Learning to Lifelong Learn

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LEARNING TO LIFELONG LEARN

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ABSTRACT

We present highlights and recommendations of the LLLight´in´Europe project about „learning to learn" skills that are relevant for individuals, enterprise, and policy makers, alike. From current research, we already know that a particular type of „learning to learn" skill – complex problem solving (CPS) –can be reliably assessed in individuals, and at the same time, that CPS is central for enabling lifelong learners to acquire and apply new knowledge in a systematic way. On the one hand, our empirical research suggests that CPS skills serve as factors that could be used to select individuals for complex work that requires continuous learning. On the other hand, the complexity of a job might be a source of learning how to lifelong learn, and thus promote CPS skills, making CPS a precursor, aggregate measure, reflection and outcome of lifelong learning. For our research, we employed psychometric instruments that enabled us to directly and easily assess CPS in populations of working adults. We tested a total of 1129 individuals in 40 enterprises and 13 countries to establish for the first time ever a cross-national, cross-industrial reference set of CPS scores. Further, we analyzed the emerging data set and obtained interesting but still preliminary results about the cross-national, cross-industrial distribution of CPS as well as its associations with predictors and outcomes of job performance that all yield new insights about the role of CPS in lifelong learning and occupational success in the increasingly complex work context of the 21st century.

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1. INTRODUCTION

Workplaces are gravitating toward complexity as they become more dynamic and utilize more elaborate technology. The modern work organization was already described by Cascio (1995) 20 years ago: focused on project-based tasks, which imply a set of ever-changing challenges, modern jobs no longer concentrate on fixed, permanently specialized tasks. In other words, as Autor, Levy, and Murnane (2003) mentioned, nowadays the core characteristic of work is complexity instead of repetition and routine. As a consequence, open work arrangements, and hence multiple career opportunities, are increasing and dominating the global market. In order to deal effectively with these new contexts, there is a need for lifelong learning. In particular, the ability to transfer one's skills to different work contexts (Anakwe, Hall & Schorr, 2000) is a modern requirement for smart-working, which, more and more, is replacing hard work.

21st century skill frameworks and „Learning to learn" skills

Recent efforts to determine what an individual must do to successfully adjust to non-routine, complex work have highlighted the importance of 21st century skills. This term refers to a broad set of skills, personal traits, and work habits that are believed to be essential in today's working world, especially in collegiate programs and dynamic careers that require the individual to lifelong learn. In research, 21st century skills have recently become a major point of interest with close ties to educational and business practices (for more details, see e.g., http://www.atc21s.org/). Many similar names for these skills exist, such as cross-curricular skills, interdisciplinary skills, transferable skills, transversal skills, and soft skills. Since the term "transversal skills" is already widely used to describe this conglomerate of skills, traits, and habits, we will use this term only to refer to 21st century skills. Examples of transversal skills include critical thinking, leadership, teamwork, global awareness, scientific literacy, information and communication technology (ITC) literacy, creativity, and complex problem solving (CPS; „21st Century Skills," 2014). More generally, transversal skills are skills that have been acquired through an individual's learning history and that can be transferred to different contexts that, for example, require an individual's critical thinking or leadership skills. Among this variety of transversal skills, so called „learning to learn" (e.g., González et. al. , 2014) skills particularly enable to deal with new and ever changing learning contexts in professional and private life. Adopting the recommendation of the European Parliament and of the Council on Key Competences for Lifelong Learning (2006) we define 'Learning to learn' as „the ability to pursue and persist in learning, to organise one's own learning, including through effective management of time and information, both individually and in groups. This competence includes awareness of one's learning process and needs, identifying available opportunities, and the ability to overcome obstacles in order to learn successfully. This competence means gaining, processing and assimilating new knowledge and skills as well as seeking and making use of guidance.

Learning to learn engages learners to build on prior learning and life experiences in order to use and apply knowledge and skills in a variety of contexts: at home, at work, in education and training."

This report emphasizes the importance of the transversal skill set of CPS that enables to learn in its basic sense, namely, via systematically overcoming obstacles to learn via solving complex problems.

The construct of CPS

CPS can be defined as a non-routine analytical skill involving domain-general mental processes that are required across diverse complex problems (e.g., Funke, 2001). Requiring the handling of non-routines (Funke & Frensch, 2007), complex problems occur in interactive, dynamic, and previously unknown, intransparent tasks as they increasingly occur in modern occupations, such as in engineering, IT, technology-based, as well as social entrepreneurship, health care, agriculture, and many more. Expertise in such areas is highly domain-specific and does not necessarily translate to problems outside the domain (Rybash, Hoyer, & Roodin, 1986). For example, automotive engineers in the research and development department of a car manufacturer are nowadays exposed to increasing complexity and a multitude of ever-changing (i.e., nonroutine) tasks. They must address technical, electronic, or even economic issues in sales, logistics, quality or project management, marketing, or consulting. They have to look at projects from different points of view and integrate the different aspects of a project into a cohesive whole. Solving such complex problems involves the basic ability to learn by acquiring and applying knowledge in its broadest sense. Furthermore, acquiring and applying new knowledge are necessary for acquiring more job-specific skills. Solving complex problems can therefore be considered a contribution to lifelong learning that promotes the ability to learn per se because, in order to acquire a concrete, job-specific skill, one must first have a solid foundation that includes the domain-general, „learning to learn" skills of knowledge acquisition and knowledge application. This domain-general, analytical, „learning to learn" skill set is what is elaborated on in this Brief as CPS.

Empirical relevance of CPS

The relevance of CPS and closely related skills for education and work is indicated by findings from the Programme for International Student Assessment (PISA; OECD, 2014) as well as the Programme for the International Assessment of Adult Competencies (PIAAC; OECD, 2013). Despite being a well-established construct in the field of education (Greiff et al., 2013; Sonnleitner, Keller, Martin, & Brunner, 2013), CPS research in an organizational context is still in its infancy with rare exceptions (see Abele et al., 2012; Kersting, 2001).

In a classical assessment approach called the Tailorshop, Danner (2011) and colleagues showed that CPS performance is closely related to professional success as measured by supervisor ratings. Only recently, Mainert, Kretzschmar, Neubert, and Greiff (2014) found positive empirical relations between CPS and career advancement even when controlling for other important cognitive predictors. Hence, CPS could be valuable to the study lifelong learning in occupational careers and a promising addition to personnel selection test batteries.

A multilevel approach to CPS: Individuals, enterprises, and countries

The importance of CPS for today's economy was analyzed in the LLLight in Europe research project on three different levels: the individual level, enterprise level, and country level. This multi-layered approach enables individual, cross-industry, and cross-country comparisons and serves to extend the understanding of CPS. All three levels are briefly introduced here:

Individual Level. A dynamic working environment puts more pressure on each individual to commit to lifelong learning in order to maintain, if not even increase, his or her lifetime income through increased salary, decreased unemployment risk, and lengthened tenure. These changes in the world of work in the 21st century have opened a new chapter of research on the prediction of career advancement as well as the assessments of skill sets required for human capital practices. Domain-general cognitive processes involved in CPS were investigated in order to explain performance in flexible and nonroutine tasks in modern jobs.

Enterprise Level. Like individuals, enterprises are forced to invest in lifelong learning to maintain, if not even increase, the human capital of the firm and eventually remain competitive. Efforts on an enterprise level are crucial since companies have a unique set of resources that can be applied to lifelong learning. Through purposeful Human Resource Management (HRM), companies are able to equip employees with a broad variety of transversal skills, while ultimately becoming more efficient and productive.

Country Level. Efforts on a country level are just as essential as the social and economic transformations from globalization have resulted in an increased demand for skills. Transversal skills in particular as a broad set of skills that are applicable to a wide variety of areas in life can help people cope with technology-rich environments, organizational changes, and competitive pressure in the global market. Countries are responsible for monitoring and facilitating the skills required to implement changes that will help them achieve prosperity and a high quality of life.

1.1 Major questions

On all three levels, four main questions guided this research:

A. How is CPS related to general mental ability (GMA) and occupational success?

B. Is CPS trainable?

C. Can individuals, enterprises, and countries increase their human capital by facilitating CPS skills and how?

D. Can CPS skills be considered a reflection of the amount of lifelong learning that an individual, enterprises or countries have engaged in? In other words does CPS have a particular Learning to Learn quality?

Answering these questions on three levels allowed us to investigate whether and how individuals, enterprises, and entire countries can facilitate CPS in order to increase the general well-being of people in society. To this end, we conducted individual, cross-industry, and cross-country comparisons of employees' CPS.
For these purposes, we modified an instrument from the cognitive research laboratory that enabled us to directly and easily assess CPS in adult populations in a work context using computer-based assessment. A detailed description of this assessment can be found in Chapter 4. Methodology.

1.2 Brief overview of the results

A brief overview of the results, presented separately for each of the four major questions A-D, will be given here. More detailed analyses and results are presented in the Observations, and Recommendations that follow later in the report.

A. How is CPS related to general mental ability (GMA) and occupational success?

The first underlying assumption of our research was that CPS enables individuals to deal successfully with complexity in their jobs by allowing them to recombine their innate cognitive capacities and is therefore an important skill in occupational careers. General mental ability (GMA; cf. Schmidt & Hunter, 1998) has been established as a construct that represents such innate cognitive capacities and is supposedly the best individual predictor of career success (Schmidt & Hunter, 1998). In our own research, we found that CPS and GMA were highly correlated in the sense that high levels of GMA predicted strong CPS performance. Furthermore, CPS predicted occupational success beyond reasoning, confirming existing research findings that CPS and GMA are highly related but yet distinct constructs (Wüstenberg et al., 2013).

B. Is CPS trainable?

Very little research has been conducted on the trainability of CPS, but research on the trainability of transversal skills has been growing consistently in recent decades.[1]
Fuchs et al. (2003) found that explicitly teaching skills so that they can be transferred facilitates both near- and far-transfer ability.
Training different types of inductive reasoning (e.g., generalization) was found to lead to increased persistence and transfer (Tomic, 1995).
Yeo (2007) postulated that meaningful learning consists of three crucial factors: problem definition, open communication, and utilization of resources; ongoing mentoring further promotes the acquisition of transversal skills, such as leader behavior.
By integrating transversal skill training (e.g., for creative thinking) into everyday work situations, employers can increase the face validity of a training, employees' motivation to participate, as well as their self-efficacy, while specifically schooling employees in company-relevant contexts, making transversal skill training profitable from the start (Leach, 2008).

In our own research, we looked at CPS score distributions within and between different companies and found that CPS scores in technology-rich environments were above the average of all companies. We argue that this might reflect the advantage of technology-rich environments, where employees have the opportunity to apply their CPS skills on a daily basis.
The prevalence of CPS in technology-rich environments has also been recognized in previous research, most notably the Program for International Assessment of Adult Competencies (PIAAC; OECD, 2013). The PIAAC study investigated problem solving in technology-rich environments (PSTRE) and found differences between countries in PSTRE proficiency. High levels of problem solving skills and participation in trainings were associated with higher levels of PSTRE, but differences in scores between countries were not consistent enough to rule out additional factors of influence, such as general cognitive ability or socio-economic status.

