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An Analysis of the Factors on the Problem-Solving Competencies of Engineering Employees in Korea

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Abstract: The purpose of this study is to analyze the effect of the factors on the problem-solving competency of engineering graduates. To this end, we use the 2016 Korean survey data among the Program for the International Assessment of Adult Competencies (PIAAC) survey data conducted by the Organization for Economic Co-operation and Development (OECD). In summary of the study's major results, older people and females have lower problem-solving competencies (Model 1); higher literacy and numeracy competencies lead to higher problem-solving competencies (Model 2); and those with more experiences of sharing work-related information have higher problem-solving competencies. However, those who give more presentations have lower problem-solving competencies (Model 3), and those who make frequent use of Information and Communications Technology (ICT) to send or receive e-mails or conduct real-time discussions have higher problem-solving competencies (Model 4). These results present implications from the two perspectives of "sustainability" and "integration." Sustainability is further classified into the following two perspectives: (1) sustainability from the longitudinal viewpoint of middle school, high school, and then job education, and (2) sustainability from the cross-sectional perspective of sustainable organization cultures. In addition, the implications of integration are based on common growth with other related core competencies besides problem-solving competencies.

Keywords: PIAAC; multi-level model; engineering graduates in Korea; problem-solving competency

1. Introduction

The problem-solving competency is one of the major competencies with which people should be equipped during the Fourth Industrial Revolution era. The concept of "competencies" as required skills for a functional society has existed since the 1970s. During the early stages, when the concept of competencies was first introduced, discussions on the subject were mostly focused on required worker abilities in the context of workplace society. Afterwards, during the 1990s, the concept of competencies was expanded when the Organization for Economic Co-operation and Development (OECD) conducted a large-scale project called the definition and selection of key competencies (DeSeCo) in which competencies were understood as the general abilities that people should possess in order to succeed in modern society [1]. According to the OECD (2005), "core competencies" refer to people's "abilities to react to certain situations by comprehensively applying the core psychological and social factors from both the cognitive and non-cognitive domains" [2,3].

With the establishment of the concept of core competencies, various academic definitions were introduced along with several types of constitutive subordinate competencies. Subordinate competencies derived from core competencies through a deduction process that utilized assessment

tools for core competencies and various academic studies on core competencies including problem-solving/holistic thinking competencies, communication competencies, creativity, leadership, global competencies, and information and communication using competencies [4]. The problem-solving competency is the most high-dimensional ability among humans' cognitive functions, and it is important as a core competency that can embrace numerous other competencies [5,6].

Based on its awareness of the core competencies' importance, the OECD conducted an assessment called the Program for the International Assessment of Adult Competencies (PIAAC). The assessment investigates literacy, numeracy, and problem-solving competencies as required core competencies for adults [7]. Literacy and numeracy are basic competencies that are directly related to reading, writing, and arithmetic. However, the problem-solving competencies can be collectively classified as an applied competency that can be developed based on the application of basic competencies. As such, problem-solving competencies are considered important alongside basic competencies as one of adults' major core competencies.

Given the international attention that core competencies have garnered, the Korean government has, since the 2000s, set the direction of national education-related projects according to the basic foundation of competencies. For example, the government has, through financial support programs such as Supporting Programs on Strengthening Educational Competencies and the Advancement of College Education, provided large single-school budgets to improve competencies for university education. In addition, the government is making efforts to monitor and manage university students' competency levels by, for instance, developing an online system called the Korea Collegiate Essential Skills Assessment (K-CESA), which assesses their core competencies. The government has also encouraged competency-based education innovation in universities by applying assessment indexes such as the Basic Competencies Assessment, which assesses the overall quality of education, to the competency-based education curriculum when operating programs [4].

Despite these efforts and government initiatives, it is difficult to positively evaluate whether those who leave higher-level educational institutions and enter society have sufficiently acquired the necessary competencies. This is because there has been unending criticism of the mismatch between the supply and demand of human resources from higher-level educational institutions. As a social issue, such a mismatch can be classified into quantitative and qualitative human resource supply and demand mismatches [8], where a qualitative mismatch refers to the gap between the competencies that are required by the industry and those that higher-level educational institutions develop. This is a phenomenon that is derived from differences in the speed of the change in the industrial structure and university education's reactive measures. Through such phenomena in Korea, it can be concluded that those who have graduated from higher-level Korean educational institutions have not sufficiently acquired the competencies that the industry needs.

