocational education and training (VET) (Hämäläinen et al., 2015; Hämäläinen et al., 2017) and on employed adults across four European countries (Desjardins & Ederer, 2015) suggest that the learning and use of general and ICT skills at the workplace as well as in everyday life outside the workplace are important determinants of problem-solving skills in TRE, in addition to socio-demographic factors. Though the population of these studies is different from the current study, it can reasonably be assumed that the learning and skill use affect the problem-solving skills in TRE of HE adults as well, even when controlling for socio-demographic background. Therefore, we assume that learning and skill use at work and in everyday life will be associated with problem-solving skills, independently from each other.

3. Material and methods

3.1. Context of the study: PIAAC large-scale assessment

In this study, we focused on PIACC assessments of problem-solving conducted in 13 European countries/regions. In these countries, a total of 61,654 16- to 65-year-old adults participated in a survey concerning problem-solving skills in TRE (participation rate between 45% (Sweden) and 72% (Ireland)). Because work-related background factors were interest in this study, we restricted our analyses to participants who were employed. In the considered countries, there were 53,407 such participants, and 14,426 (27 %) of them had a bachelor, master or research degree. The objective of the PIAAC assessments was to determine how well adults' basic skills prepared them to respond to the needs of today's and tomorrow's everyday and work-related needs. PIAAC data were gathered from both a background questionnaire (including questions about what kinds of skills participants used and how actively) and a test of problem-solving skills in TRE (OECD, 2013a). The background questionnaire, test, and assessment framework were designed by international expert groups (OECD, 2012). (A detailed description of the data and the scaling of cognitive data are provided in the PIAAC technical report [OECD, 2013b, chapter 17]).

3.2. Distinguishing the level of problem-solving skills in TRE

In PIAAC, proficiency is considered a continuum of ability which involves the mastery of information-processing tasks of increasing complexity. In assessing problem-solving in TRE, the aim was to evaluate adults' ability to use technology in accomplishing complex problem-solving tasks. Problem-solving in TRE is defined as follows:

> Problem solving in technology-rich environments involves 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 will focus on the abilities to solve problems for personal, work and civic purposes by setting up appropriate goals and plans, accessing and making use of information through computers and computer networks. (OECD, 2012, p. 47)

During the PIAAC test, participants solved tasks using various sources of information on a laptop computer, using, for example, an Internet browser, e-mail, and word processing software (OECD, 2012). The results were represented on a 500-point scale. For the present study, the problem-solving scale was divided into proficiency levels based on the knowledge and skills required to complete the tasks within those levels. The levels were defined and used by the OECD for reporting on PIAAC data. Level 1 included scores from 241 points to 290 points ('weak performers'), Level 2 included scores from 291 points to 340 points ('moderate performers'), and Level 3 ('strong performers') included scores equal to or higher than 341 points. Participants scoring below Level 1 were classified as 'at risk'. In addition, corresponding to the study procedures (OECD, 2013b), the sample included a 'not classified' group that, for example, failed the basic ICT test, did not know how to use a computer, or opted out of participating in the computer-based test. For these participants, the problem-solving proficiency scores were absent and not included in the analyses. In our study, as a first step of the statistical analysis, the level and distribution of problem-solving skills for all participants were calculated, the results of which are described in section 4.1 of this article.

3.3. Studying the differences between the problem-solving skills of adults with a degree in higher education and other adults (RQ1)

Through a descriptive investigation of means and skill-level distributions by educational qualification, adults' problem-solving skills in TRE were examined. Educational qualifications were categorised into six distinct levels based on the International Standard Classification of Education (ISCED 1997): (1) primary education or less (ISCED 1 or less); (2) lower secondary education (ISCED 2, ISCED 3C short); (3) upper secondary education (ISCED 3A-B, 3C long); (4) post-secondary, non-tertiary education (ISCED 4A-B-C); (5) tertiary education - professional degree (ISCED 5B); and (6) tertiary education - bachelor/master/research degree (ISCED 5A, 6). Our primary research interest was focused on adults with a bachelor/master/research degree and descriptive analyses were performed to (1) gain insight into the level and distribution of problem-solving skills for this group and (2) ascertain whether the problem-solving skills of this group were sufficiently different from other educational categories to warrant separate treatment, especially when compared to adults in the tertiary education - professional degree group.