Going further, we also analyzed the relation between CPS performance and job complexity and found evidence for an interaction between the two constructs: We argue that high CPS performance increases an employee's chances of landing a highly complex job and that working a complex job most likely increases CPS performance due to consistent exposure to complex problems.

[1] Google scholar reports a rapid increase in searches on „transversal skills" from 1980-1989 (139 hits), 1990-1999 (885 hits), 2000-2009 (8,690 hits), 2010-today (15,800 hits), and 2015 (1,760 hits).

C. Can individuals, enterprises, and countries increase their human capital by facilitating CPS skills and how?

To understand whether and how individuals, enterprises, and countries can increase their human capital by facilitating CPS skills, we first looked at distributions of CPS across companies, sectors, and countries.
Cross-industry analyses of CPS scores were run to reveal differences in the CPS scores of individuals distinguished by company sector. We expected technology-rich enterprises to be the top performers on CPS tests, such as companies in the IT, engineering, and science sectors. If the empirical data supported this idea, it could be due to a work environment that requires CPS skills on a daily basis, thereby weaving continuous CPS training into everyday work situations, but other explanations for this pattern are plausible as well.

The distribution of mean CPS scores per country is at the center of understanding ways to improve human capital, and the corresponding pattern is shown in Figure 5 (p. 27). The results suggest that the variance in CPS scores varies strongly between countries. However, no clear pattern could be distinguished, and all results stemmed from data from an unrepresentative small sample, which could have led to biased outcomes.

D. Can CPS skills be considered a reflection of the amount of lifelong learning that an individual, enterprises or countries have engaged in? In other words does CPS have a particular learning to learn quality?

The answers this question combines every previous major question and will be given at the very end of the observations section. Using findings on CPS trainability, its relations to general mental ability and other constructs, and its impact on human capital, this section aims to answer whether and how CPS can be considered as a placeholder for measuring lifelong learning on all three levels discussed in this report.

1.3 The development of a CPS assessment

With respect to assessment, one goal of LLLight´in´Europe was to develop a measurement device that will provide a reliable measure of CPS. To this end, we further developed and applied a fully computer-based approach with sound psychometric qualities from previous research, resulting in a psychometrically sound assessment. In recent research, Greiff et al. (2015) attempted an overview of the history and current state of assessing complex problem solving, accumulating empirical and theoretical arguments for the importance of this CPS assessment approach.

More specifically, early research in the field resulted in great advances in the understanding of the CPS processes knowledge acquisition and application, but results were not comparable between these assessments because "complexity" had yet to be consistently defined. This changed once Funke (2001) advocated the use of formal frameworks to better compare assessment scenarios. Formal frameworks allowed scores to be summed across different scenarios, eliminating the scalability problem inherent in common single-task testing and thereby improving the accuracy of measuring complex problem solving. This was done by introducing frameworks that enabled the standardized description of CPS tasks, allowing for formal comparisons of underlying structures independent of surface features or semantic contexts of specific assessment scenarios. Since then, the framework has been constantly improved to produce better psychometric quality and more heterogeneity in the scenarios than previous assessment instruments had shown.
On the basis of this assessment approach, we obtained empirical data on actual learned transversal skills, which had not been previously available. The purpose of developing a sound CPS assessment was to know more about what people actually know, instead of relying on screening data, such as a person's level of occupation or number of years on the job. CPS comes into play when we aim to achieve a higher level of specificity on the whats, wheres, whens, and hows of lifelong learning promoted by politicians, business strategists, and individuals.

2. OBSERVATIONS[2]

2.1 CPS in relation to other transversal skills

Understanding different transversal skills and their relations to CPS can greatly enhance our understanding of CPS skills and thereby lead to more effective recommendations for trainings. Recent research findings on the relations between CPS and other transversal skills are discussed here:
Transversal skills are considered generative, meaning they can be utilized in a variety of contexts, hence increasing lifelong learning and employability (Sicilia, 2009). A good example of a transversal skill is time management. Time management is a skill that can be mastered during one's academic education (e.g., of a graduate in an IT course); however, it can be assumed that the graduate will be able to transfer his/her time management skills to a new environment (e.g., an entry-level job).

According to the TUNING research project (Sánchez & Ruiz, 2008), we can distinguish between instrumental, interpersonal, and systemic competences. Instrumental competences demand a combination of manual skills and cognitive capacity, such as analytical, reflective, or creative thinking as well as problem solving. High problem solving proficiency is achieved by being able to "develop solutions for unusual problems in matters with which [the students] are not familiar." Unfamiliar and previously unknown problems are the contexts to which CPS skills are applied and developed.

[2] as published in the Public Report „Transversal Skills, lifelong learning, and learning mechanisms" on the Person, Enterprise, and Country Levels.

Transversal skills, in general, are abstract in nature, which mandates that a person first acquires such skills in specific contexts before being able to transfer them to other domains. For example, our graduate could not exhibit such excellent time management skills in his professional life if he had not acquired this essential skill during his studies. In accordance with this learning process, transversal skills have to be tested in a contextualized (i.e., domain-specific) situation. In addition, tests including different contexts facilitate the evaluation of the domain-generality of the tested skill. Sicilia (2009) therefore recommends that transversal skills be tested using multiple tasks in different contexts in order to develop a better understanding of this domain-general skill that is as broad as possible while keeping the applications close to real-life work situations.

There are good reasons to assume, that understanding CPS skills and establishing efficient career management strategies go hand in hand, and for career management to be effective, it has to follow a relational approach (Anakwe et al., 2000). The relational approach focuses on understanding the context of work, a transversal skill also named environmental knowledge, and its interplay with self-knowledge and interpersonal knowledge. As CPS is considered to facilitate the acquisition of knowledge in general, CPS might also facilitate the acquisition of self-knowledge, interpersonal knowledge, and environmental knowledge, ultimately leading to realistic goal setting as well as the development, implementation, and adjustment of useful career strategies.

Transversal skills such as CPS are theoretically distinct but closely associated constructs of self-regulated learning as they represent the skills necessary to succeed in a dynamic world (Wolters, 2010). For example, by self-regulating one's organization, elaboration, and motivation, an individual can solve academic tasks more easily. This competency in self-regulated learning depends to some degree on effective problem solving and critical thinking skills. As with environmental knowledge (see Anakwe et al., 2000), CPS includes self-regulated learning, which in turn facilitates knowledge acquisition, general academic achievement, engagement, and persistence. Although the research by Wolters (2010) was conducted on undergraduates, we argue that his study's implications could be generalized to the working population because, from our point of view, there is no reason to believe that the underlying mechanisms of academic and job-related achievements are inherently distinct.

Further influences on transversal skills were discussed by Rocha (2011).[3] Transversal skills are seen as important predictors of employability and career development. Career adaptability, the ability to deal with present or anticipated tasks in one's vocational development, increases as one engages in qualitatively high vocational practices. This emphasizes the multi-context, multi-task approach to CPS assessment proposed by Sicilia (2009).

[3] As with Wolters' (2010) study, these findings come from an academic setting. Again, there is no reason to believe that the relations between transversal skills will be inherently different in academic and professional contexts.

Applying these assessment recommendations to training situations, transversal skills are best acquired and improved through real-life, versatile practice. In anticipation of our own research results, this might help explain the relation between CPS and lifelong learning or why higher job complexity is associated with higher CPS scores. For a more detailed discussion of this relation, see 2.3 Our Own Research Questions.

2.2 Previous research results that have informed this report

Some aspects of most of this report's main questions (A, B, C) can be answered by looking at previous research. In this part, we take a look at what recent research has generated on the nature and trainability of CPS separately for the individual, enterprise, and country levels. To reiterate, here are the first three main questions guiding this report:

A. How is CPS related to GMA and occupational success?

B. Is CPS trainable?

C. Can individuals, enterprises, and countries increase their human capital by facilitating CPS skills and how?

Not every question could be addressed on every level, e.g., the country-level analyses employed in previous research have focused solely on major question C, and major question D will only be answered as a synthesis of questions A.-C. in the observations section. We began addressing these questions by looking at the individual level, before proceeding to the enterprise and country levels.

Individual level. Workplaces are gravitating toward complexity as modern work organizations become increasingly focused on project-based tasks, implying a shift from repetition and routine to complexity (Autor, Levy, & Murnane, 2003).
These developments put greater pressure on each individual to commit to lifelong learning in order to maintain if not even increase his/her lifetime income through increased salary, decreased unemployment risk, and lengthened tenure. These changes in the world of work in the 21st century have opened a new chapter of research on the prediction of career advancement as well as the assessments of skill sets required for human capital practices. In this chapter, a look at the trainability of CPS and its influence on human capital is provided.

A. How is CPS related to GMA and occupational success

CPS has been found to be related to GMA but remains distinct and predicts job level and salary even beyond GMA (see 2.3 Our Own Research Questions).

In previous cognitive research in an educational context, CPS as the ability to solve complex problems independent of context (domain-general problem solving) was distinguished from related constructs, such as reasoning, working memory capacity (WMC), or domain-specific problem solving. All of these related constructs were found to be connected to but also distinct from CPS (e.g., Greiff, Wüstenberg, et al., 2013). Reasoning and CPS can be distinguished on the basis of the need for "experimental interaction with the environment" (Raven, 2000). The resources needed to solve complex problems might exceed the capacity of working memory, defining WMC as a limit to CPS (Wirth & Klieme, 2003; Bühner et al., 2008; Wittmann & Süß, 1999). There is a functional difference between WMC and CPS as CPS requires a much more complex interaction of planning, executing, and evaluating the aspiration of one or more goals (Funke, 2010). Research has found moderately high correlations between WMC and CPS (Bühner et al., 2008), further supporting the idea of connected yet distinct constructs.

B. Are transversal (CPS) skills trainable?

In childhood education, initiatives to enhance transversal skills date back to the beginnings of institutionalized schooling without a unified and valid underlying conceptual framework and valid instructional methods (Greiff et al., 2014). Stand-alone programs and programs that embedded transversal skills into the existing curriculum are two general educational approaches to transversal skills. Stand-alone programs offer a variety of separate lessons to foster thinking and problem solving skills but lack empirical evidence on significant or long-lasting effects (Jonassen, 2000). With respect to programs that embed transversal skills into the school curriculum, Barak (2013) pointed out the possibility of teaching students deep analyses and heuristics that are relevant in new problem situations that require the individual to learn on a continuous basis. Acquired via instructional training, these structured, semi-structured, and heuristic skills could accumulate into a portfolio of relevant problem solving strategies. For instance, Fuchs et al. (2003) investigated transfer effects of explicit teaching. To do so, students were taught to broaden their categorization of problems with the same solution method as well as to search for novel problems that could be solved within these categories. The researchers found an improvement in near- and far-transfer measures when explicitly teaching for transfer. Similar findings were reported earlier by Tomic (1995), who trained children in different types of inductive reasoning, most notably generalization, and found evidence for persistence and transfer.
These exemplary findings suggest the trainability of transversal skills and present ideas on how to prepare individuals to continuously tackle unforeseeable complex problem situations in the 21st century, and thereby maintain to be lifelong learners. However, the properties of effective CPS training still require further research. So far, research on training in general suggests different facilitators and boundary conditions.

