A Preliminary Analysis of the Competency and Skills of Japanese IT Engineers in Managerial Positions

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***Abstract*—As globalization and digitization progress rapidly, the world as well as the talent in demand and the skills and competencies required are changing. Under these circumstances, every corporation is under great pressure to adopt its organization to prepare for the coming future changes. Therefore, a discussion about how to develop new leaders who are capable of tackling complex problems in the future is required. Although the demand for talent in science and engineering is increasing over the course of digitalization, many engineers struggle in management jobs, especially regarding intangibles. This study aims to measure the competency of Japanese Information Technology (IT) engineers, utilizing the Progress Report on Generic Skills (PROG) assessment tool to identify the talent development opportunities in the field of engineering and science. Thus, this study demonstrates that general competencies, such as teamwork, personal, and problem-solving skills, were more often exhibited by IT engineers with a background in social sciences and liberal arts compared with those with a background in engineering and science. The results suggest that engineers have both challenges and opportunities to grow their competencies by increasing their training in non-cognitive skills.**

***Index Terms*—Science and engineering, assessment, skills, competency, talent development**

I. Introduction

With the rapid progress of globalization and digitalization, the world is changing, along with the required talent, skills, and competencies in demand. Livert et al. highlight two notable changes: the growth of digital technology and the ongoing exponentially increasing pace and magnitude of the change [1]. Taking a more aggressive approach to developing leadership capability in the workforce is not new, as most organizations have tried to do so. However, 74% of organizations in a study reported that their efforts have not been successful [2]. Therefore, a discussion about how to develop new leaders capable of solving the complex problems that will arise in the future is required at this time.

As one of the classic studies about the core skills required to be a good administrator, Katz's "three managerial skills"—which includes technical skills to work with things, human skills to work with people, and conceptual skills to envision an organization as a whole—was introduced between 1955 and 1974 [3], [4]. Katz illustrated the increasing importance of intangible skills, such as human and conceptual skills, for employees as they rise to upper management positions (see Fig. 1).

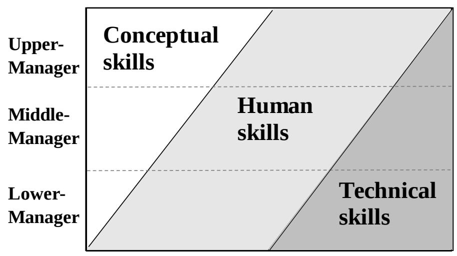

Figure 1. Three managerial skills by Robert L. Katz

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According to *Skill Shift*, a discussion paper issued by the McKinsey Global Institute, in 2018, 3,031 leaders across 15 countries and 30 industries in the United States and Western Europe were measured, and it was determined that many activities performed by workers today have the potential to be automated and that by 2030, the following five skills that are essential for future workers will be changed significantly [5].

1) Physical and manual skills

General equipment operation and navigation, general equipment repair and mechanical skills, craft & technical skills, fine motor skills, gross motor skills and strength, and inspecting and monitoring skills.

2) Basic cognitive skills

Basic literacy in numeracy and communication and basic data input and processing.

3) Higher cognitive skills

Advanced literacy and writing, qualitative and statistical skills, critical thinking and decision-making, project management, complex information processing and interpretation, and creativity.

4) Social and emotional skills

Advanced communication and negotiation skills, interpersonal skills and empathy, leadership and managing others, entrepreneurship and initiative-taking, adaptability and continuous learning, and teaching and training others.

5) Technological skills

Basic digital skills, advanced information technology (IT) skills and programming, advanced data analysis and mathematical skills, technology design, engineering and maintenance, and scientific research and development.

The McKinsey report forecasted growth in the demand for each skill by 2030 versus the year 2016; it found that physical and manual skills would decrease by 14% and that basic cognitive skills would decrease by 15%. On the contrary, there would be significant growth of 55% for technological skills, for which people with academic backgrounds in engineering and science would have an advantage over others. In addition, similar growth was indicated for higher cognitive skills such as creativity, which would increase by 24%, and social and emotional skills, such as leadership and managing others, which would increase by 8% [5].

Given noted over 60 years ago that many engineers encounter difficulty when they step into management jobs, due to their lack of capability with human relations, which cannot be solved by logic alone [6]. According to the 2015 PROG Whitepaper project, university students in engineering and science achieved lower scores in competencies (i.e., non-cognitive skills) such as teamwork and interpersonal skills [7].