3.4. Developing a model to identify background factors associated with problem-solving skills in TRE (RQ2)

This study expands upon previous research in which we investigated the problem-solving skills of adults with a vocational education and training background (see Hämäläinen et al., 2015). In this study, we focused on European HE adults´ problem-solving skills. We explored problem-solving skills and competencies in TRE from the standpoint of the socially situated nature of learning. Namely, we saw that the test results of adults were always associated with their personal life history and their experiences; therefore, we needed to try to get a picture of how these elements link together to build plausible explanations. We aimed to identify factors explaining the variation in adults' problem-solving skills in TRE—factors based, firstly, on theoretical assumptions, and secondly, on empirical support.

3.4.1. Stage I: Theoretical assumptions

Typically, studies on adults' skills and competencies lie at the intersection of research on (1) workplace learning (e.g. Billett, 2016; Messmann, Segers, & Dochy, 2018), (2) school-based learning (e.g. vocational education and training [Hämäläinen et. al., 2015] or higher education [Postareff, Mattsson, Lindblom-Ylänne, & Hailikari, 2017]), and (3) boundary crossing between workplaces and schools (Akkerman & Bruining, 2016; Flynn, Pillay, & Watters, 2016). Furthermore, the growing trend seems to be that studies take into account learning that supports everyday life (Tour, 2017; see Table 1). In our previous study, we conducted a thematic analysis of PIAAC variables (see OECD, 2013a, for a description of the 1,600 variables) and identified three clusters of variables for our model (see Hämäläinen et al., 2015, for a detailed description): (1) socio-demographic factors, (2) work-related learning variables, and (3) variables related to everyday learning). In this study, 24 variables were carefully chosen to serve as indicators for the three clusters.

<Insert Table 1 approx. here>

3.4.2. Stage II: Explanatory models for weak and strong problem-solving skills

Since the need for problem-solving in TRE is likely to increase in the future, this study also empirically identified the factors that explain differences in problem-solving skills. Binary logistic regression analyses were completed to explain and predict strong performers (Level 3) on the basis of theoretical assumptions (Stage I described in section 3.4.1). Similar analyses were then carried out to explain weak performers (Level 1 or below). In both cases, the moderate problem-solvers' group (Level 2) served as the reference category for the group of interest, i.e. for strong and relatively weak performers[1].

We fitted four different models that might explain strong performance, and the same models were considered for weak performance. All models employed the three clusters of explanatory variables in various combinations. Since the socio-demographic variables (Cluster 1) are fundamental in the sense that they cannot be manipulated or otherwise influenced, they were fitted in Model 1, which serves as the basis for subsequent models. Only those variables which were found to be statistically significant for predicting either weak or strong performance were kept in the final models.

In Model 2 all work-related variables (Cluster 2) were added to Model 1 (i.e. Model 2 = socio-demographic + work-related factors, or Clusters 1 and 2) to estimate their impact on problem-solving skills, while controlling for socio-demographic factors[1] Again, only those variables which were found to be statistically significant for predicting either weak or strong performance made their way into the final reported models. Model 3 contained all learning variables associated with everyday life (Cluster 3) but no work-related variables; it also included the socio-demographic factors (i.e. Model 3 = socio-demographic + everyday-life-related factors, or Clusters 1 and 3). Here, the purpose was to assess the importance of