Two such facilitators and boundary conditions are (1) job complexity (context) and (2) level of GMA (individual). (1) Kraiger, Ford, and Salas (1993) suggested that complex behaviors are internalized through continued practice. As CPS is a complex behavior, and complex jobs offer continued exposure to complex tasks that require continuous learning, employees in complex jobs have more frequent opportunities to practice CPS because of their work context. In this sense, complex jobs can be considered a path to continued CPS practice because complex tasks are a playground to learn how to learn per se. We will further examine the role of complexity in section 2.3. Our Own Research Questions.

With respect to the individual, (2) Lievens et al. (2003) understand GMA to be a main influence on learning and skill acquisition. They studied the validity of a wide range of predictors for selecting managers for an international training program and found GMA to be significantly correlated with language acquisition. Furthermore, high levels of GMA are a strong determinant of effective coping in unforeseen situations that are prevalent in modern jobs (LePine et al., 2000). This relation between GMA and job performance is mediated by task complexity, meaning that it is stronger for more complex tasks. These findings inform CPS training research in so far as GMA is a prerequisite for building CPS skills and thus a boundary condition.

Already two decades ago, Warr and Bunce (1995) anticipated the rising importance of open learning. Open learning refers to the enhancement of learning opportunities through learner-oriented learning, i.e., focusing on a learner's needs and interests. Conditions for a high learning curve are training attitude, an analytical approach to learning, and younger age. CPS fits into an "open learning" format as it represents an analytical approach to learning through strategic and domain-general knowledge acquisition and application. Thus, CPS could be considered a facilitator of the open learning of specific job skills.

In this regard, Ehlers (2013) emphasized the need to transfer "from knowledge acquisition to competence development." Pressured by growing uncertainty and complexity in the workplace, companies and employees alike need to shift their focus away from basic, theoretical knowledge acquisition toward "actionable knowledge" (Siemens, 2005), meaning that not only should employees be able to accumulate knowledge but they should also be able to apply it quickly in a variety of contexts. This shift demanded by Ehlers is in accordance with this Brief's emphasis on the importance of CPS, as Ehlers' focus on practical, versatile knowledge application conforms to our emphasis on training transversal skills and applying them directly on the job.

More specific findings on training methods that can help people deal more effectively with complex problems were summarized by Kluge (2008). Investigating the effect of three training methods on performance with different levels of task complexity, Kluge (2008) found that direct instruction outperformed both guided exploration and a mixed-method approach at all levels of task complexity.

In sum, CPS training research should focus on strategies that enhance CPS (e.g., the „learning to learn" skills knowledge acquisition, knowledge application) and be aware of facilitators and boundary conditions for learning CPS skills (e.g., job complexity, levels of GMA).). In open learning, CPS seems to be a promising candidate for a „learning to learn" skill that facilitates the acquisition of job-specific skills. Finally, direct training instructions are presumably a method of choice as previous research has suggested.

C. How can working individuals develop, support, and even increase their lifetime income and employability?

As CPS is considered to be strongly related to lifelong learning, it is assumed that a set of variables influence this skill. First, very recent research from PIAAC showed that self-reported socio-demographic characteristics are highly related to CPS-related skills such as problem solving in technology-rich environments (PSTRE; Desjardins & Ederer, in press). The OECD defines PSTRE as "using digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks" (PIAAC; OECD, 2013). With a focus on demographics, PIAAC found that foreign-born adults with a foreign language as a mother tongue were disadvantaged in their PSTRE as were adults with parents who never attained an upper secondary education. Likewise, adults without higher education were more likely to score at rudimentary levels on PSTRE. Educational and socio-demographic characteristics aside, ICT used at work and at home was found to be strongly related to proficiency. These results on socio-demographic characteristics do not explain learnability, but they do show a contextual influence, which is going to be examined more precisely in this report.

Second, in order to facilitate CPS, it seems promising to search for additional variables that affect CPS. Therefore, we set our focus on the impact of working conditions (e.g., perceived complexity in the workplace) on CPS. Finding relations between CPS performance levels with working conditions opens up possibilities for purposively designing conditions that enable people to achieve a high proficiency in CPS via different formal, informal, and non-formal activities that constitute the source pool of work skills. Referring to the Policy Brief "Resources of Skills," participants in such formal, informal, and non-formal trainings reported positive impacts on their efficiency and job security. In order to analyze the practice of such training opportunities, this Policy Brief compared employees from different EU countries, Africa, as well as South America. The most widely established types of informal learning activities were seminars and on-the-job trainings across all countries. Simultaneously, EU countries differed considerably in the training they provided due to differences in employers' support, costs, and work-family conflicts. This is where efforts for comprehensive informal training in general, and CPS training in particular, should begin. The report recommends that the European Commission provide incentives to national states and that national states provide incentives to firms.

Informal training should receive the same recognition as formal education for its widely demonstrated benefit in equipping employees with new, much needed skills. The Policy Brief also advises employees to seek informal training as it appears to be a key to sustainable employment.
Our empirical research findings provide additional grounds for the first empirical results in support of CPS trainability and efficiency, e.g., by looking at the empirical relations between CPS, job complexity, and job level.

Enterprise level. The shift toward complexity also forces enterprises to act if they want to maintain, if not increase, a firm's human capital and eventually remain competitive. Companies are able to equip employees with a broad variety of transversal skills, while ultimately becoming more efficient and productive. Ways in which companies can increase human capital as well as the best practices are subsequently discussed.

C. Can an enterprise increase human capital by facilitating CPS skills and training transversal skills and other lifelong learning activities and thereby become more valuable to its owners?

Again turning to pre-existing research, we also looked at how CPS interacts with innovation and entrepreneurial behavior and asked how a company can use CPS skills to become more innovative.

Leach (2008) viewed the ability for divergent (out-of-the-box) thinking as a direct precursor of increased creativity and innovation. In-depth knowledge facilitates creative thinking, whereas a positive assessment of one's own creativity is empowering. By "weaving innovation into the fabric and core values of learning" (Leach, 2008), companies can utilize employees' enhanced creative thinking skill sets for meeting company goals, as was already stated above.

While CPS skills and Leach's creativity are certainly not identical, we argue that there are some commonalities that legitimate a comparison. Both skills require divergent, out-of-the-box thinking and are needed primarily in complex and novel situations. Also, both involve processes for acquiring and applying new knowledge, and both are subsumed, together with other skills, under the term transversal skills, which describe the conglomerate of skills necessary to survive and flourish in the complex workplaces of the 21st century. Due to these similarities, a transfer of Leach's findings onto CPS, stating that CPS might best be used by "weaving it into the fabric and core values of learning," is a likely possibility. Of course, future research will have to test this hypothesis, which builds on the common underlying processes of knowledge acquisition and knowledge application.

Country Level. As seen in the individual and enterprise level analyses, CPS might be globally relevant for increasing workplace efficiency. Differences in CPS at the country level can be a good starting point for further analyses. Also, efforts on the country level are crucial, as the social and economic transformations from globalization result in increased demands for skills. Transversal skills in particular as a broad set of skills applicable to a wide variety of life areas can help people cope with technology-rich environments, organizational changes, and competitive pressure in the global market. Countries are responsible for monitoring and facilitating the skills required to carry out the changes to prosperity and a high quality of life. We look next at major question C to find out whether and how countries can increase their human capital by facilitating CPS skills.

C. How can a country increase its economic welfare by monitoring and facilitating CPS?

The Programme for the International Assessment of Adult Competencies (PIACC; OECD, 2013) revealed that countries differ in their level of problem solving proficiency in technology-rich environments (PSTRE), a skill closely related to CPS. Generally, four levels of competency are distinguished in PSTRE: below Level 1 (about 12.3% of the sample score at this level), Level 1 (29.4%), Level 2 (28.2%), and Level 3 (5.8%). The shape of the pattern depends primarily on level of education, job complexity, socio-economic background, immigration status, and training participation, although further research is needed to investigate possible alternatives. A brief overview of the factors of influence is given next.

Across countries, 52% of highly educated adults (tertiary level) have Level 2 PSTRE scores or higher. The percentage is higher in the Netherlands and Sweden and lower in Estonia and Poland (ranging from 36% to 64%). These levels typically involve tasks with the use of generic and more specific technological applications. In comparison, only 19% of adults at lower educational levels score at Level 2 or higher, varying between 7-10% (England, Ireland, and North Ireland) and 26-28% (Czech Republic, Finland, and Germany). It can be seen that a high level of education is associated with a higher level of PSTRE proficiency, but the differences between countries indicate additional factors. The survey also indicated that people in more highly skilled occupations, with a higher socio-economic background and without an immigration background, scored higher on PSTRE across and between countries. Again, the patterns differed between countries. For example, the differences between high- and low-skilled occupations are especially high in Norway, UK, Germany, Belgium, and Austria, and social equity and proficiency in PSTRE are high in Japan, Australia, the Netherlands, Norway, and Sweden, whereas they are below average in France, Germany, Poland, and the U.S. Again, the results show advantages in CPS-similar skills (i.e., PSTRE) for people in more highly skilled jobs and with higher socio-economic backgrounds, whereas immigration status is related to lower CPS proficiency.

Participation in adult training is highest in Denmark, Finland, the Netherlands, Norway, and Sweden and lowest in Italy, Cyprus, Poland, and Slovakia. Those with the highest levels of training participation are also most successful at extending opportunities for adult learning (highly educated workers are more likely to participate in lifelong learning opportunities).
To sum up, previous research suggests the trainability of transversal skills as well as the definitive impact of such skills on human capital. Due to the similarities between the presented transversal skills and the construct of CPS, the idea that CPS can also be trained to increase human capital within a company as well seems promising. However, there is no hard proof yet, and future research will have to focus on CPS in particular to verify this idea.

2.3 Our Own Research Questions

After presenting existing research, we will present our own research findings on the four major questions. To reiterate, here are all four main questions guiding this report:

A. How is CPS related to GMA and occupational success?

B. Is CPS trainable?

C. Can individuals, enterprises, and countries increase their human capital by facilitating CPS skills and how?

D. Can CPS skills be considered a reflection of the amount of lifelong learning that an individual, enterprises or countries have engaged in? In other words does CPS have a particular learning to learn quality?

