World Transactions on Engineering and Technology Education
Vol.14, No.2, 2016

Construction of problem-solving indexes for technicians in industry-oriented higher technical education

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ABSTRACT: This article aims to examine the nature and the industrial demand for problem-solving ability for technicians in industry-oriented higher technical education, which constructed the basic research for further probing into an overall evaluation of the construction and teaching system of industry-oriented demand and higher technical education. In-depth interviews and the Delphi technique were employed to establish the significance of enhancing problem-solving ability for higher technical education. The results of this study suggest that the significance of enhancing problem-solving ability in higher technical education could be divided into five constructs, i.e. attitude, intelligence, knowledge, skills and environment. Related indexes for such constructs were adjusted by experts and scholars, covering 40 items. The results from the Delphi technique questionnaires indicated that the top three significant indexes for problem-solving constructs were *attitude*, *skills* and *intelligence*, respectively.

INTRODUCTION

In an era of knowledge economies and globalisation, how to enhance personal problem-solving ability and creativity, increase overall competitiveness national wide, cultivate students' independent thinking, problem-solving ability, as well as good demeanours, have become the most significant issues for every school and institutions in Taiwan. Csikzentmihalyi stated that the learner-centred approach has become the mainstream; the school's curriculum must be devoted to students' active learning, as well as discovering new problems and solutions [1]. Technical education plays a vital role in Taiwan's industries and economic development. Both the quality enhancement and quantity expansion of Taiwanese technical education have provided a basic skilled workforce for economic development demand.

According to the Global Competitiveness Report 2015 by the International Institute for Management Development, Taiwan stepped two places forward in comparison to 2014 and was ranked 11th among 61 economies. In addition, the World Economic Forum (2016) indicated that Taiwan was ranked 15th in 2015, one place lower than in 2014; the ranks for three main indexes, such as innovation factor, basic demand and efficiency improvement all stepped back, suggesting room for improvement in its competiveness, especially, in the aspects of talent fostering, innovation enhancement and development capacity. From the above-mentioned perspectives and facts, when technologies thrive and innovate societies and lifestyles, technical education should place more emphasis on how to empower students with creative thinking and problem-solving abilities, whereby developing their future careers in such a changing society.

Meaning of Problem-solving Ability

Kerns et al indicated that problem-solving is a cognitive process, as well as a way to respond [2]. Fulcher perceived that successful problem-solving requires accurate understanding of a problem and, then, development targeting its inner meaning [3]. Based on the aforementioned viewpoints, this study would define problem-solving as a thinking process; a multiple ability containing knowledge, skills and attitude; a mind-set process to decrease the differences between his/her current situation and ideal goal or an ability to solve problems as reaching the ultimate goal; whereby, an individual can provide an effective solution by applying his/her own knowledge and experience to a problem by a process of rethinking, distinguishing and managing.

Connotation of Problem-solving Ability

The American Association for Advancement of Science (AAAS) suggests that problem-solving ability includes necessary knowledge, skills and attitudes [4] and, therefore, requires the capacity of distinguishing problems, setting up an agenda, practising solutions and evaluating the feasibility of a solution. Sternberg considered that the problem-solving ability contains six capacities: 1) problem identification; 2) organisation of information; 3) strategy formulation; 4) problem definition and representation; 5) resource allocation; and 6) monitoring [5].

Hill-Briggs, from an education research perspective, considered *problem-solving* as a learning process. An individual will not only adapt his/her own knowledge in such a process, but also practise the strategy for solving the problem. For instance, steps such as presenting and describing a problem, analysing a problem, demonstrating multiple steps of the solution and evaluating the after-effect of the solution can consistently enhance personal ability and performance through the process of solving a problem [6].

Yan stated that problem-oriented teaching and learning could lead students to analysing problems, collecting information and solving problems; thus, enhancing students' autonomous learning and independent thinking. Problem-oriented learning strengthened students' problem-solving abilities. In addition, students' ability on communication skills, collaborative actions and information collection are also increased [7].

Compared to traditional teaching methods, Tseng et al indicated that problem-oriented learning helped advance the ability to analyse and solve problems, resulting in autonomous learning, active collaboration, and development of feasible practices, as well as innovative thinking [8]. By practising problem-based learning, Yong Li helped students develop solutions by posing questions, whereby, their active learning attitude, teamwork spirit and responsibility were all increased. Students gained greater confidence, implementation capacity, innovative thinking and practical experiences of solving engineering problems [9].