[1] The usual recommended approach to statistical PIAAC analyses is to use the 10 problem-solving plausible values, provided in the data set, as the dependent variables. The desired analysis would then be performed for each plausible value separately, and the results of the 10 analyses would be combined following the multiple imputation approach (PIAAC technical report; OECD, 2013b, chapter 15). However, in our case, where the starting point of our analysis was to group individuals into weak, moderate, and strong problem-solvers, the usual approach led to complications. For our purposes, it made sense to have three fixed problem-solver categories, which then would be exposed to logistic regression analyses. Since each of the 10 plausible values leads to a slightly different grouping, we decided to categorise the individuals on the basis of just one plausible value. Using the mean of plausible values would lead to grouping with an overly large moderate-performer group. The skill groups used as response categories in our models were formed using the problem-solving plausible value number 2. We selected the plausible value number 2 because it yielded skill groups whose percentages were the closest to the percentages obtained by averaging over all 10 plausible values in the usual way. As a consequence, our modelling procedure was not based on the multiple imputation technique with 10 plausible values. Using just one plausible value yields results which are approximate in respect to results obtained with the recommended approach. Nevertheless, the results are unbiased. For comparison, we recalculated some analyses using all 10 plausible values. The results were practically the same.

everyday-life learning, adjusted for socio-demographic factors. The final Model 4 contained the significant explanatory variables from all three clusters.

The computations of the logistic regression analyses were carried out with the SURVEYLOGISTIC procedure of SAS® software, employing the maximum likelihood estimation method. Variance estimates were obtained by Taylor series linearization. Survey weights were used in all analyses to account for the PIAAC sampling design.

4. Results

4.1. Problem-solving skills of adults with HE

Our results indicate that, among adults with HE, there is a tendency to have high problem-solving skills, which corroborates prior findings (Desjardins & Ederer, 2015; Hämäläinen et al., 2015). The descriptive results (as presented in Figure 1) show how problem-solving skills are distributed over the different educational levels. Figure 1 shows that the average level of problem-solving in TRE was highest for adults with a bachelor, master, or research degree (mean = 303). In addition, 15% of adults with an HE degree were situated at the highest level (Level 3) of problem-solving. The percentage of strong problem-solvers was about twice as large compared to adults with a tertiary professional degree (7%) or a post-secondary, non-tertiary degree (8%). Furthermore, this percentage was three times larger than adults with an upper secondary degree and five times larger than adults with a lower secondary degree. Likewise, the proportion of weak problem-solvers (i.e. Level 1 and below) was a lot smaller for adults with an HE degree. Nevertheless, for adults with the highest level of education, it is still worth noting that while 50% of them performed moderately (Level 2), a mere 15% were strong problem-solvers, and 35% were weak problem-solvers. Since a somewhat small percentage ranked as strong performers, the next phase of our research sought to shed light on what factors are related to this strong, respectively weak, performance within this group of higher educated adults.

<Insert Figure 1 approx. here>

4.2. Background variables associated with problem-solving proficiency

Table 2 presents a summary of the explanatory factors found to be significant in explaining either strong or weak problem-solving (PS) proficiency in the fitted models 1-4 (RQ2). The detailed numerical estimation results for all models are given in Table A1 (predicting weak PS) and Table A2 (predicting strong PS) in the appendix.

<Insert Table 2 approx. here>

Regarding the socio-demographic factors examined in Model 1, Table 2 shows that all four variables—i.e. age group, gender, parental education, and being a native speaker of the test language—were significantly associated with both weak and strong problem-solving skills. The explained variation, measured with Nagelkerke R-square, was slightly higher for weak (10%) than for strong (7%) problem-solving performance. Male gender, parental educational level, and being a native speaker all had a positive association with skills. That is, they all increased the probability of being a strong performer and reduced the probability of being a weak performer. However, the effect of age group was negative, and it was the strongest of the socio-demographic factors. The odds ratio of being a weak performer instead of a moderate performer was 3.5 for the oldest age group (55–65 years old), the youngest age group being the reference (see Table A1 in the appendix). On the other hand, the odds of being a strong performer instead of moderate were 1/0.23, meaning the odds are 4.3 times greater for the youngest age group than the oldest age group (see Table A2 in the appendix).