In light of this phenomenon, the Korean government has focused on the seriousness of the human resources supply and demand mismatch issue in the Korean engineering field in particular. Only two Korean schools (Korea Advanced Institute of Science and Technology (KAIST) and Seoul National University) were listed among the world's 100 engineering schools as named by the Times in 2006. In addition, criticisms have been leveled at 4.009×10^{12} KRW per annum cost of re-educating new employees who graduated with engineering degrees. Therefore, since the mid-2000s, the government has presented various methods for engineering education innovation (such as Innovative Visions and Strategies for Engineering Schools and the like) to improve Korean engineering schools' international competitiveness [9]. These attempts have the potential to transform Korean engineering education from knowledge- and theory-based to education that is focused on developing engineering talents who have problem-solving competencies [10].

However, the human resources supply and demand mismatch between universities and companies that belong to engineering-based industries remains an important social issue. In addition, criticism of comprehensive construction competencies, creativity, and the failure to apply various solutions has not yet been silenced [11]. Therefore, it is necessary to identify the factors that affect problem-solving

competencies with a focus on these competencies as a comprehensive concept of the various core competencies that are required in society and to investigate methods for improving problem-solving competencies. In particular, identifying these factors in adults from the engineering field in which there is a significant gap between industry-required competencies and the competencies that were developed through university education will facilitate the identification of significant implications for improving engineering field graduates' competencies.

Among the current studies on adults' core competencies using PIAAC data, there are studies that have analyzed the effects of participating in informal lifelong education, correlations between learning strategies and core competencies, and how using core information-processing abilities affects wages [7]. However, even among these, it is difficult to find studies that focused on adult engineers' problem-solving competencies, which is the category of research that would most benefit Korea at present. Therefore, this study aims to identify the factors that affect Korean adults' problem-solving competencies in the engineering field. This study is consistent with previous literature that identified a need for the continuous improvement of the problem-solving skills of engineering students [12–14]. The study secondarily aims to deduce significant implications from the lifelong education perspective based on sustainability from middle and high school through to job education in search of methods for improving the problem-solving competencies of adults in the engineering field.

The research hypotheses in this study are as follows: (1) the problem-solving skills of Korean engineering graduates may be contingent on age; (2) the problem-solving skills of Korean engineering graduates may be contingent on individual students' personal traits (e.g., age, gender); (2-1) the problem-solving skills of Korean engineering graduates may be related to literacy and numeracy capabilities; (2-2) the problem-solving skills of Korean engineering graduates may be contingent on whether individual students possess offline work skills; and (2-3) the problem-solving skills of Korean engineering graduates may be contingent on whether students have the level of work skills needed for the Information and Communications Technology (ICT)-based online environment.

2. Literature Reviews

2.1. The Concept of Problem-Solving Competencies

Wikipedia defines "competency" as "a standardized requirement for an individual to properly perform a specific job." Synonyms include competence, capability, capacity, and ability [15]. This study elected to use the term "competency" according to the "competencies" terminology that the OECD uses in the definition and selection of key competencies (DeSeCo) and the Program for the International Assessment of Adult Competencies (PIAAC) [2] (See Table 1).

Comprehensively defined by the dictionary, competencies can be classified as either acquired or displayed. Acquired competencies refer to the basic abilities that are required to do something (knowledge, functions/techniques, attitudes, etc.) while displayed competencies refer to actually demonstrated acquired abilities that lead to a particular performance. The competencies that companies or educational institutions ultimately seek are technically displayed competencies [4].

As shown above, among the competencies with a concept, core competencies are conceptualized concepts that focus on the important competencies that society needs to perform necessary jobs. According to the OECD (2005), which first established the concept of core competencies, they refer to people's "abilities to react to particular situations by comprehensively applying the necessary psychological and social conditions that include both the cognitive and non-cognitive domains." In addition, many international and Korean scholars have suggested various academic definitions of core competencies [2]. For example, Kim and Seong (2016) defined them as "The concept that expresses the abilities of individuals who adapt to the changes of the modern society" [16] while Ju et al. (2010) defined them as the "combination of knowledge, skills and self-concept required to efficiently improve the performance of an organization" [17].