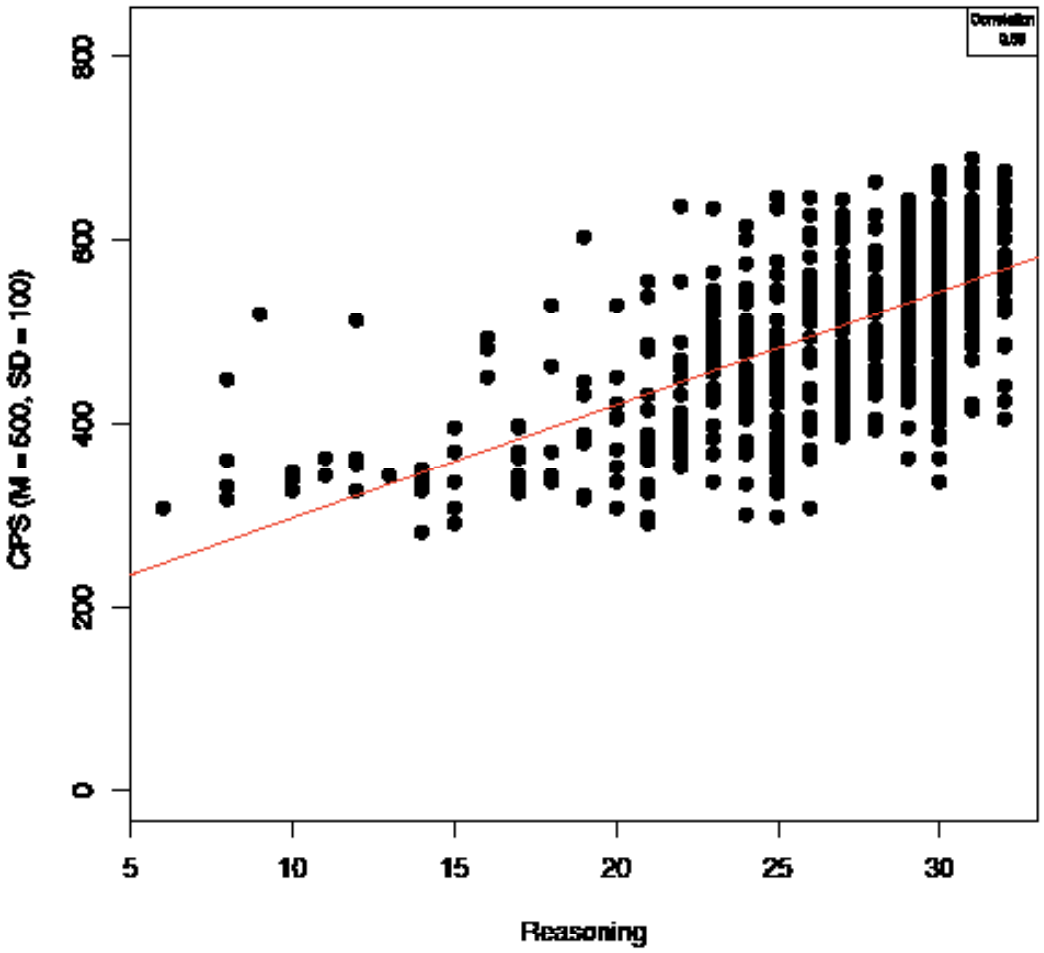
For both major questions A and C, we analyzed two separate questions. For question A, we looked at the relation between CPS and GMA (A1) and the relation between CPS and occupational success beyond GMA (A2). For question C, we explored the distribution of CPS across companies and sectors (C1) and the distribution of CPS across countries (C2). For question D, we report results of the PIAAC study that we introduced.

A1 How are CPS and GMA related?

The main finding here is that there is a close empirical relation (i.e., a high positive correlation) between reasoning as a proxy for GMA and CPS. Employees who exhibit a great deal of reasoning in their jobs and in general fulfill the requirements of CPS. Participation in adult training is highest in Denmark, Finland, the Netherlands, Norway, and Sweden and lowest in Italy, Cyprus, Poland, and Slovakia. Those with the highest levels of training participation are also most successful at extending opportunities for adult learning (highly educated workers are more likely to participate in lifelong learning opportunities).

To sum up, previous research suggests the trainability of transversal skills as well as the definitive impact of such skills on human capital. Due to the similarities between the presented transversal skills and the construct of CPS, the idea that CPS can also be trained to increase human capital within a company as well seems promising. However, there is no hard proof yet, and future research will have to focus on CPS in particular to verify this idea.

Figure 1: Relation between CPS and reasoning as a proxy for GMA



Note. The correlation between CPS and reasoning was significant (p < .000).

In a regression analysis, Figure 1 shows the relation between CPS and reasoning as a measure of GMA. This analysis revealed a significantly positive linear slope for reasoning as a predictor variable with p = .63, α < .000. A high parameter value in reasoning statistically predicted a higher value in the dependent variable CPS. Therefore, the CPS score was associated with employees' reasoning capacity but also involved variance that could not be explained by reasoning (rest = 1 - .63 = .37).

Previous research by Wüstenberg, Greiff, and Funke (2012) supported these findings. They identified a substantial amount of variance in CPS that was independent of reasoning.
Even further, Wüstenberg et al. (2012) reported the incremental predictive validity of CPS for school grade point average beyond reasoning. In a representative sample of secondary school students, Sonnleitner et al. (2013) also found support for the notions that (1) CPS is substantially related to reasoning and to different indicators of educational success, but (2) a major part of its predictive validity could be attributed to the variance that CPS shared with reasoning.

A2 How is CPS related to job level and salary when controlling for GMA?

As noted earlier, job levels are positively associated with employees' CPS skills. Further empirical findings indicate that CPS is a relevant skill that can be used to explain academic achievements beyond GMA (e.g., Greiff, Wüstenberg, et al., 2013). Further, in very recent research, Ederer and colleagues (2015) found that an increase of one standard deviation in CPS paralleled a 10 percent wage increase, and the returns for CPS were sizeable even after controlling for GMA.

Table 1: Regression Analyses

	Job Level		Income	
	Model (a1)	Model (a2)	Model (b1)	Model (b2)
Intercept	.00 (.29)	.00 (.32)	.00 (517.53)	.00 (522.20)
Reasoning	.25** (.01)	-.01 (.01)	.29** (19.10)	.00 (26.56)
CPS		.37** (.00)		.39** (1.34)
R^2	.06	.13	.08	.15
ΔR^2		.07		.07

*Note. Regression analyses showing the influence of reasoning on job level (Model 1) and income (Model 3) as well as the influence of reasoning and CPS on job level (Model 2) and income (Model 4). N = 229. Standardized regression coefficients and R2 values are reported. The standard errors (SE) of the unstandardized coefficients are in parentheses. CPS = Complex Problem Solving. The ΔR2 represents the comparison between Models (1) and (2) and Models (3) and (4). One-tailed p-values: *p < .05. **p < .01*

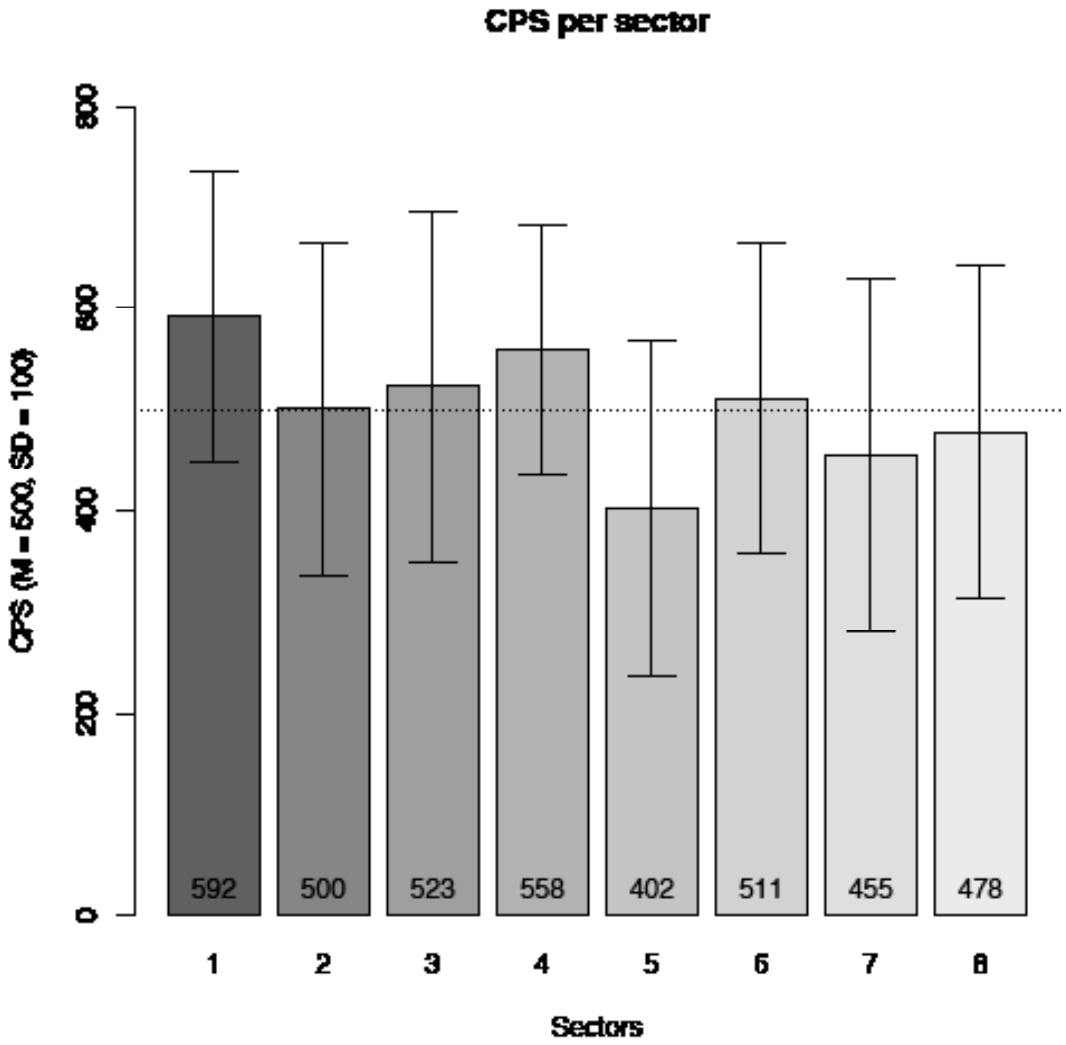
By computing a regression analysis on a sample of N = 229 participants from the same data set that Ederer and colleagues (2015) used, we confirmed the incremental effects of CPS on job level and salary beyond GMA (Table 1).

Our subsample contained all the necessary values for the variables of interest. We measured job level (Models 1 and 2) and job performance (Models 3 and 4) as employees' mean net income (i.e., salary). Standardized regression coefficients were used in this analysis. Model 1 revealed that reasoning ($\beta = .25$, $p < .01$) was a significant predictor of job level. Model 2, which included CPS ($\beta = .37$, $p < .01$), revealed that CPS significantly predicted job level and incrementally explained 7% of the variance in job level beyond reasoning. Reasoning ($\beta = -.01$, $p > .05$) remained nonsignificant. Similar results were obtained when salary was used as the outcome measure. Model 3, with reasoning as the sole predictor of income, revealed that reasoning was a significant predictor. In comparison with Model 3, Model 4 with reasoning and CPS, showed that CPS ($\beta = .39$, $p < .01$) explained an additional 7% of the variance in employees' salary, whereas reasoning ($\beta = .00$, $p > .05$) remained nonsignificant. In sum, CPS explained additional variance in individual job level as well as income beyond reasoning. These and other results (see also Abele et al., 2012; Kersting, 2001) point toward the practical value of CPS measures for explaining professional achievement when also accounting for GMA (Danner et al., 2011) and are in accordance with empirical evidence that has shown that CPS is an independent and relevant skill in job structures in the 21st century (e.g., Danner et al., 2011; Mainert et al., 2014).
More detailed findings are reported in the Public Report „Transversal Skills, lifelong learning, and learning mechanisms" on the person level.