The assumption that skill use at work affects problem-solving was examined by adding the work-related factors to Model 1. This increased Nagelkerke R-square by 6.4 percentage points for weak problem-solving skills and 3.0 percentage points for strong skills. Thus, the Rsquares for Model 2 were 16.5% for weak performance and about 10% for strong performance (Table 2). Note that having a skilled occupation played a significant role in explaining both weak and strong skills. The effect was positive; a skilled occupation increased the probability of being a strong problem-solver and, correspondingly, reduced the probability of being a weak problem-solver. The use of ICT skills at work was strongly associated with weak problem-solving skills—the most passive users of ICT skills appeared significantly more often as weak performers than the more active users (odds ratio 1/0.39 = 2.5). However, the use of ICT skills did not show association with strong performance. Instead, learning at work had an interesting nonlinear association with strong performance; those with an average (not too much, not too little) amount of learning outperformed the other groups. Participation in job-related adult education and training had a small 'protective' effect on weak performance; it reduced the probability of having weak skills. In general, socio-demographic factors were still more powerful predictors of problem-solving skills than work-related factors (see Tables 2, A1, and A2).

Model 3, which contained the everyday-life-related factors as well as the socio-demographic factors, explained 15% of the variation in the case of weak problem-solvers and some 9% in the case of strong problem-solvers (Table 2). Thus, the variation explained by the everyday-life variables was slightly smaller than that explained by the work-related variables. Also, the amount of explained variation was again slightly higher for weak performers than for strong performers. The use of numeracy skills and a large number of books at home had positive effects on problem-solving performance; they reduced the probability of having weak skills and increased the probability of having strong skills. Active use of numeracy skills at home was especially strongly related to the highest level problem-solving skills (odds ratio 2.5 with the most passive users being the reference category). Additionally, the use of ICT skills and writing skills at home reduced the probability of weak performance but did not affect strong performance. Specifically examining the use of writing skills, the odds of being a weak problem-solver were two times greater among the most passive users than among the most active users (odds ratio 1/0.51 = 2.0). Participation in non-job-related adult education and training had a small association with strong problem-solving skills (see Tables 2, A1, and A2).

Because work-related and everyday-life-related factors may be correlated, factors from all three clusters were tested simultaneously in the Model 4. The model explained 20% and 12% of the variation in the case of weak and strong problem-solving skills, respectively (Table 2). Regarding the weak performers, nearly half of the explained variation was due to introducing work-related and everyday-life-related factors. For the strong performers, the increase of explained variation was somewhat smaller. The data clearly corroborates previous findings of the importance of skill use both at work and at home, among HE adults (Desjardins & Ederer, 2015; Hämäläinen et al., 2015). As for the weak performers, all socio-demographic factors maintained their significant associations. Instead, for the strong performers, gender and being a native speaker were no longer significant, meaning that these variables were associated with some of the work-related and everyday-learning-related factors in the model when strong problem-solving skills were considered. The effects of work-related factors were approximately the same as in Model 2, except that the industry came in as a small but significant factor for both weak and strong performance. It appeared that people working in education possessed weak skills more often than people working in other industry sectors. On the other hand, people working in health and social work possessed strong skills less often than those in other sectors. (Table A2). When looking at the everyday life related factors in Model 4 it can be noted that the number of books at home is the only variable which has a significant effect on both weak and strong performance. Like in Model 3, the use of numeracy skills at home seems strongly associated with level 3 problem-solving skills (odds ratio 2.4).

Regarding the weak skills, the use of writing skills at home (odds ratio 2.1) is the only significant everyday related factor in addition to the number of books. Overall, the strongest predictor of problem-solving performance in Model 4 was still age; the odds of being a weak performer were 4.2 times greater for the oldest age group than the youngest age group. Then again, the odds of being a strong performer were 1/0.29 = 3.5 times greater for the youngest age group than the oldest age group (see Tables 2, A1, and A2).

It is worth mentioning another particular finding: ICT skill use in everyday life was not significant anymore in Model 4 for explaining weak performance, which may be due to the introduction of ICT skill use in work life (as all work-related variables were added to Model 3 to create Model 4). Therefore, we checked the correlations between the four skill-use variables appearing to be significant in Models 2–4 (see Table A3 in the appendix). While it turned out that the correlation between ICT in everyday life and ICT at work was 0.26, our supplementary analyses showed that the use of writing skills at home and the use of ICT skills at home had a reasonable positive correlation (0.38). It appeared that replacing the use of writing skills with the use of ICT skills gave almost as good a model fit here. Therefore, we can surmise that the positive effect of actively using writing skills represents, to some extent, the positive effect of actively using ICT skills at home, in addition to some use at work.