Problem-solving competencies constitute one of the various subordinate core competencies that make up the above-mentioned core competencies. The problem-solving competency that was suggested by the OECD's (2013) Assessment of Higher Education Learning Outcome (AHELO) is a type of generic skill and is defined as "An individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious" [18]. In addition, problem-solving competencies are defined by the Association of American Colleges and Universities (AAC&U) (2009) as "The process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal" [19].

Table 1. Definitions and subfactors of problem-solving competencies.

Authors	Definitions/Subfactors of Problem-Solving Competencies
Organization for Economic Co-operation and Development (OECD)'s (2013) [14]	An individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious.
Association of American Colleges and Universities (AAC&U) (2009) [15]	The process of designing, evaluating, and implementing a strategy to answer an open-ended question or achieve a desired goal.
Lee et al. (2009) [20]	Problem recognition, Finding solutions, Implementing and evaluating solutions, Logical thinking, Critical thinking
Cho et al. (2018) [21]	Problem clarification, Cause analysis, Alternative development, Planning and execution, Performance evaluation

In summary, problem-solving competencies—which refer to competencies that allow people to analyze, apply, or evaluate alternatives in problematic situations from various dimensions by comprehensively and creatively integrating a diverse portfolio of knowledge, techniques, and information—constitute one of the major competencies that people should possess during the Fourth Industrial Revolution era.

2.2. Factors that Affect Problem-Solving Competencies

Problem-solving competencies comprise one of the core competencies that are required by society. They are the results of a lifelong education through various types of formal and informal educational pathways. Therefore, this study investigated the factors that can affect problem-solving competencies by classifying influential factors into three areas that promote or hinder individuals' learning performances [22].

2.2.1. Learners' Personal Characteristics

Learners' personal characteristics have been emphasized among the factors that affect the problem-solving competencies [23–25]. Firstly, basic characteristics such as gender and age affect problem-solving competencies. Kim and Lee (2003) suggested gender and school grades as input factors among the factors that affect problem-solving competencies [26]. Kang et al. (2014) showed that male students had higher problem-solving competencies than female students. Cognitive skills also affect problem-solving competencies [27]. According to Mayer (1998), among the cognitive skills, the ability to break subjects down into instructional objectives is especially important to finding solutions [25]. Furthermore, according to Clark and Mayer (2003), problem-solving competencies are greatly affected by cognitive skills such as using facts, concepts, and procedures [23].

Problem-solving competencies are also affected by meta-cognitive skills [28]. Prior studies such as Moore's (1995) have reported that meta-strategies like monitoring solution outcomes and reflecting on the nature of a task may affect problem-solving competencies [29]. Furthermore, Cho and Kim (2006) stated that problem solving necessitates the use of meta-cognitive skills such as planning, monitoring, and evaluating [30].

Lastly, learners' ICT literacy is a factor that affects problem-solving competencies. This factor has received attention with an emphasis on the influence of online educational environments on

problem-solving competencies [31]. Park and Chae (2002) specifically highlighted ICT literacy as a critical competency for learners to solve problems within the online-based education environment [32].

2.2.2. Educational Institution/Program(s) Characteristics

Alongside learners' personal characteristics, the characteristics of the educational institution that learners attend or the program(s) in which they participate may affect problem-solving competencies. Firstly, an online learning environment acts as a support system that provides the resources and tools that are required to demonstrate problem-solving competencies. These competencies are acquired during the process of developing knowledge based on experience, and an online education environment is critical for learners to actively develop knowledge [31].

Teacher quality is another important factor that affects problem-solving competencies. According to Grave et al. (1998), teacher intervention during the learning process affects improvement levels with regard to problem-solving competencies. The specific teacher roles that affect learners' problem-solving competencies are elaboration, directing the learning process, integrating knowledge, stimulating interaction, and individual accountability [33].

Studies that focused on the factors that affect learning performance, which is a more comprehensive concept than problem-solving competencies, reported that when educational institutions provide higher-quality support services, individual learning performance improves [34]. For instance, a learning performance increase was observed when learners had a more positive awareness of education-related environmental factors [35,36].