B. How is CPS distributed across employees in different occupations and with different levels of job complexity?

Figure 2 shows the distribution of CPS scores, reported as means and standard deviations, among employees in different occupations, which were divided into eight sectors (IT, Engineering, Entrepreneurs, Management, Health, Science, Agriculture, and Others, such as Service Providers). Various companies represent these different sectors. The range of the means was 404 to 588. The average mean score was 500 with a standard deviation of 100. The IT sector scored the highest (588), whereas the scores for the sectors Engineering (500), Entrepreneurs (520), Management (550), and public and commercial Science (513) were quite similar on average with overlapping standard deviations. Lower scores in CPS were found for the "Other" category, for instance, service providers (482). The Agriculture sector (458) also scored slightly below the average of 500 with confidence intervals that overlapped with the „Others" category that contains, for example, customer service jobs. Finally, the lowest score was reported for the Health sector, which was mainly comprised of medical caregivers, with an average score of 404.

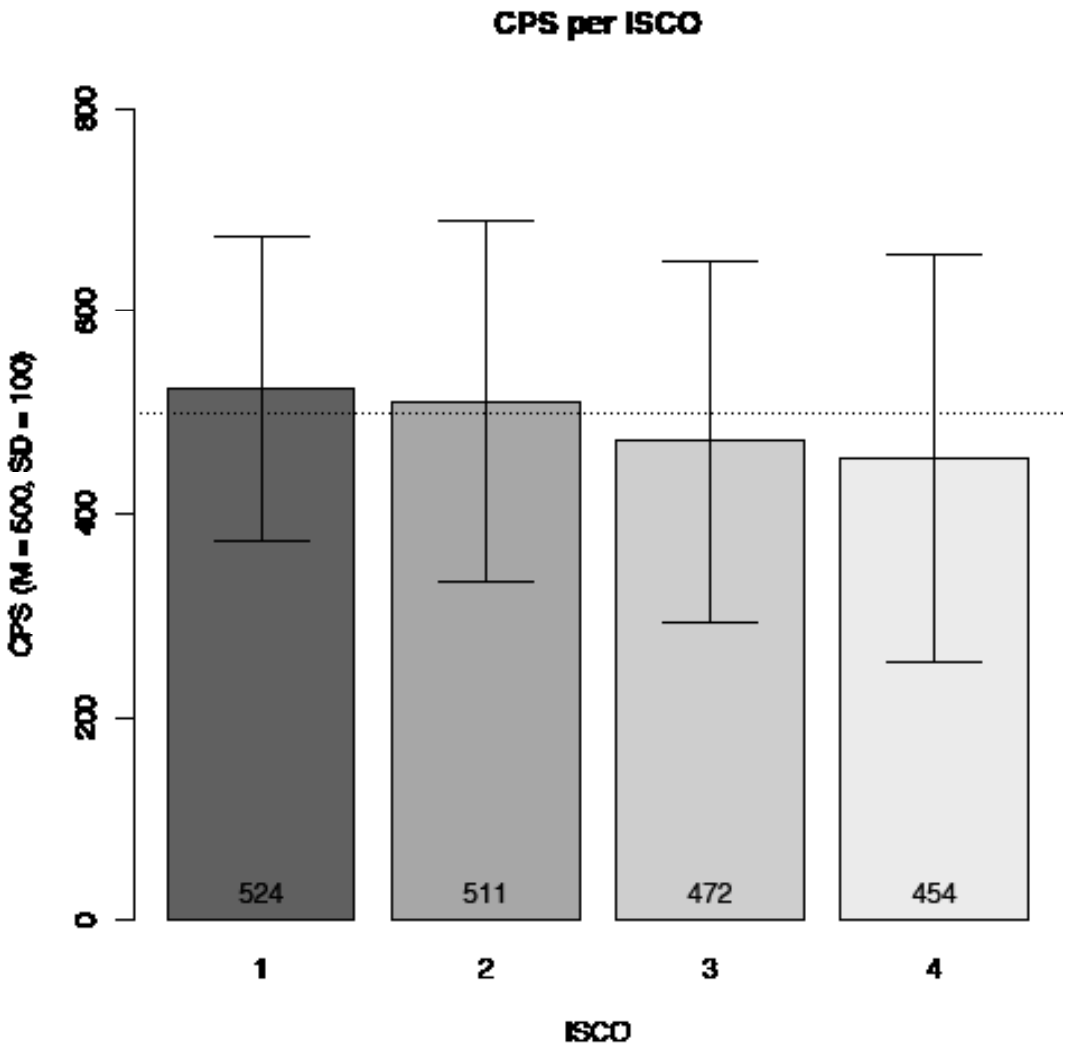
Figure 2: Company sectors and their respective CPS scores and standard deviations



Note. Sector 1: IT (73 participants); 2: Engineering (267); 3: Entrepreneurs (194); 4: Management (33); 5: Health (93); 6: Science (40); 7: Agriculture (175); 8: Other (service providers and students; 85)

In our non-representative convenience sample that was derived from more than 30 cooperative companies, workers in technology-rich environment sectors such as IT, Management, or Science scored above average, whereas people who predominantly worked in the health sector scored the lowest. All in all, knowledge workers in technology-rich environments were the top-performers on these CPS tests. This could reflect the advantage of technology-rich jobs whereby employees have the opportunity to apply their CPS skills on a daily basis.

Figure 3: Relation between CPS and occupational level, based on the international standard classification of occupations (ISCO)

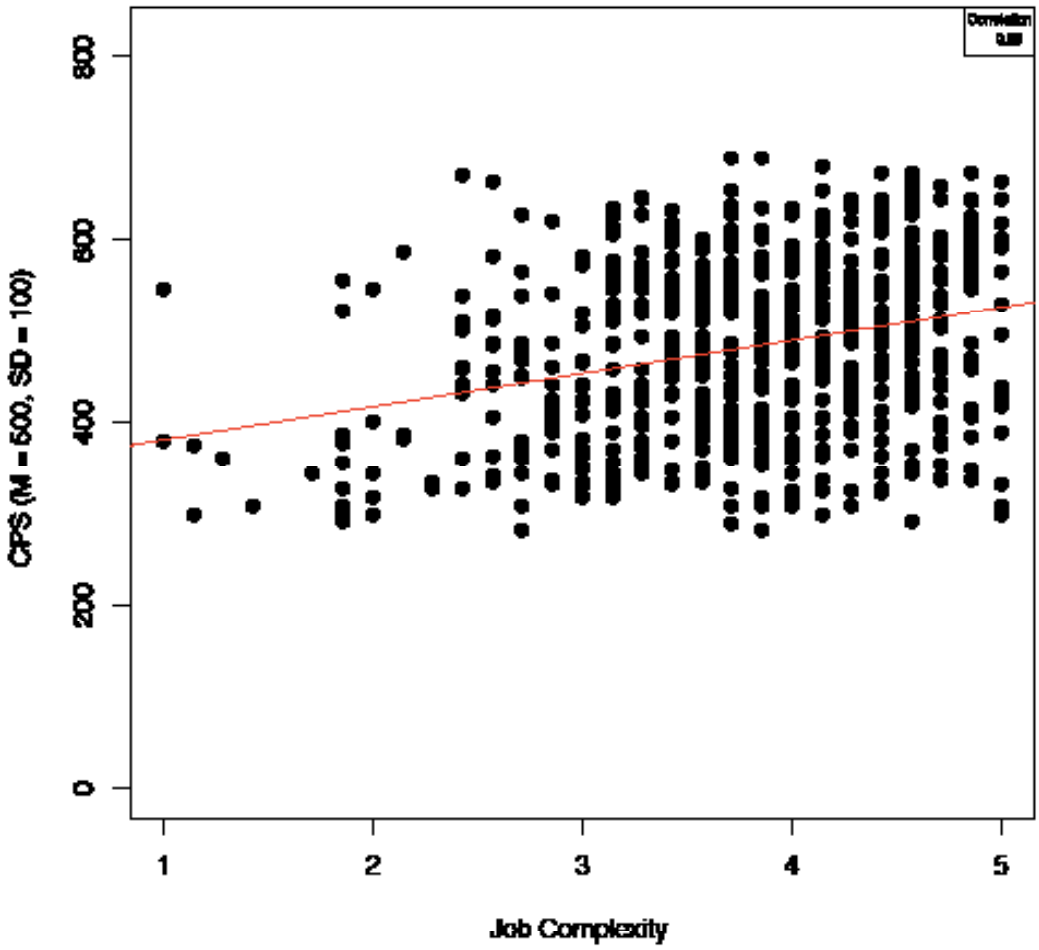


Note. ISCO level 1 (highest) with N = 98, level 2 with N = 352, level 3 with N = 99 and level 4 with N = 2

Figure 3 shows the CPS scores, reported as means and standard deviations, for different job levels. The means ranged from 455 (e.g., assembly line workers) to 520 (e.g., Management). These results might illustrate that higher job levels have an advantage in facilitating a high proficiency in CPS test performance. Here, as the job level of any employee increased, the mean level of CPS proficiency increased as well. Concerning the large number of overlapping confidence intervals, it is important to mention that the results reflect only trends in differences in CPS proficiency. Considering the competition in the job market, high-performers on CPS tasks might have better chances in the job market. Furthermore, those seeking higher level jobs in the job market might have plenty of opportunities to facilitate their CPS skills even more.

The second main finding here is that CPS skills are more prevalent amongst individuals who work in more complex work and learning environments, whereas CPS skills are also a precondition for getting into these complex jobs. However, the correlative nature of results made it impossible to draw conclusions about causality in either direction. The complexity of a job is based on many unique problems, which each pose a challenge and also offer an opportunity to learn on a continuous basis. It is relevant to mention that CPS could be associated with other unexamined skills (e.g., creativity). To some extent, these complex environments may promote the „learning to learn" skills of knowledge acquisition and knowledge application that constitute CPS. Complex work environments can thus be considered a source of lifelong learning. Therefore, CPS can be seen as a precursor, aggregate measure, reflection and outcome of lifelong learning.

Figure 4: Relation between CPS and Job Complexity



Note. The correlation between CPS and job level was significant (p < .01)" at .28.

Complex environments measured by the complexity of jobs[4] may promote employees' CPS skills. Figure 4 shows a regression analysis of job complexity in relation to employees' CPS score. Here, the graph reveals a positive linear slope for the dependent variable CPS with $r = .28$, $p < .01$.