5. Discussion

Although the adults in our sample all had a HE degree (bachelor, master, or research), it is noteworthy and surprising that only 15% were strong problem-solvers and that 35% could be considered weak problem-solvers. Even though this proportion of strong problem-solvers is higher (and the proportion of weak problem-solvers is lower) when compared to adults with lower educational levels (see also Desjardins & Ederer, 2015; Hämäläinen et al., 2015), these findings show that educational level alone does not guarantee high levels of problem-solving in TRE. When analysing this group of HE adults in more detail, to understand better what makes them a strong or a weak performer, we focused on three clusters of factors—namely, socio-demographic, work-related, and everyday-life-related variables.

The socio-demographic cluster was quite important; age, gender, and parents' education were found to be associated with problem-solving skills in TRE. Furthermore, the following factors were the same for both strong and weak performers: younger, male adults with parents having a tertiary or upper-secondary degree had a greater chance of being strong problem-solvers (and also a lesser chance of being weak problem-solvers). Being a native speaker was an exception; it was found to reduce the chance of being a weak performer, though it did not increase the chance of being a strong problem-solver. These results are in line with the previous findings, indicating that socio-demographic factors are associated with problem-solving skills in general (Lindberg and Silvennoinen, 2017) and problem-solving skills in TRE in particular (Desjardins & Ederer, 2015; Hämäläinen et al., 2017). A specific pedagogical implication of our study could be to invest in (extra) support for specific groups (e.g. based on gender, parental education, and home language). Providing this support, e.g. in the form of a tutoring programme (e.g. Stevick & Brown, 2016), or more scaffolding (e.g. Devolder, van Braak & Tondeur, 2012), may improve their problem-solving skills.

The work-related cluster was notable, as a skilled occupation played a significant role in explaining both weak and strong skills. In our final model (Model 4), the industry in which a person works came in as a significant factor for both weak and strong performance. Thus, the findings signal that what people do at work seems to be associated with their problem-solving skills in TRE. Different job requirements may lead to different applications of problem-solving skills at work, and thus skills can be influenced by daily job activities (see also Desjardins & Ederer, 2015). In addition to the influence of daily work and job requirements, work contexts may have an influence on the opportunities to learn problem-solving skills in

TRE at work. The findings indicate that the problem-solving skills in TRE of people working in education were lower compared to other fields. Future research is necessary to find out what is causing this difference. (i.e. Are educational workers less exposed to technological environments? Are they less exposed to team collaboration? Do they have fewer opportunities to learn at work?). These findings are worrisome and as an implication, new pedagogical initiatives are needed to help education workers enhance their skills and competencies regarding problem-solving in TRE. Such an initiative could be to organise more accessible adult education and training. In this respect, our findings show that participating in adult education and training for job-related reasons is related to a lower chance of being a weak problem-solver (see also Vanek, 2017).

Besides adult education and training, more and more skills may be developed through informal learning activities at the workplace (see, Messmann et al., 2018). In this respect, we share the view of Tews, Michel, and Noe (2017) that future research should focus on shedding more light on learning at work (see also Billett, 2016). We argue that future research on digitalization must investigate learning at work, for example, while previous research has focused on collaboration between people in technology-enhanced contexts, future pedagogical implications must account for human-machine interactions (Koops, van der Vleuten, de Leng, Houterman, & Snoeckx, 2014; Russakovsky, Li, & Fei-Fei, 2015). Finally, a specific pedagogical implication could be the systematic development of individualised workplace curricula (see e.g. ten Cate & Billett, 2014) to get adults more experienced and skilled in problem-solving in TRE.