2.2.3. Learners' Skills

In addition to the above factors, the skills that learners use have received recent attention as a factor that affects learning performance [37]. "Learning transfer" is one of the concepts that can be applied to adult corporate education in relation to learner skills. Learning transfer is defined as a process in which learners apply and maintain the knowledge, techniques, and attitudes that they learn on their jobs. The transfer environment refers to the environmental factors that give rise to learning transfer, major examples of which include support and restrictions from superiors or colleagues as well as opportunities to apply skills [38]. Opportunities to apply skills are important because they lead to effective learning transfer if there are more opportunities for people to apply the skills they acquired through learning on the job or learning during the course of everyday life. Past research has indicated that performance opportunities and learning transfer have strong positive correlations [39]. In addition, it was reported that performance opportunities directly or indirectly affect learning transfer with learning as a mediator [40].

As shown above, problem-solving competencies may vary according to factors such as learners' personal characteristics, the characteristics of the educational institutions that learners attend or the program(s) in which they participate, and the skills that learners use. In order to analyze the factors that affect problem-solving competencies by deducing variables that can be applied with PIAAC, this study used three categories, namely learners' personal characteristics, the characteristics of the educational institutions that learners attend or the program(s) in which they participate, and the skills that learners use.

3. Methods

3.1. Data for Analysis

This study used data from the OECD's Program for the International Assessment of Adult Competencies (PIAAC). PIAAC is an international OECD assessment that assesses adults' basic competencies by country and identifies the level and status of countries' human resources. Twenty-four countries participated in the Round 1 Survey, and nine more countries were included in the Round 2 Survey [18]. There were approximately 160,000 PIAAC participants with per country participant

numbers ranging from 4500 to 27,300 [37]. The study used the Public Use Files (PUF) that were publicly posted for PIAAC. Data from Korea were only used for analysis in the larger context of all PIAAC data. The Korean sample consisted of 6650 people and 8830 households. From that sample, this study used data from 579 participants who graduated with an engineering degree. There were 138 participants who were in their 20s, 240 who were in their 30s, 122 who were in their 40s, 71 who were in their 50s, and 8 who were either in their 60s or older. Male participants numbered 444 while 135 were female (See Table 2).

Table 2. Sample.

	Variables	N	Percentage
Age(Groups)	20–29	138	23.83
	30–39	240	41.45
	40–49	122	21.07
	50–59	71	12.26
	60+	8	1.38
Gender	Male	444	76.68
	Female	135	23.31
	Total	579	100

3.2. Measured Variables

This study developed a model based on the background survey and competency levels that were obtained from PIAAC. Table 3 shows the variables and assessment items.

Table 3. Measurement variables.

Component	Variables	Items	Scale
Personal Attribute	Age	Can you please tell me in which year you were born?	Continuous
	Gender (Female)	Is the respondent male or female?	M/F
Competency	Literacy	Literacy Scale Score	Scale Score
	Numeracy	Numeracy Scale Score	Scale Score
Work Skills (offline)	Sharing work-related info	Sharing work-related information with co-workers?	5 scale
	Teaching people	Instructing, training, or teaching people, individually or in groups?	5 scale
	Presentations	Making speeches or giving presentations in front of five or more people?	5 scale
	Planning own activities	Planning your own activities?	5 scale
	Organizing own time	Organising your own time?	5 scale
Work Skills (Information and Communications Technology (ICT) based online)	For mail	Use email?	5 scale
	Work related info	Use the internet in order to better understand issues related to your work?	5 scale
	Conduct transactions	Conduct transactions on the internet, for example buying or selling products or services, or banking?	5 scale
	Programing language	Use a programing language to program or write computer code?	5 scale
	Real-time discussions	Participate in real-time discussions on the internet, for example online conferences, or chat groups?	5 scale

3.3. The Analysis Model

This study aimed to identify the factors that affect the problem-solving competencies of adults who work in the engineering field in Korea. Competencies have a hierarchical data structure nested among age groups. Such data show similar tendencies from participants who are in the same age group. This can be problematic if it violates the individuality of observations, which is one of the fundamental assumptions when estimating the regression model using ordinary least squares and may also lead to Type 1 error inflation by underestimating the standard error when estimating the regression coefficient [41]. Therefore, this study used the random effect multi-level model (MLM). Stata MP 15.0 [42] was used to analyze the MLM.