In summary, problem-solving ability contains various dimensions, such as attitude, intelligence, knowledge and skills, that is, abilities of defining the nature of a problem, analysing a problem, collecting information, analysing information, setting up problem-solving strategies, executing related strategies and evaluating the overall effect of a solution.

Research Methods

This study aimed to explore the nature of problem-solving ability for technicians in industry-oriented higher technical education, and the gap between current educational training and industrial demand (see Figure 1).

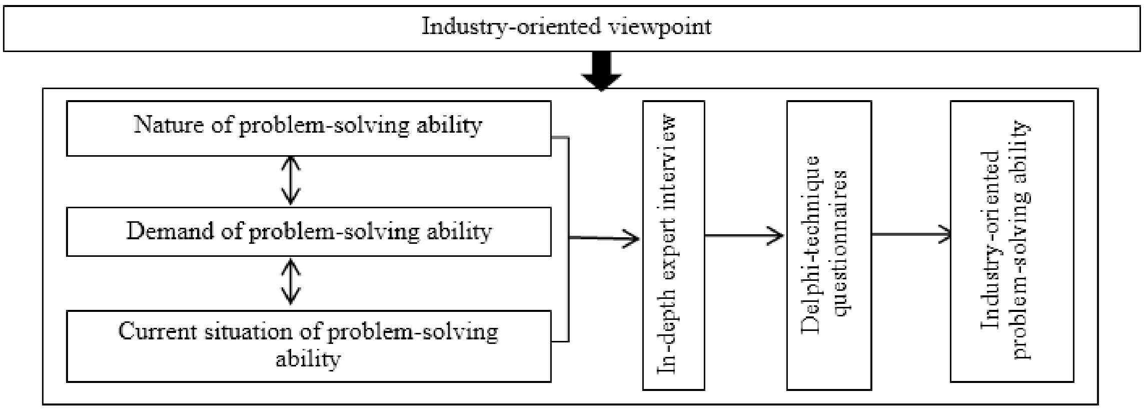

Figure 1: Framework of the study.

Qualitative research was employed for data collection and analysis, with in-depth interviews being the main method and documentary analysis as the supplementary method. Collected data were interpreted qualitatively.

In-depth Interview

To examine the *status quo* of problem-solving ability in industry-oriented higher technical education, experienced experts and scholars were invited to offer their perspectives as reference for further questionnaire development. Purposive sampling was adopted in the current study. Interview data from three experts are shown in Table 1.

Table 1: Interview data from three experts.

Interviewee	Occupation	Working experience
Scholar X	Director of a vocational education centre in a university	Knowledgeable in school subjects and abundant experience in interactions with industries business.
Mr Y	Manager in a financial service sector	Well experienced in credit checks and loan with manufacturers.
Mr Z	Owner of a shoe manufacturing company	Well experienced in interactions with manufacturers.

Delphi Technique

Based on documentary analysis and an in-depth interview, a …*Delphi technique questionnaire of problem-solving ability in industry-oriented higher technical education* was developed.

A total of 20 interviewees (scholars in relevant fields, supervisors in relevant industries and vocational school teachers) were invited to validate the nature of problem-solving ability in industry-oriented higher technical education.

RESEARCH RESULTS

The results using quantitative coding and documentary comparison have been listed in Table 2, revealing the inclusion of five constructs (attitude, intelligence, knowledge, skills and environment) in the nature of problem-solving ability in industry-oriented higher technical education.

The accumulated frequencies of attitude, intelligence, knowledge, skills and environment were respectively 4, 8, 10, 16 and 6.

Table 2: Analysis for the nature of problem-solving ability.