According to Munegumi's report, Science, Technology, Engineering, and Mathematics (STEM) was named by Ramaley, the representative director of the National Science Foundation in 2001 and he positioned Science, Technology, Engineering, Art, and Mathematics (STEAM) education as an opportunity to solve the current problems in the world [8]-[10]. Connor mentioned the importance of moving from STEM to STEAM education in his paper. One of the most important guidelines for doing so was seeking experience outside of traditional engineering teaching to inform a possible direction and promoting the engineering discipline to embrace creativity in the education of future engineers [11].

Since it has been a challenge to transform engineers into middle and upper management by fostering their competencies (i.e., non-cognitive skills), this study focuses on measuring the competencies of IT engineers objectively and explicitly by utilizing the assessment tool called the Progress Report on Generic Skills (PROG) to discover development opportunities for their future growth.

II. About the PROG Test

A. Development and Utilization

The PROG assessment tool of competency and literacy was launched in 2012 to make the measurement methods for non-cognitive abilities less subjective and it has been one of the most widespread measurement methods for core generic skills among institutions of higher education in Japan. It has also been used as a standard for diploma policymaking by measuring both literacy and competency [12]. In terms of applications, 455 of 1,000 higher educational institutions in Japan selected the PROG test; over approximately 850,000 of all students and the graduates took the PROG test by April 2019. Since it has been recognized as a unique assessment tool that secures objectivity and affords ease of operation, the PROG test is available in both English and Japanese, and the literacy part is also translated into the Thai language [13].

B. Measuring Skills

In the PROG assessment, measuring skills are divided into two aspects; the ability to utilize knowledge (i.e., cognitive ability, referred to as "literacy" skills) and a person's action tendency and decision-making style, which is derived from one's experiences (i.e., non-cognitive ability, referred to as "competency" skills) (see Fig. 2).

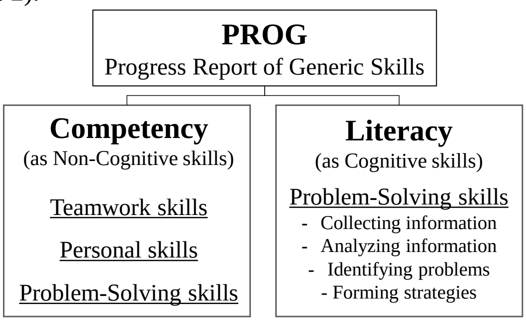

Figure 2. Two components of PROG Test

C. PROG "Competency"

In this study, scaling competency as either a non-cognitive or an intangible skill is the essential topic of inquiry. The PROG test was selected as an assessment tool since it can provide a precise analysis of nine components of competency (see Table I), which enables educators to identify and build strategic talent development programs.

TABLE I. SKILLS AND COMPONENTS OF PROG COMPETENCY

Competency Action/Decision Making Tendency		
Personal skills	**Teamwork** skills	**Problem-Solving** skills
・Self-control	・Relating with others	・Problem identification
・Self-confidence	・Collaborating with others	・Planning Solution
・Behavior Control	・Team management	・Implementing solutions

III. METHODOLOGY OF THE SURVEY

The survey was applied to IT engineers in managerial positions in legitimate companies employing over 1,000 employees during the time period between July 2019 and January 2020.

A. Measument

The PROG competency test was used to measure IT engineers' competencies and skills; based on its objectivity, it had been in wide usage since 2012. We focused on evaluating IT managers' competencies. Because engineers are generally confirmed to score highly in literacy, this study aims to identify developmental opportunities in increasing the competency skills of students with backgrounds in engineering and science by demonstrating where they tend to show lower scores [7].

The competency test, which takes 45 minutes, was used to measure three skills—namely, teamwork skills, personal skills, and problem-solving skills—including nine components of those three skills. In the test, 30 questions were asked, and the competency elements were tested with multiple choice questions having five potential answers solely based on cognition of the answers and employs two-sided questions to reflect the honest feelings of the respondents objectively. The results were shown on a seven-point scale, one to seven, for three skills and nine components of competency.

B. Respondents

In total, 25 respondents who were IT engineers participated in the survey. The composition of the age groups was as follows: 52% of the respondents were in their 30s and 48% in their 40s. Twenty respondents were in managerial positions and five were in director positions. Out of the 25 respondents, three females were included in this survey as shown in Table II, Table III, and Table IV. The respondents were asked about their academic history, such as their highest level of education, in terms of the type of school they attended and their major; 76% of respondents graduated from undergraduate or graduate school and 24% were graduates of a vocational or a high school (see Table III).