First level model: Personal level

$$Y_{ik} = \pi_{ok} + e_{ik}, e_{ik} \sim N(0, \sigma^2) \quad (1)$$

- Y_{ik} = Problem-solving competency value, dependent variable;
- π_{ok} = Mean of age groups belonging to each person;
- e_{ik} = Standard error of each person.

Second level model: Age group level

$$\pi_{ok} = \gamma_{oo} + u_{ok}, u_{ok} \sim N(0, \sigma^2) \quad (2)$$

- π_{ok} = Mean of age groups;
- γ_{oo} = Mean of population;
- u_{ok} = Standard error of age groups.

4. Results

4.1. Descriptive Statistics

Table 4 shows descriptive statistics for the major variables. The mean of the problem-solving competency, which was a dependent variable, was 297.32. Among the competencies, the mean of literacy was 293.83 and the mean of numeracy was 290.73. Among work skills, the variable with the highest mean was organizing one's own time with 4.29 and the variable with the lowest mean was presentations with 2.59. The variable with the highest mean among Information and Communications Technology (ICT) capabilities was work-related information with a mean of 4.65 while programing language had the lowest mean at 2.62.

The results of verifying the differences among the groups by the age variable revealed that problem-solving competencies were statistically higher in the youngest group where participants were in their 20s as compared to participants in other groups who were in their 30s, 40s, and 50s. Those in their 30s had higher scores than those in their 40s and 50s. Literacy competency was statistically higher for those in their 20s in comparison to those in their 40s and 50s, and those in their 30s also had statistically higher scores than those in their 40s and 50s. Numeracy competency was statistically higher for those in their 30s than for those in their 40s. Among work skills, although scores for sharing work-related information were statistically higher among those in their 20s when compared to those in their 50s, participants in their 40s had statistically given more presentations than those in their 20s.

Table 4. Descriptive statistics in the variables of interest.

Component	Variables	N	Mean	SD	ANOVA (post-hoc test)
Dependent Variable	Problem-Solving Competency	524	297.32	30.85	19.56 *** (20s > 30s, 40s, 50s 30s > 40s, 50s)
Competency	Literacy	579	293.83	28.51	7.92 *** (20s > 40s, 50s 30s > 40s, 50s)
	Numeracy	579	290.73	30.49	2.99 * (30s > 40s)
Work Skills (offline)	Sharing work-related info	579	4.08	1.32	2.36+ (20s > 50s)
	Teaching people	579	3.09	1.64	0.95
	Presentations	579	2.59	1.65	2.51 * (20s < 40s)
	Planning own activities	579	4.16	1.33	1.79
	Organizing own time	579	4.29	1.30	0.80
Work Skills (ICT based online)	For mail	579	4.64	1.28	0.68
	Work related info	579	4.65	1.17	1.30
	Conduct transactions	579	3.35	1.88	1.10
	Programing language	579	2.62	2.05	0.76
	Real-time discussions	579	2.95	2.03	0.82

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.2. Model Analysis

Table 5 shows the results of analyzing the factors that affect the problem-solving competencies of adults in the engineering field in Korea using MLM. Firstly, Model 0 was an absolute model that verified the differences in problem-solving competencies among adults by age in order to identify the distribution proportion for each level by individuals and age. After verifying the Intra-Class Correlation (ICC), which is the proportion of random effect age variables among the total variables, 29.4% had random effects by age. Therefore, the multilevel analysis model was verified as the most appropriate.

Model 1 was based on the personal characteristics variable. There were lower problem-solving competencies with age ($B(SE) = -1.30(0.14)$, $z = -9.39$, $p < 0.001$) and females had lower problem-solving competencies than males ($B(SE) = -9.61(2.93)$, $z = -3.28$, $p < 0.001$).

Model 2 was based on the competencies variable. There were higher problem-solving competencies with higher literacy competencies ($B(SE) = 0.54(0.06)$, $z = 9.33$, $p < 0.01$) and higher problem-solving competencies with higher numeracy competencies ($B(SE) = 0.26(0.05)$, $z = 4.78$, $p < 0.001$).

Model 3 was based on the work skills variable. Although problem-solving competencies increased with an increased number of experiences of sharing work-related information ($B(SE) = 2.72(0.80)$, $z = 3.40$, $p < 0.001$), there were lower problem-solving competencies with more presentations ($B(SE) = -1.51(0.72)$, $z = -2.10$, $p < 0.05$). Variables such as teaching people, planning one's own activities, and organizing one's own time did not statistically affect problem-solving competencies.