Our findings illustrate that, in addition to the work-related cluster, the everyday-life-related cluster is influential. The use of numeracy skills at home, as well as having a large number of books at home, reduced the probability of having weak problem-solving skills and increased the likelihood of having strong skills. We can make a distinction between two types of everyday activities. First, some activities can be seen as necessary and required for life in this century. Problem-solving in TRE is important for electronic banking, finding your way through public transport, booking trips, etc. These activities occur during what could be perceived as people's leisure time; however, we can consider them to be requirements (e.g. the skill requirements to pay our bills via online pay service). Second, there are the activities that people are more voluntarily engaged in and that are more related to leisure time, such as hobbies and special interests. To a certain extent, adults are involved in problem-solving in TRE based on these activities.

Previous studies have indicated that education seems to be associated with how actively problem-solving skills in TRE are used and which type of activities adults are involved in during their leisure time. For example, Howard et al. (2001) showed that adults with HE use the Internet in their leisure time relatively often for financial, political, governmental, and health purposes, as well as to read the news, book travel, and produce information, while less-educated adults use it more often for casual activities (e.g. watching videos, listening to music, downloading media, and playing games). Furthermore, a study by van Deursen and van Dijk (2014) showed that people with lower levels of education use the Internet for more hours a day in their spare time than those who are highly educated. Although people who are highly educated spend less time on the Internet, the Internet seems to provide more capital-enhancing opportunities for them. Currently, HE seems to be positively associated with being an active citizen, fully participating in the democratic society, well read, and with a critical mind in novel TRE settings.

6. Conclusions

Our findings indicate that, among adults with HE degrees, there is a tendency to have high problem-solving skills. Citizens of this century need more and more skills to solve problems in TRE. Problem-solving skills are needed not only for their professional (work) life but also for their nonprofessional (everyday) life. In this study, we introduced 14 factors that are associated with problem-solving skills. However, there were also several other factors which did not show significance in any of the fitted models. Neither the use of numeracy, reading, or writing skills at work nor the use of reading skills at home had any effect. The same was observed with the variable of employment status; it did not matter whether the individual had a full-time or part-time job. Instead, our findings indicate that job tasks and jobs requirements seem to be associated with problem-solving skills. The results also suggest that the use of numeracy and ICT skills play a significant role in HE adults' problem-solving performance in TRE. Weak problem-solvers tend to use their skills less than others, both at work and outside of work. Both strong and moderate problem-solvers use their numeracy and ICT skills fairly actively as a part of their work, but strong performers typically also use their skills actively outside of work. Thus, problem-solving skills appear to be useful in people's spare time, time which increasingly benefits from advanced skills that help to analyse information and solve problems in TRE environments. The models presented in this study may be helpful when developing HE practices as well as new approaches to foster HE adults' problem-solving skills to meet the needs of technological advancement at work and in everyday life.

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Table 1
Overview of the Three Clusters of Explanatory Variables and the Outcome Variable (Adapted from Hämäläinen et al., 2015)

(1) **Socio-demographic factors** that shape adults' life experiences (including background variables, such as age or gender)	
(2) Work-related learning (e.g. Billet, 2008; Tynjälä, 2013); learning taking place at work, through work, and for work, including formal and non-formal educational activities that are related to the adults' work	**(3) Everyday-life learning** (e.g. Tour, 2017); learning taking place in everyday life / outside the work context, including ICT skills used in everyday life and formal and non-formal education for non-work-related reasons
Outcome: Problem-solving skills in TRE	

Table 2

Summary of significant factors explaining weak and strong performance in different logistic regression models.

	Model 1		Model 2		Model 3		Model 4	
	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong
$R^2_{Nagelkerke}$ (%)	10.1	6.8	16.5	9.8	15.0	9.4	20.0	11.8
Cluster 1: Socio-demographic factors								
Age	***	***	***	***	***	***	***	***
Gender	***	***	***	**	***	**	***	(ns)
Parental education	***	***	***	***	***	*	**	*
Native speaker	***	*	***	*	***	(ns)	***	(ns)
Cluster 2: Work-related factors								
Occupation			**	*			**	*
ICT skill-use at work			***	(ns)			***	(ns)
Learning at work			(ns)	**			(ns)	**
Adult education or training (job-related)			*	(ns)			**	(ns)
Industry (ISIC)			(ns)	(ns)			*	*
Cluster 3: Everyday life related factors								
Books					***	*	***	*
Numeracy skill-use at home					*	***	(ns)	***
ICT skill-use at home					**	(ns)	(ns)	(ns)
Writing skill-use at home					***	(ns)	***	(ns)
Adult education or training (non job-related)					(ns)	*	(ns)	(ns)