TABLE II. JOB TITLES AND AGES OF THE RESPONDENTS

Ages	Director	Manager	Total	%
30-34	0	5 (1)	5 (1)	20
35-39	2 (1)	6	8 (1)	32
40-44	3	8 (1)	11 (1)	44
45-49	0	1	1	4
Total	**5 (1)**	**20 (2)**	**25 (3)**	**100**

* The number of female respondents were shown in brackets.

TABLE III. ACADEMIC HISTORY OF RESPONDENTS BY GRADUATED SCHOOLS

Type of Schools	# of person	%
Graduate school	1	4
Undergraduate	18 (3)	72
Vocational school.	4	16
High school.	2	8
Total	**25 (3)**	**100**

* The number of female respondents were shown in brackets.

TABLE IV. ACADEMIC HISTORY OF RESPONDENTS BY MAJOR

	# of respondents	%
(Engineering & Science)		
Engineering (Information System, etc.)	7	28
Information management	2	8
Science	2	8
Sub-total	**11**	**44**
(Social Science & Liberal Arts)		
Social Science	12 (2)	48
Liberal Arts	1	4
Law	1 (1)	4
Sub-total	**14**	**56**
Total	**25 (3)**	**100**

* The number of female respondents were shown in brackets.

Regarding the academic background of the respondents, 44% had an engineering and science background in a field such as information systems or information management and 56% had a social sciences and liberal arts background (*see* Table IV). We also extended the analysis to a comparison with managers by academic background since there were 10 IT managers with two different backgrounds in managerial positions.

IV. RESULTS

The PROG competency test results were analyzed according to two dimensions: academic background and job title.

A. Results by Academic Background

In terms of competency skill comparison by academic background according to major, we looked at managers (n = 20) who had similar responsibilities in the organization.

As a result, IT engineering managers with a social sciences and liberal arts background showed superiority to those with an engineering and science background for eight out of the nine components. The biggest gaps were seen in problem-solving skills, such as problem identification and planning solutions by one point, and those differences were considered significant by showing 29% to 42% of differences. Also, IT engineering managers with a social sciences and liberal arts background marked higher score by 0.7 for human-related skills such as "relating with others," "team management," "self-control" and "implementing solutions," which was another component of problem-solving skills (see Table V).

TABLE V. COMPETENCY COMPARISON BY ACADEMIC BACKGROUND

Category of skills	Components of skills	Social Science & Liberal Arts i. (n=10)	Engineering & Science ii. (n=10)	Gap (i−ii)
Teamwork skills	Relating with others	4.9	4.2	0.7
	Collaborating with others	6.1	5.9	0.2
	Team management	5.4	4.7	0.7
Personal skills	Self control	5	4.3	0.7
	Self confidence	4.4	5	-0.6
	Behavior control	5.1	4.8	0.3
Problem Solving skills	Problem identification	4.4	3.4	1
	Planning solutions	3.4	2.4	1
	Implementing solutions	3.9	3.2	0.7
Total		10	10	

B. *Results by Job Title*

We also analyzed the competency skill comparisons of all respondents (n = 25) by job title. There was a gap between directors (n = 5) and managers (n = 20). Although the sample size was small, the superiority of "director" was shown in seven out of nine components versus "manager" and the biggest gap was seen in problem-solving skills, such as problem identification and problem solutions, which were higher in IT engineers with a social sciences and liberal arts background. Additionally, personal skills such as self-confidence and behavioral control were higher among directors (see Table VI).

TABLE VI. COMPETENCY COMPARISON BY TITLE

Category of skills	Components of skills	Director ① (n=5)	Manager ② (n=20)	Gap
Teamwork skills	Relating with others	4.6	4.55	0.05
	Collaborating with others	4.6	6	-1.4
	Team management	5.2	5.05	0.15
Personal skills	Self control	4.6	4.65	-0.05
	Self confidence	6.2	4.7	1.5
	Behavior control	6.4	4.95	1.45
Problem solving skills	Problem identification	5.6	3.9	1.7
	Planning solutions	4.4	2.9	1.5
	Implementing solutions	4	3.55	0.45
Total				