Lastly, Model 4 was based on the ICT capabilities variable. There were higher problem-solving competencies when ICT was frequently used to receive or send e-mails ($B(SE) = 1.78(0.92)$, $z = 1.94$, $p < 0.05$). In addition, there were also higher problem-solving competencies when ICT was used to facilitate real-time discussions ($B(SE) = 1.00(0.55)$, $z = 1.82$, $p < 0.10$). However, there were lower problem-solving competencies when ICT was used to conduct transactions ($B(SE) = -1.36(0.57)$, $z = -2.38$, $p < 0.05$) or utilize programing language ($B(SE) = -1.07(0.56)$, $z = -1.91$, $p < 0.10$). Using ICT to communicate work-related information was not shown to have a statistically significant effect.

Table 5. Multi-level model analysis.

Variables	Model 0		Model 1		Model 2		Model 3		Model 4	
	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD
Personal Attribute										
Age			−1.30 ***	0.13	−0.87 ***	0.09	−0.82 ***	0.10	−0.77 ***	0.10
Gender (Female)			−9.61 *	2.93	−5.14 **	1.91	−4.99 **	1.95	−4.07 *	1.97
Competency										
Literacy					0.54 ***	0.06	0.52 ***	0.56	0.52 ***	0.06
Numeracy					0.26 ***	0.05	0.27 ***	0.55	0.25 ***	0.05
Work Skill										
Sharing work-related info							2.72 ***	0.80	2.49 **	0.80
Teaching people							−0.41	0.74	−0.56	0.74
Presentations							−1.51 *	0.72	−1.48 *	0.73
Planning own activities							0.31	1.12	0.20	1.11
Organising own time							0.18	1.11	0.15	1.10
ICT Capability										
For mail									1.78 *	0.92
Work related info									0.73	1.11
Conduct transactions									−1.36 *	0.57
Programing language									−1.07+	0.56
Real-time discussions									1.00+	0.55
Intercept	294.26	2.42	347.51	5.41	94.49	10.04	86.42	10.23	87.57	10.40
Random Effect	SD	Chi ² (1)	SD	Chi ² (1)	SD	Chi ² (1)	SD	Chi ² (1)	SD	Chi ² (1)
	12.28	2.25 ***	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Model Log-likelihood	−2525.97		−2498.00		−2268.60		−2261.15		−2253.56	

5. Discussion

This study aimed to analyze the factors that affect the problem-solving competencies of Korean adults in the engineering field. In summary of the study's major results, older people and females had lower problem-solving competencies (Model 1); higher literacy and numeracy competencies led to higher problem-solving competencies (Model 2); and those with more experiences of sharing work-related information had higher problem-solving competencies. However, those who gave more presentations had lower problem-solving competencies (Model 3) and those who made frequent use of ICT to send or receive e-mails or conduct real-time discussions had higher problem-solving competencies (Model 4).

These results presented implications from the two perspectives of “sustainability” and “integration”. Sustainability is further classified into the following two perspectives: (1) sustainability from the longitudinal viewpoint of middle school, high school, and then job education, and (2) sustainability from the cross-sectional perspective of sustainable organization cultures. In addition, the implications of integration are based on common growth with other related core competencies besides problem-solving competencies.

- Sustainability 1: The sustainable sharing of a continuous vision from middle and high school education to job education

This study's first result, which stated that older age led to lower problem-solving competencies, may initially seem insensible since it is commonly thought that because older people have more years

of workplace experience, they will also have better problem-solving competencies in the context of on-the-job experiences. In order to interpret these results, it is necessary to consider two things. Firstly, although age and experience may be correlated, different levels of problem-solving competencies can exist among people who have the same years of experience. Secondly, problem-solving competencies by age are correlated to educational experiences during adolescence.

The latter can lead to a more careful interpretation by investigating Korea's educational characteristics. Korean students' cognitive achievement levels are recognized at the international level. They are ranked at the top in mathematics and science in the Program for International Student Assessment (PISA), which the OECD has organized for 15-year-old students every three years since 2000. Although Korean students show high cognitive competencies, one must ask why their problem-solving competencies decrease as they age and become working adults when high achievement levels in mathematics and science as measured by the PISA results should be strongly correlated with adult competency development, especially for those who work in the "engineering field." On the contrary, the results of a comparative study have shown that Korean adults' competencies are continuously declining in comparison to the OECD average [43], thus encouraging awareness of an imbalance that needs to be improved.