Therefore, a high parameter value in complexity is associated with a high CPS score. However, the correlative nature of the results made it impossible to draw conclusions about causality in either direction.
More detailed findings on this analysis are reported in the Public Report „Transversal Skills, lifelong learning, and learning mechanisms" on the person and enterprise levels.

C.1 How is CPS distributed across companies and sectors?

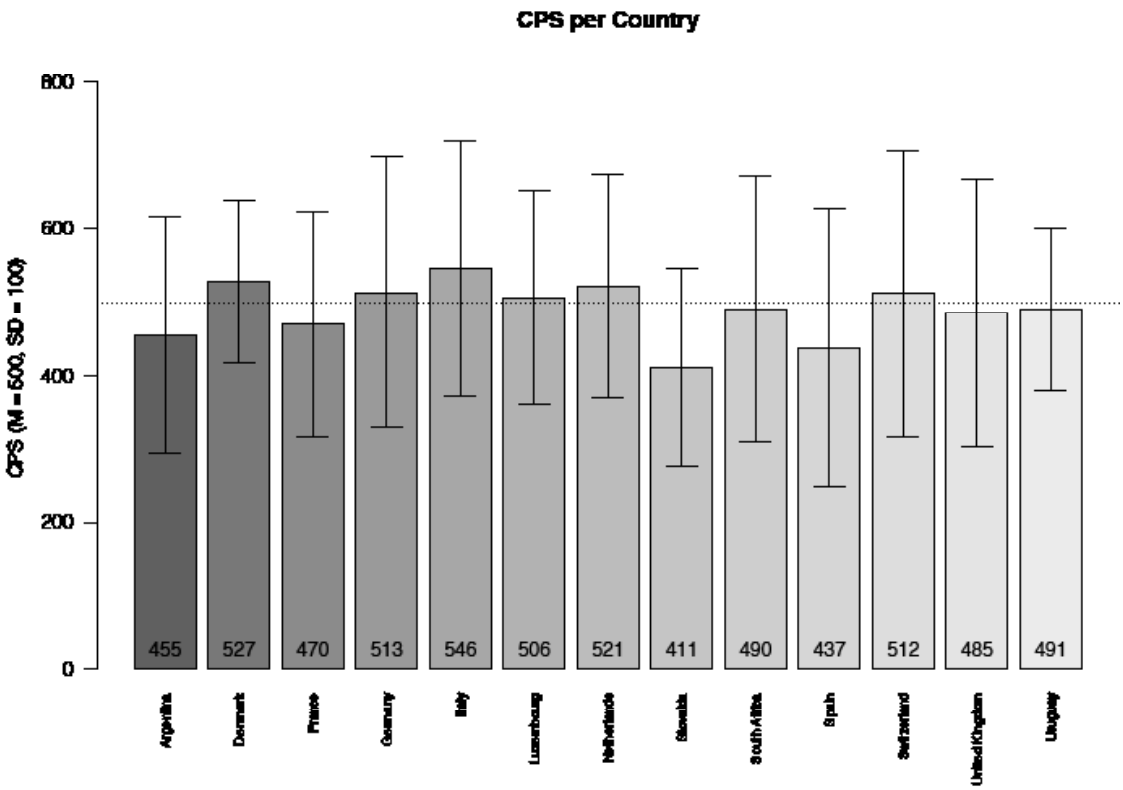
As part of our own research, we looked at the current distribution of CPS skills across different working sectors.
The companies that we surveyed were divided into sectors, and their respective CPS scores were computed. As can be seen in Figure 2, technology-rich enterprises were the top-performers on CPS tests, as companies in the IT, engineering, and science sectors showed average to above-average scores. This could be the result of a working environment that requires complex problem solving skills on a daily basis, thereby weaving continuous CPS training into everyday work situations. However, there is currently no formal, evidence-based CPS training available. Building on this policy report, future research should try to combine the findings described in this brief with the upcoming recommendations to develop a research-based CPS training that can be used in a variety of workplace contexts.
More detailed findings are reported in the Public Report „Transversal Skills, lifelong learning, and learning mechanisms" on the enterprise level.

C.2 How do countries differ in their CPS skills?

Within the limits of a non-representative convenience sample, mean CPS scores differed by country but did not show an obvious pattern.

[4] To measure job complexity, each participant answered seven questions from the Federal Institute for Vocational Education and Training Survey (BIBB; Rohrbach & Schmidt, 2013). For further details, see the Policy Brief „Transversal Skills" on the person level (p. 11).

Figure 5: Means and standard deviations for CPS proficiency across thirteen countries



Note. "Argentina (N = 55 participants), Denmark (N = 20), France (N = 10), Germany (N = 420), Italy (N = 73), Luxembourg (N = 10), The Netherlands (N = 60), Slovakia (N = 40), South Africa (N = 56), Spain (N = 137), Switzerland (N = 20), United Kingdom (N = 22), and Urug

Figure 5 shows the means and standard deviations for the CPS proficiency of thirteen different countries (Argentina, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Slovakia, South Africa, Spain, Switzerland, United Kingdom, and Uruguay) on three continents. The means ranged from 418 to 539 points with an average of 500 and a standard deviation of 100. The Netherlands, Germany, Luxembourg, and Denmark had quite similar scores and were the highest at around 510-540 points with overlapping confidence intervals. In comparison, France, South Africa, Switzerland, and Uruguay scored lower from to 488 to 498 with really close means. Argentina, the United Kingdom, Spain, and Slovakia showed relatively low scores at 418-457 points with overlapping confidence intervals.

Furthermore, it is interesting that the ranges of the error bars differed: While the United Kingdom, Uruguay, and Denmark showed confidence intervals with ranges of about 200 points, the intervals of most other countries were larger at about 350 points. On the basis of non-representative data, this result suggests that the samples from the United Kingdom, Uruguay, and Denmark were less diverse than the other samples. Again, no clear pattern was found, and all results were based on non-representative data. More detailed findings are reported in the Public Report „Transversal Skills, lifelong learning, and learning mechanisms" on the country level.

D. Can CPS skills be considered a reflection of the amount of lifelong learning that an individual, enterprises or countries have engaged in? In other words does CPS have a particular learning to learn quality?

According to Funke (2001), we defined CPS as a non-routine analytical skill involving domain-general mental processes that are required across diverse complex problems. These processes are to acquire and apply knowledge in its broadest sense. Like transversal skills in general, these abstract processes can, if internalized and mastered, be applied to a variety of other, previously unknown contexts. Kraiger, Ford, and Salas (1993) suggested that this internalization of complex behaviors can be achieved through continued practice. For transversal skills in general, Sicilia (2009) recommends that they be tested using multiple tasks in different contexts in order to develop a better understanding of these domain-general skills while keeping the applications close to real-life work situations.

As CPS is a complex behavior, and complex jobs offer continued exposure to complex tasks that require continuous learning, employees in complex jobs have more frequent opportunities to practice CPS because of their work context. In this sense, complex jobs can be considered a path to continued CPS practice because complex tasks are a playground to learn how to learn per se. CPS can therefore be utilized as a reflection of an individual's amount of lifelong learning.

The relation between CPS level and the complexity of jobs is supported by current research findings: As was already elaborated above, the PIAAC study (OECD, 2013) analyzed problem solving skills in technology-rich environments (PSTRE) and identified high job complexity as substantially correlated with PSTRE. Our own research supports this finding. The increased demand within highly complex jobs to fulfill complex tasks therefore leads to increased problem solving skills.

PIAAC also associated high levels of problem solving skills and participation in training with high levels of PSTRE, meaning that the current ability level as well as continued practice influence PSTRE proficiency.

Complex jobs therefore facilitate CPS while CPS allows one to be successful in complex jobs.

Regarding career paths, Rocha (2011) found transversal skills to be an important predictor of employability and career development. Career adaptability, the ability to deal with present or anticipated tasks in one's vocational development, increases as one engages in qualitatively high vocational practices, i.e. situations requiring CPS skills. Transversal skills appear to have a learning to learn quality that enhances career adaptability, ultimately increasing employability. Also, Wolters (2010) found transversal skills such as CPS to be theoretically distinct but closely associated constructs of self-regulated learning as they represent the skills necessary to succeed in a dynamic world. This competency in self-regulated learning depends to some degree on effective problem solving and critical thinking skills.

CPS can be thought of as including self-regulated learning, which in turn facilitates knowledge acquisition, general academic achievement, engagement, and persistence, further emphasizing the learning to learn quality inherent in CPS. Most of the current research findings deal with transversal skills in general as a measure of lifelong learning. However, CPS is a very similar construct within the broader framework of transversal skills. This close theoretical relation and the fact that our own research findings, which focused on the same relations but looked specifically at CPS, propose similar relations, suggests that a thoughtful transfer of ideas and findings from transversal to CPS skill research is justified. CPS could therefore be seen as a reflection of the amount of lifelong learning an individual, enterprises, and countries have engaged in.

3. CONCLUSIONS AND RECOMMENDATIONS

We analyzed CPS data from 1129 individuals residing in 13 countries in 40 enterprises from 8 different industry sectors and formulated recommendations for specific policies and lifelong learning opportunities to improve their CPS skills, thus aiming to increase their prospects of securing well-paying employment and high productivity. The complexity of jobs appears to require, and simultaneously promote CPS within the limits of individuals' innate cognitive capacities, and can thus be considered a source of CPS as a „learning to lifelong learn" skill set. Furthermore, CPS seems to be closely related to self-regulated learning, career adaptability, and other skills that are essential to lifelong learning. Although most research has been carried out on the broader concept of transversal skills, the closeness of the two constructs and the strong fit of previous transversal skills research with our own CPS research support our claim of CPS as an adequate and practical reflection of the amount of lifelong learning individuals, companies, and countries have engaged in. Specifically, we consider CPS to be a transversal, „learning to learn" skill set of how to systematically acquire and apply new knowledge that enables people (a) to purposefully exploit their innate cognitive capacities and (b) to acquire job-specific skills. Hence, we encourage individuals to select employment on the basis of the opportunities that jobs offer for CPS improvement, thereby offering prospects for employability even into late age. Organized by the first three main questions A.-C. that guided this research, we will delineate recommendations for how individuals, enterprises, and countries can increase their prospects.

A. How is CPS related to general mental ability and occupational success?

CPS has been found to be closely related to yet distinct from constructs such as general mental ability, working memory capacity, and reasoning. CPS has shown incremental validity in predicting job level and salary beyond related constructs. With respect to its relations to occupational success, previous research has reported that transversal skill training in general can have long-term effects on employees' satisfaction or company revenue, although it is yet unclear how additional variables factor into the equation.

Recommendations regarding the importance of CPS for occupational success will be given next on all three levels.

Individual-Level Recommendations

- Embrace complexity. Employees should practice constructively coping with any feedback they receive about their work performance in order to be mentally open to improvements and lifelong learning.

Enterprise-Level Recommendations

- Utilize on-the-job training. It increases employees' acceptance of the training, thereby augmenting motivation, the acquisition of transversal skills, and self-efficacy. Overall increases in employee satisfaction can in turn lead to increased long-term revenue and employee retention.