V. CONCLUSION

Science and engineering employees have been recognized as having a high literacy advantage among undergraduate students according to PROG test results of 100,000 students. In today's digital world, the hiring needs of science and technology employees are accelerating. This survey suggests that IT engineers with a social sciences and liberal arts background who have acquired IT literacy after graduating from school may have higher problem-solving skills and may perform better in society. Conversely, IT engineers with a background in engineering and science, despite the recognizable advantage of literacy, may perform at a lower level owing to their lack of education in the social sciences and liberal arts. If this is the case, it would pose a major challenge to the precepts of STEM-focused education, which is currently being strengthened nationally to prepare for the rapidly increasing demands of digitization and automation. Moreover, the education for the social sciences and liberal arts might be further diminished. As Connor et al. stated, the benefits to adopting liberal arts into a STEM education, switching to a STEAM education (adding the "A" for "Liberal Arts"), is that it would foster greater capability of talent in engineering and science and increase the efficiency in educational outcomes. The results of this preliminary survey indicate the possibility that general competency would be improved, especially in problem-solving skills, by applying liberal arts-involved education on top of STEM education. Problem-solving skills involve conceptual thinking, which is the ability to see a phenomenon as a whole, which is what Katz theorized and publicized between 1955 and 1974. Katz's theory still makes sense in the modern era. The results indicate a need for engineers to develop problem-solving skills as they climb the organizational hierarchy, as the comparison between managers and directors suggest that a director's position requires higher problem-solving skills, or that the director position is assigned to individuals capable of developing problem-solving skills.

This study was initiated as a preliminary study to investigate how IT engineering managers' competencies and skills had been developed up to the managerial position, and it confirmed their need for problem-solving skills development as a hypothesis.

For future research, owing to these satisfactory results, we plan to enlarge the sample size and to extend this PROG competency test to other types of engineers, such as mechanical engineers, to observe whether there are any differences in the development of competency and skills according to the duties and responsibilities in the enterprise. In addition, it may help us find a way to better educate engineers, such as by applying adequate education to engineers or creating new assignments in the organization.

We believe that such further study will benefit engineers by leading them into higher positions such as managers and above in the organization.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Akiko Ryu Innes-Taylor composed and wrote this paper; Atsuko Yamazaki and Masahiro Inoue supervised the creation of paper and design of research; Naoki Matsumura and Fumiaki Hirata operated and coordinated PROG test for respondents; Katsutoshi Waki proceeded with the recruitment of respondents and analyzed the data.

REFERENCES

[1] B. Libert, M. Beck, and J. Wind, *The Network Imperative: How to Survive and Grow in the Age of Digital Business Models*, 1st ed. Boston, The United States: Harvard Business Review Press, 2016, Part 4, pp. 190-191.

[2] M. J. Paese, A. B. Smith, and W. C. Byham, *Leaders Ready Now: Accelerating Growth in a Faster World*, 1st ed. Pennsylvania, The United States: DDI Press, 2016, ch. 1, pp. 3-4.

[3] R. Katz, "Skills of an effective administrator," *Harvard Business Review*, vol. 33, no. 1, pp. 33-42, January-February, 1955.

[4] R. Katz, "Skills of an effective administrator," *Harvard Business Review*, vol. 2, no. 5, pp. 90-102, September-October, 1974.

[5] J. Bughin, E. Hazan, S. Lund, P. Dahlstrom, A. Wiesinger, and A. Subramaniam, "Skill shift-automation and the future of the workforce," *McKinsey Global Institute*, pp. 5-9, May, 2018.

[6] W. B. Given, "The engineer goes into management," *Harvard Business Review*, vol. 33, no. 1, pp. 43-52, January-February, 1955.

[7] PROG Hakusho Project. *PROG Hakusho 2015 (in Japanese) [PROG Whitepaper 2015]*, 1st ed. Tokyo, Japan: Gakuji Shuppan, 2015, pp. 84-85.

[8] T. Munegumi, "STEM Education and STEAM Education: History, definition, and integration," *Bulletin of Naruto University of Education (in Japanese)*, vol, 34. pp. 58-71. 2019

[9] B. Maes. (October 21, 2010). Stop talking about "STEM" education! "TEAMS" is way cooler! The Future of CNC Manufacturing Education. [Online]. Available: http://www.halcyon.com/pub/journals/21ps03-vidmar

[10] J. M. Breiner, S. S. Harkness, C. C. Johnson, and C. M. Koehler, "What Is STEM? A discussion about conceptions of STEM in education and partnerships," *School Science and Mathematics*, vol. 112, no. 1. pp. 3-11. 2012.

[11] A. M. Connor, S. Kamokarkar, and C. Whittington, "From STEM to STEAM: Strategies for enhancing engineering & technology education," *International Journal of Engineering Pedagogy*, vol. 5, no. 2, pp. 37-47, 2015.

[12] H. Ito, "Assessing an assessment tool of higher education: Progress Report on Generic skills (PROG) in Japan," *International Journal of Evaluation and Research in Education*, vol. 3, no. 1, pp. 1-10. March 2014.

[13] N. Matsumura and A. Tanabe, "The development of PROG, and performance assessment of international PBL with PROG," in *Proc. JSEE Annual Conference & AEESEAP Workshop in Sendai*, September 2019.

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