As previously mentioned, this can be interpreted as connected to adolescent educational experiences. Since the education curriculum that is delivered during adolescence in Korea centers on repeated memory exercises for the purpose of gaining entrance to universities, it does not help students learn how to react effectively and efficiently to the various problematic situations that may arise in their adult lives [44]. In particular, despite the many hours that are dedicated to education, low emotional efficacy during adolescence leads to limitations in qualitative educational levels such as responsiveness to future society [44,45]. Korea's education system has recognized these problems and efforts are being made to overcome the identified limitations through the application of initiatives such as the free-semester system for middle schools, which aims to develop as a research- and experience-centered education system.

On the other hand, prior studies have shown that the generation of Korean adults who reaped the benefits of universal middle and high school education demonstrated relatively higher achievement levels with regard to adult competencies (numeracy, etc.) in comparison to other generations [44]. In other words, those who entered universities developed competencies that were not fully developed during middle school thanks to the influence of higher education teaching and learning systems. According to these results, adults who did not receive adult high school level education should be provided with job education at the high school level in order to compensate for the deficit [44]. This leads to a richer interpretation of this study's results, which showed that older people had lower problem-solving competencies.

In order to reap elastic effects from the systematic improvement that has been offered as an alternative, it is important not only to establish the system but also to maintain the "sustainability of sharing the vision." In other words, it will only be possible to solve the problem of manpower supply and demand in the engineering industry and the conflicting educational phenomenon in Korea if the middle school to high school through to job education system shares an education curriculum that has a universal vision for improving practical competencies with an eye towards their application to practical problem solving.

- Sustainability 2: Companies' efforts to establish learning organizations

"Sustainability" is just as important for organizations as the primary process that develops numerous policies and executes them positively. Many policy planners focus on the secret to overcoming the limitations of reform discontinuity, which can occur when reform leaders leave organizations. This secret is the key to maintaining sustainability. Various organizational theory experts, including Senge (1990), have identified this secret by examining learning organizations [46–49]. Learning organizations refer to the establishment of cultural and organizational conditions to encourage learning

so that organization members can continuously learn to develop individual as well as organization-wide competencies. Such organizations establish learning cultures, engage in conversation and co-operation, seek empowerment, secure education-sharing systems, embody management learning leadership, and feature connected systems [46].

This study's results showed that regularly sharing work-related information with colleagues and having real-time discussions by exchanging e-mails and using other forms of ICT led to higher problem-solving competencies, thus indicating that organizations that have a more academic atmosphere are closely linked to adult competencies including problem-solving competencies. In other words, there should be an organization culture that allows for active interactions among members regardless of whether these interactions are online or offline. This is preferable to job processes that are one-directional or limited to a single person. In such an organization culture, management should support the organization by strengthening members' job authorities. Since learning organizations are like organisms, they are not fixed and may evolve in response to continuous efforts from within the organization. Therefore, in the early stages, organizations that are seeking long-term development as a learning organization should benchmark examples from other departments or organizations that have mastered sustainable cultures. In order to naturally develop and maintain such an organization culture, there should be an appropriate mix of traditional classes and the team development of problem-solving competencies beginning at the middle and high school levels.

- Integration: Efforts towards the common growth of related core competencies

This study showed that higher literacy and numeracy competencies led to a higher problem-solving competency. The results indicated that major core competencies do not develop and improve independently. Rather, they are correlated with and affect one another. Since prior studies have already identified that various competencies such as cognitive and meta-cognitive skills and ICT literacy affect problem-solving competencies [25,28,31], this study's results contributed to the body of related research by supporting that argument. Accordingly, middle and high school classes should support the development of comprehensive competencies by implementing various methods and feedback, including lectures, project classes, and field trips, instead of concentrating on developing a single competency. Corporate education should also widen its perspective by continuously and sustainably supporting core competency training even if the competencies are not directly related to employees' job descriptions in the short term since this investment will allow employees to develop the competencies they need to react to complex situations. This approach has an aspect in common with systematic thinking, which states that partial change pertains to the entire organization [46] and will lead to a more mature developmental direction that can help overcome limitations in adult competencies as a result of the chronic imbalances in Korean education.