Country-Level Recommendations

- Facilitate and subsidize the implications of CPS trainings. Increased metacognitive skills are correlated with job performance. On a larger scale, increased job performance across many companies will increase a country's economic revenue.

B. Is CPS trainable?

Previous research has revealed rather clear results on the trainability of transversal skills in general. Open communication and teaching, teaching in a variety of contexts, integration into everyday work situations, and ongoing mentoring throughout the training all facilitate successful transversal skill acquisition. Barak (2013) pointed out the possibility of teaching students a portfolio of relevant problem solving strategies. However, the transfer of these findings to the construct of CPS has been based primarily on the similarity between the constructs that have been researched and CPS. Further research, specifically aimed at CPS, is needed to support the idea that CPS is trainable, too. We will next provide recommendations for CPS training on all three levels.

Individual-Level Recommendations

- Train transversal skills early on. Transversal skills are positively correlated with GMA, and both are valuable for job performance, such as salary.

- Practice lifelong learning. Transversal skills are increasing in importance due to an increase in complexity in today's occupational life. Work demands will continue to shift and change at a high pace, and continuous CPS training enables individuals to stay ahead of the complexities and react to dynamic changes.

Enterprise-Level Recommendations

- Differentiate work areas within a company by the respective CPS demands of the work as this is a useful criterion for classification. Every company should ask itself which jobs demand how many non-routine, complex problem tasks in comparison with the rest.

- Efforts directed toward the awareness, selection, and training of CPS should focus on specific target groups that work in dynamically changing, technology-based environments. As an example, CPS testing can be used as a measure that complements candidate selection, job-candidate-fit measures, or the composition of work teams.

- Strengthen CPS skills, especially in CPS-heavy positions, as this is essential for improving a company's human capital. Employees in less CPS-heavy positions should be compensated with cognitive trainings.

- Successful leadership behavior can facilitate problem-solving-oriented behavior. Therefore, future leaders should be supplied with trainings for enhancing their transversal skills, such as creativity, motivational ability, or time management. These trainings are ideally accompanied by long-term mentoring.

Country-Level Recommendations

- Embrace transversal skills as an essential prerequisite for successful careers in a variety of occupational areas.

- Provide guidelines and benefits for individuals and companies that engage in transversal skill trainings and lifelong learning.

C. Can individuals, enterprises, and countries increase their human capital by facilitating CPS skills and how?

Recent research has shown the importance of lifelong learning for increasing CPS skills in the short run and human capital in the long run. However, further research is needed to provide more definite and more detailed information on the relation between CPS and human capital. Listed below are research-based recommendations for increasing human capital through CPS on all three levels.

Individual-Level Recommendations

- Engage in continuous CPS training. Adults in highly skilled positions have been found to engage in more adult training, and adults who partake in adult training are more likely to be found in highly skilled positions.

Enterprise-Level Recommendations

- Connect CPS training to company goals, e.g., through on-the-job training. This can help reach company goals (e.g., increased efficiency, long-term revenue, or employee retention) faster.

- Focus on innovative positions (e.g., managers, project leaders) first when conceptualizing CPS trainings, as these employees have the highest demand.

- Successful leadership behavior can facilitate problem-solving-oriented behavior. Therefore, future leaders should be supplied with trainings for enhancing their transversal skills (e.g., creativity, motivational ability, or time management). These trainings are ideally accompanied by long-term mentoring.

- Give incentives to participating employees. This can increase their motivation to participate continuously and thereby facilitate lifelong learning.

Country-Level Recommendations

- Implementing long-term training schemes facilitates CPS training and lifelong learning.

- Provide guidelines and incentives for individuals and companies to engage in lifelong learning, thereby distributing and increasing the effort to promote CPS training.

- Promote high minimum wages in order to nudge companies towards the provision of more complex jobs that facilitate the companies' productivity, as higher minimum wages force companies to create productive, and thus more complex jobs.

A prerequisite and core output of this research project is the CPS assessment tool, which is reported in detail in Chapter 4. Methodology. Eventually, future research across various fields (e.g., economics, business innovation, educational design, or social welfare, etc.) can make use of an instrument that yields empirical data on actual CPS skill levels, which so far has not been available.

4. METHODOLOGY

4.1 Sample

Testing took place in 12 different countries (Argentina, Denmark, France, Germany, Luxembourg, Netherlands, Slovakia, South Africa, Spain, Switzerland, United Kingdom, and Uruguay) on three different continents. Data from 1129 employees (38.1% female, 60.7% male) were available for the analyses. Ages ranged from 18 to 64 with a mean of 36.2 (SD = 11.76).
Different testing tools and materials were used to assess CPS proficiency, reasoning, as well as job level and complexity. These are presented next.

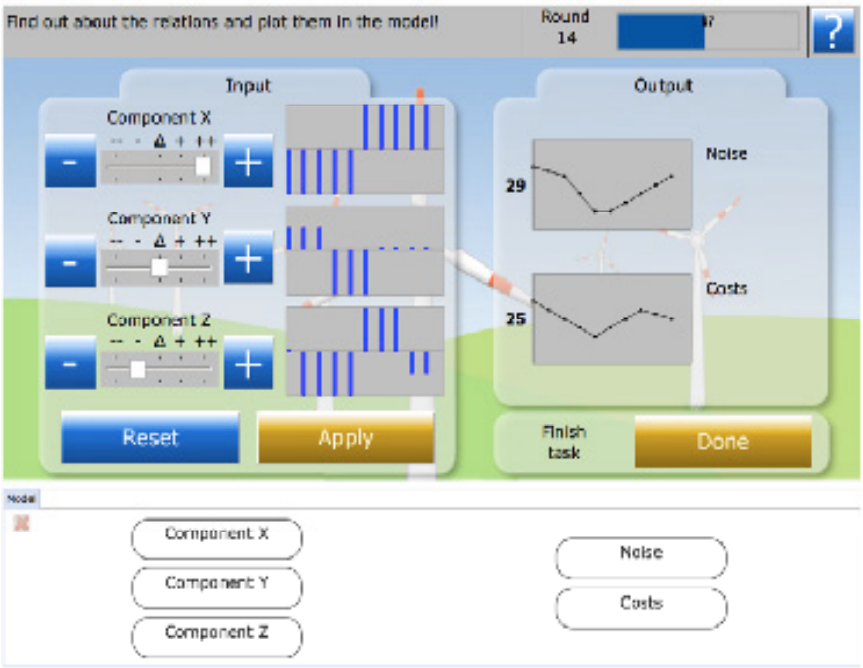
4.2 Material

A comprehensive assessment of CPS skills was conducted using two computer-based instruments, MicroDYN and MicroFIN (7 items each), which have both been validated in the educational context (e.g., Greiff et al., 2013; Neubert et al., 2014) and can be applied as good measures of lifelong learning activities (e.g., knowledge acquisition, knowledge application).
MicroDYN is a computer-based CPS assessment tool with good psychometric qualities (consistent Cronbach's α >.70) and validity (Greiff, Fischer, et al., 2013; Schweizer et al., 2013 ; Wüstenberg et al., 2012). In line with current research, MicroDYN allows the administrator to assess the two core aspects of CPS that can be considered lifelong learning activities: knowledge acquisition and knowledge application (cf. Fischer et al., 2012), which we presume play significant roles in complex and technology-based jobs. In the MicroDYN simulations, problem solvers have to detect causal relations between several variables in the exploration phase (knowledge acquisition). After acquiring information about the system, problem solvers are asked to reach certain target values in the control phase (knowledge application). Figure 6 explains how these two phases are implemented in the MicroDYN Wind Power Station task. Defining CPS as a domain-general, analytical skill, we used tasks that allowed us to reduce the effects of prior knowledge while still being realistic and motivating.

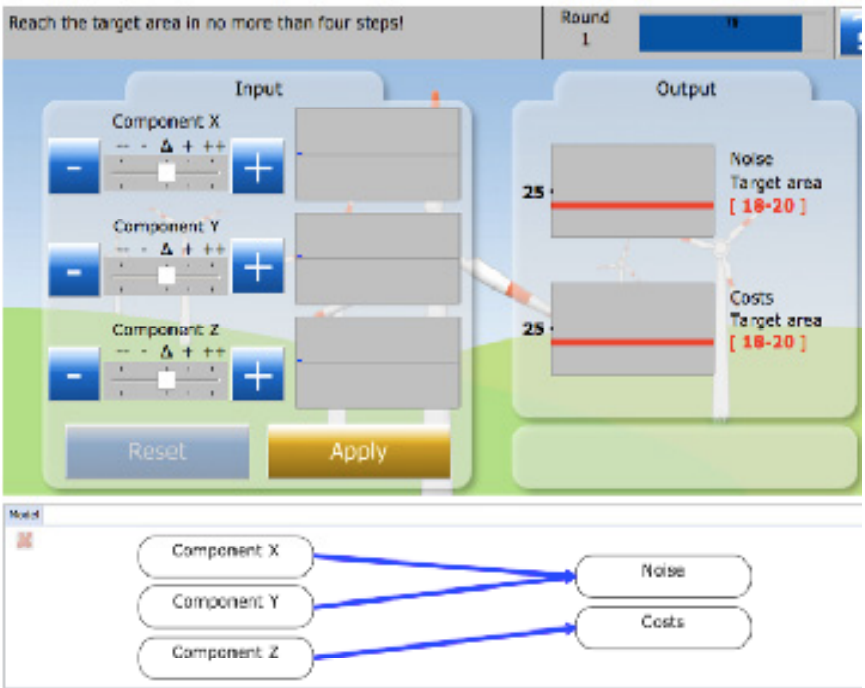
7 items were presented with different levels of complexity due to varying relations between variables (quantity, strength, pattern). The testing time was 35 minutes, including two trial laboratory tasks. Each task consisted of 3.5 minutes of unguided exploration followed by 1.5 minutes of controlling and applying acquired knowledge. At no point during the instructions was information given about how to best explore, understand, or control the tasks. The set of 7 tasks included 24 items and 24 performance indicators for three dimensions: information retrieval, model building, and forecasting. The actions of the participants were automatically recorded. The two facets of knowledge acquisition and knowledge application were combined into a general CPS factor (i.e., a latent second-order factor), following Kretzschmar et al.'s (2014) recommendations. A closer look at the scoring is presented next for the second CPS measure MicroFIN.

Figure 6: Screenshot of the MicroDYN Wind Power Station task

Left side:



Right side:



Note. Screenshot of the MicroDYN Wind Power Station task. Left side: Exploration phase. X, Y, and Z influence noise and costs. Participants are asked to draw their acquired knowledge about the relations in an onscreen causal diagram (Funke, 1985, 2001; see bottom of Figure 1, left side). Right side: Control phase (cf. Wüstenberg et al., 2012). Target values for each output variable (red areas and numbers in brackets) have to be met within a maximum of four steps.

Note. Screenshot of the MicroDYN Wind Power Station task. Left side: Exploration phase. X, Y, and Z influence noise and costs. Participants are asked to draw their acquired knowledge about the relations in an onscreen causal diagram (Funke, 1985, 2001; see bottom of Figure 1, left side). Right side: Control phase (cf. Wüstenberg et al., 2012). Target values for each output variable (red areas and numbers in brackets) have to be met within a maximum of four steps.