Note. *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; $^{(ns)}$ $p > 0.05$

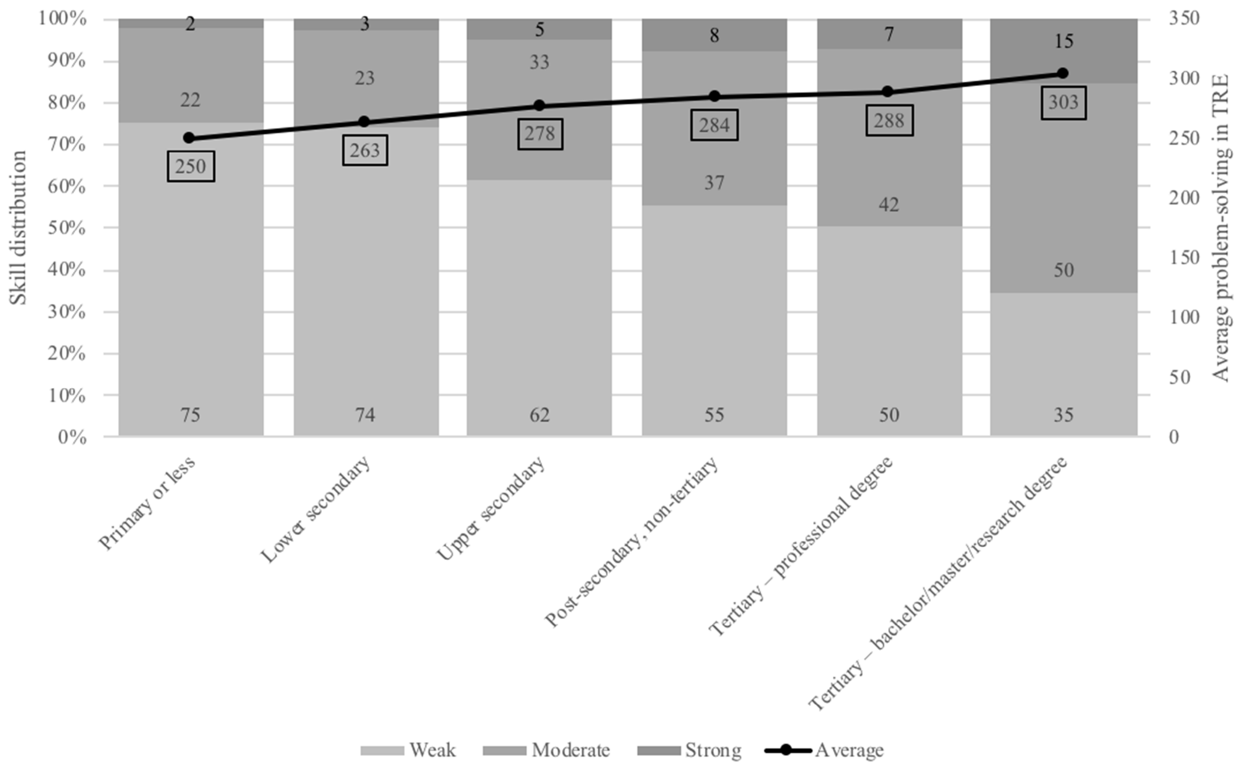

Figure 1. Problem-solving in TRE skills, average and skill distribution by educational level

- The data from the PIAAC by the OECD comprise the most comprehensive source of information of adult skills ever undertaken.
- The study builds on PIAAC to understand HE adults' (N=53,407) skills for solving problems in technology-rich environments.
- More HE adults have high problem-solving skills in TRE, but still only 15% of HE adults are strong problem-solvers.
- We investigated which socio-demographic, work-related and everyday-life factors are associated with strong or weak skills.
- The models predict HE adults' problem-solving performance on the basis of theoretical assumptions and empirical support.