6. Conclusions

The problem-solving competency is one of the major competencies with which people should be equipped during the Fourth Industrial Revolution era. The problem-solving competency is the most high-dimensional ability among humans' cognitive functions and it is important as a core competency that can embrace numerous other competencies [5,6]. Therefore, this study aimed to identify the factors that affect Korean adults' problem-solving competencies in the engineering field.

This study was consistent with previous literature that identified a need for the continuous improvement of the problem-solving skills of engineering students [12–14]. The study secondarily aimed to deduce significant implications from the lifelong education perspective based on sustainability from middle and high school through to job education in search of methods for improving the problem-solving competencies of adults in the engineering field.

Competencies have a hierarchical data structure nested among age groups. Such data show similar tendencies from participants who are in the same age group. This can be problematic if it violates the individuality of observations, which is one of the fundamental assumptions when

estimating the regression model using ordinary least squares and may also lead to Type 1 error inflation by underestimating the standard error when estimating the regression coefficient [41]. Therefore, this study used the random effect multi-level model (MLM).

The results of verifying the differences among the groups by the age variable revealed that problem-solving competencies were statistically higher in the youngest group where participants were in their 20s as compared to participants in other groups who were in their 30s, 40s, and 50s. Those in their 30s had higher scores than those in their 40s and 50s. Literacy competency was statistically higher for those in their 20s in comparison to those in their 40s and 50s, and those in their 30s also had statistically higher scores than those in their 40s and 50s. Numeracy competency was statistically higher for those in their 30s than for those in their 40s. Among work skills, although scores for sharing work-related information were statistically higher among those in their 20s when compared to those in their 50s, participants in their 40s had statistically given more presentations than those in their 20s.

The results of model analysis were as follows. Model 1 was based on the personal characteristics variable. There were lower problem-solving competencies with age and females had lower problem-solving competencies than males. Model 2 was based on the competencies variable. There were higher problem-solving competencies with higher literacy competencies and higher problem-solving competencies with higher numeracy competencies. Model 3 was based on the work skills variable. Although problem-solving competencies increased with an increased number of experiences of sharing work-related information, there were lower problem-solving competencies with more presentations. Variables such as teaching people, planning one's own activities, and organizing one's own time did not statistically affect problem-solving competencies. Lastly, Model 4 was based on the ICT capabilities variable. There were higher problem-solving competencies when ICT was frequently used to receive or send e-mails. In addition, there were also higher problem-solving competencies when ICT was used to facilitate real-time discussions. However, there were lower problem-solving competencies when ICT was used to conduct transactions or utilize programming language. Using ICT to communicate work-related information was not shown to have a statistically significant effect.

The interpretation of factors affecting problem-solving skills depends on the specific educational context of each nation. Thus, the unique educational context of Korea presented in this paper (i.e., education in middle and high schools focused on college admission influences adults' problem-solving skills) cannot be applied to all nations. However, three points are offered from the findings of this study: (1) a reflective introspection of adult capability must be made from a longitudinal perspective encompassing secondary education, higher education, and vocational training, rather than from a unidimensional perspective of vocational training; (2) learning systems in workplaces should be established; and (3) education aimed at pursuing a balanced growth of core capabilities, including problem-solving skills, is necessary. These three findings would be applicable to every nation, despite the unique historic and educational context. Through the findings of this study, we expect that these points will provide significant insights for educational policymakers, school managers at schools of various levels, and corporate education managers in each country.

Irrespective of the significance of this research, there were some limitations. Firstly, Korean students were the subjects of this study's analysis, thus, the findings cannot be applied in other countries using educational curricula that are different from Korea's. Nonetheless, the Program for the International Assessment of Adult Competencies (PIAAC), which is utilized in most OECD countries, can be interpreted by applying the uniform research methodology to the specific educational policies and curricula of each nation. Secondly, this research targeted only engineering students, meaning the interpretation of research outcomes is rather limited. A comparison with research covering students of other majors would produce more meaningful implications. Lastly, future research may be needed to establish a plan to provide continuous support for long-term analysis to ensure research of a longitudinal correlation between secondary education, higher education, and vocational training.

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