MicroFIN tasks are multiple, dynamic tasks based on a slightly different formal framework of finite state automata (Buchner & Funke, 1993) with good reliability (McDonald's $\Omega = .78$) and convergent validity (correlation with MicroDYN : $r = .56$ to $.73$; cf. Neubert et al., 2014). Input variables influence output variables in a certain relation. Test-takers are asked to explore and derive this causal structure. Test items contain values that change dynamically with the user's interaction and various nontransparent interactions between variables, such as threshold or equilibrium states in the input variables (Fischer et al., 2012). MicroFIN tasks are, e.g., managing a concert hall (variables: type of music, price level, atmosphere) or planning a city (needs of different interest groups).

Two items per task asked participants to explore several states and relations and, from there, to derive the causal structure of the task (i.e., knowledge acquisition). Subsequently, one more item per task asked participants to apply their knowledge to manipulate each task toward achieving a previously set goal to thereby gain control over the system, or in other words, to solve the complex problem (i.e., knowledge application). Both phases contributed to a general CPS performance score.

Testing time was 5 minutes per task, including item of both knowledge acquisition and knowledge application, or 35 minutes in total. The performance-based measure of CPS stemmed from theoretical considerations (Greiff, Holt, et al., 2013) and was empirically validated (Neubert et al., 2014).

Figure 7: Screenshot of the MicroFIN item "Plan-o-mat" (Neubert et al., 2014)

Note. Screenshot of the MicroFIN item "Plan-o-mat" (Neubert et al., 2014). Problem solvers have to balance the interests of various parties in a city by making alterations to the urban landscape. Along the bottom and the right side: the keys for altering the location of the interest groups. In principle, two stakeholders change places when triggered. On the right side: a city mall and a factory. On the left side: a family home and a playground. Between these parties, smiley faces indicate the atmosphere. The problem solver has to improve the atmosphere by finding one of several optimal setups.

To examine the relations between CPS and reasoning, job level, and salary in the modern work context (see question A), in particular the incremental value of CPS beyond reasoning, we assessed these constructs using the tools described below.

Reasoning was assessed using Raven's Standard Progressive Matrices (SPM). SPM assesses non-verbal intelligence and logical reasoning through the ability to recognize a certain order within apparent disorder. Items with different levels of difficulty were presented, and participants had to select one of the given solutions. Test form S5 was used, which is a short form of the SPM, consisting of 32 Rasch-homogenous items with a time limit of 15 minutes.

Participants' job level was classified and ranked according to the International Standard Classification of Occupations (ISCO-08; International Labor Office, 2012). ISCO-08 is a hierarchically structured four-level classification, categorizing all jobs in the world into 10 major groups of decreasing skill levels. Managers (1) are aggregated into the first major group, professionals (2) in the second, followed by technicians (3), clerical support workers (4), service and sales workers (5), skilled agricultural workers (6), craft and trade workers (7), plan and machine operators and assemblers (8) and so on. The ISCO-08 contains a detailed description of every job level.

We used a slightly adjusted ranking as explained in detail in Policy Brief „Transversal Skills“ on an individual level. In sum, ISCO-08 reflects job complexity and ranks the advancement of an individual´s career.

4.3 Selected Background Questions

A background questionnaire was used to gather information on demographics, work behavior, income, attitudes, and personality.
First, job complexity was assessed and used in a regression analysis (Table 1) to analyze its relation to CPS. The basic idea underlying the assessment of job complexity is that each job consists of different tasks ("problems"). These can be described with various levels of complexity and pose a concurrent challenge to and opportunity for learning. It is assumed that the amount of learning in this kind of learning environment depends on job complexity: The gap between the skill level that is possessed and the level of task complexity is higher in complex jobs as they provide more complex tasks in larger quantities. Thus, higher gaps facilitate and increase the potential for learning. To measure job complexity, each participant answered seven questions from the Federal Institute for Vocational Education and Training Survey (BIBB; Rohrbach & Schmidt, 2013). These questions are based on the concept that every job is a conglomerate of tasks of different complexity levels (Nedelkoska, Patt, & Ederer, 2014). Due to its complexity, every job creates a learning environment in which employees can learn by completing a task. How much they can learn depends on the difference between their current skill level and the complexity of the task. Therefore, more complex jobs offer greater opportunities for learning. Questions that ask about job complexity include items on flexibility (how often employees have to react to unexpected problems), novelty (how often employees have to improve a process or try out something new), responsibility (how often employees have to make difficult decisions by themselves), and other related constructs.
Making sure that these seven items indeed represent one common factor (i.e., job complexity), a principal component analysis (PCA) was computed. The PCA results were consistent with the one-factor theory, meaning that all seven items represented job complexity.
As a result, we used a sum score compiled of all seven items to describe job complexity.

Income was operationalized as the monthly net labor income from the participant's main job. This was also used later in regression analysis as an indicator of salary.

4.4 Statistical Methods

Descriptive statistics including means were computed to determine how company sectors differed in their CPS skills. We show the CPS scores for 8 different sectors, namely IT, Engineering, Entrepreneurs, Management, Health, Science, Agriculture, and other (see Figure 1).

In order to determine how countries differed in their CPS skills, we computed the CPS points for 12 countries. Further investigations focused on the question of how countries differed in their CPS skills per occupation such that we compared the mean number of CPS points for 11 countries depending on their ISCO level.
We used multiple regression analyses to examine question B2 (How are CPS, job level, and salary related to each other when controlling for GMA?).

All statistics were calculated using the R software package.

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PROJECT IDENTITY

LLLight'in'Europe is an FP7 research project supported by the European Union, which has investigated the relevance and impact of lifelong learning and 21st century skills on innovation, productivity and employability. Against the background of increasingly complex tasks and jobs, understanding which skills impact individuals and organizations, and how such skills can be supported, has important policy implications. LLLight'in'Europe pioneered the use of an instrument to test complex problem solving skills of adults in their work environment. This allowed for the first time insights into the development of professional and learning paths of employed individuals and entrepreneurs and the role that problem solving skills play. Additionally, LLLight'in'Europe draws on a series of databases on adult competences from across the world to conduct rich analyses of skills and their impact.

These analyses were conducted in concert with different disciplines. Economists have been analyzing the impact of cognitive skills on wages and growth; sociologists have been investigating how public policies can support the development of such skills and lifelong learning; innovation researchers have been tracking the relationships between problem solving skills, lifelong learning and entrepreneurship at the organizational level;. educational scientists have investigated how successful enterprises support their workforce's competences; cognitive psychologists have researched on the development and implications of cognitive skills relevant for modern occupations and tasks; and an analysis from the perspective of business ethics has clarified the role and scope of employers' responsibility in fostering skills acquisition in their workforce. The team has carried out its research and analyses on the value of skills and lifelong learning in EU countries, USA, China, Latin America and Africa.

The result is a multi-disciplinary analysis of the process of adult learning and problem solving in its different nuances, and of the levers which can support the development of these skills for both those who are already in jobs, and for those who are (re)entering the labor market, as well as the development of effective HR strategies and public policy schemes to support them.

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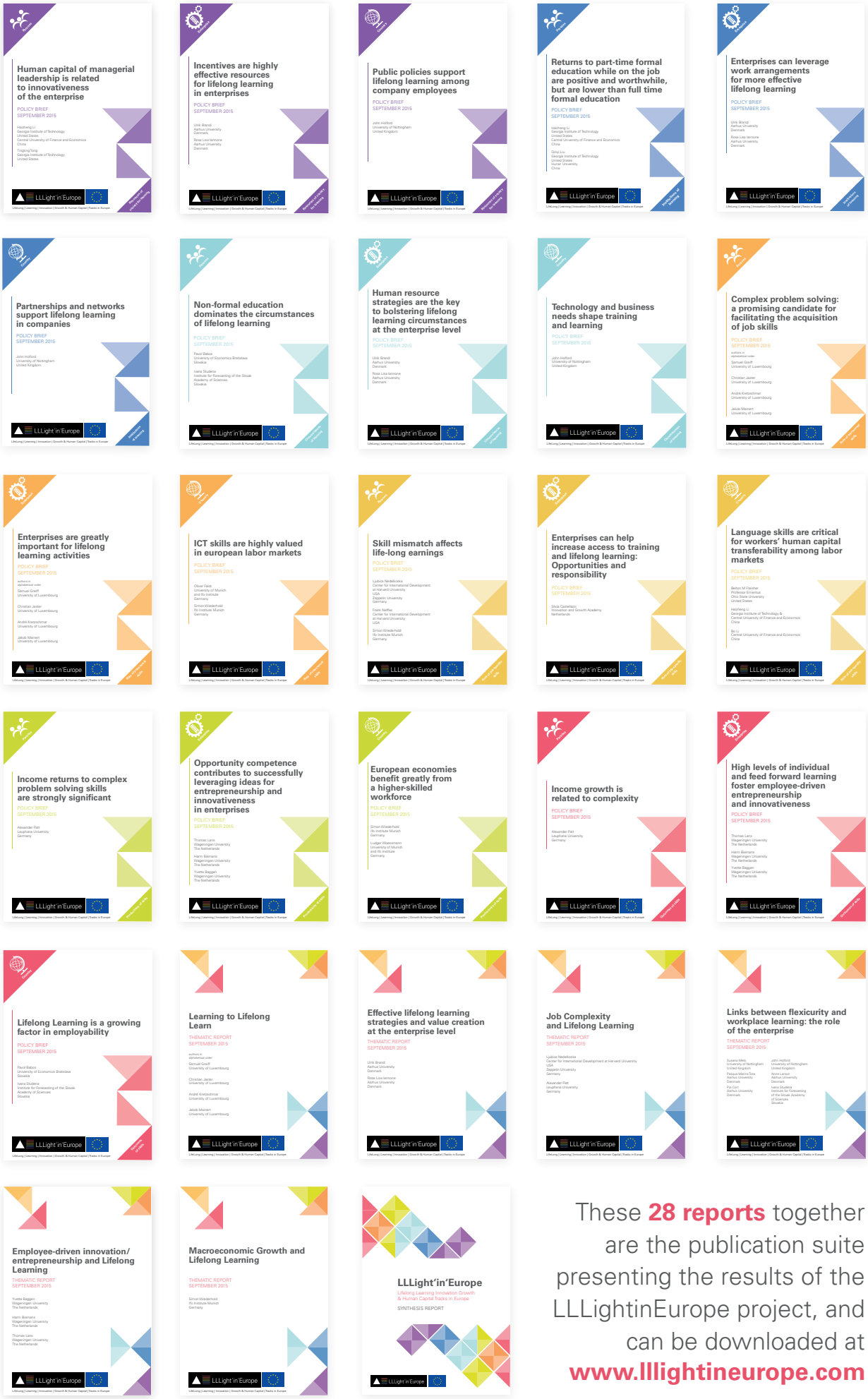

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