Constructs	Concepts	Interview		Reference		Total
		Interviewee	Times	Source	Times	
Attitude	1. Personality trait 2. Personality trend	X Y Z	3	American Association for Advancement of Science, ASSS [4]	1	4
Intelligence	1. General intelligence 2. Intelligence of problem-solving mind-set	X Y	2	Ellis [10], D'zurilla and Nezu [11], Hatch [12], Smith [13], Fulcher [14]	6	8
Knowledge	1. General knowledge 2. Professional knowledge	X	1	Gagne [15], Krulik and Rudnick [16], Brandsford and Stein [17], D'zurilla and Nezu [11], Smith [13], American Association for Advancement of Science, ASSS [4], Sternberg [18]	9	10
Skills	1. Information collecting ability 2. Acknowledgement of problem-solving contextuality	X Y	2	Ellis [10], Brandsford and Stein [17], D'zurilla and Nezu [11], Krulik and Rudnick [16], Hatch [12], Smith [13], American Association for Advancement of Science, ASSS [4], Kahey [19], Henna, Potter and Hagaman [20], Sternberg [18]	14	16
Environment	1. Social environment 2. Family 3. Peer interaction 4. Good mentor	X Y Z	3	Ellis [10], Reiter-Palmon and Illies [21]	3	6

The results from the in-depth interviews with two experts suggested that with regard to the core of problem-solving ability, teaching should focus on *instructional goals*, while practical application should centre on *policy*. Setting up instructional goals helped teachers to emphasise the cultivation of abilities rather than the teaching contents.

Obsession with the teaching contents drives teachers only to control the teaching progress, rather than the cultivation of students' problem-solving abilities.

In the process of analysing the problem-solving ability for technicians in industry-oriented higher technical education, problem-solving indexes were adjusted by experts and scholars and covered 40 items. Analysis resulted from Delphi technique questionnaire are as shown as follows:

Table 3 shows the mean, standard deviation and significance rank of the third Delphi techniques questionnaire, among which attitude topped the rank, followed by skills and intelligence.

Table 3: Mean, standard deviation and significance rank of the third Delphi techniques questionnaire on professionals.

Field	Standard	Mean	SD	Significance rank
Problem-solving ability	Attitude	6.11	0.68	1
	Intelligence	5.33	0.86	3
	Knowledge	5.28	0.68	5
	Skills	5.67	0.84	2
	Environment	5.29	0.92	4

The significance rank of each index of every standard, mean, standard deviation and relative significance for every standard were determined through analysis.

Problem-solving Ability

- The significance rank of *attitude*

According to Table 4, the most significant index for *attitude* is *motivation for solving problem when dealing with problems* and the second significant index is *autonomous learning*.

Table 4: Mean, standard deviation and significance rank of attitude.

Standard	Index connotation	Mean	SD	Significance rank	Kolmogorov-Smirnov test
Attitude	1. Motivation for solving problems when dealing with a problem	6.80	0.45	1	1.789**
	2. Be curious when dealing with a problem	6.40	0.55	3	1.342
	3. Independent thinking when dealing with a problem	5.80	0.45	6	1.789**
	4. Confidence for solving problems when dealing with a problem	5.80	0.84	6	0.894
	5. Active in raising questions when dealing with a problem	6.00	0.71	5	0.671
	6. Active in trying errors when dealing with a problem	6.20	0.84	4	0.894
	7. Autonomous learning	6.60	0.55	2	1.342
	8. Consistently in exploring the causes of a problem	5.80	0.45	6	1.78**
	9. Be self-motivated when facing the difficulties	5.60	0.55	7	1.342

$^{*}p < 0.05$, $^{**,}p < 0.01$, $^{***}p < 0.001$

- The significance rank of *intelligence*

According to Table 5, the most significant index for standard of *intelligence* is *good memory when solving a problem*, and the second significant index is to *be strategic to select the problems to solve*, as well as *be capable of distinguishing the problems to solve*.

Table 5: Mean, standard deviation and significance rank of intelligence.

Standard	Index connotation	Mean	SD	Significance rank	Kolmogorov-Smirnov test
Intelligence	10. Be capable of analysing the machinery problems	5.40	0.89	5	1.342
	11. Be capable of inducing and solving the machinery problems	4.60	0.89	10	1.342
	12. Good memory when solving a problem	5.80	0.84	1	1.789**
	13. Good imagination when solving problems	5.40	0.89	5	0.894
	14. Be capable of organising the knowledges when solving a problem	5.40	1.14	5	1.342
	15. Be strategic to select the problems to solve	5.60	1.14	2	0.596
	16. Logical mind-set when solving problems	5.20	0.84	8	0.596
	17. Be capable of expressing when solving a problem	5.20	0.84	8	0.894
	18. Be capable of distinguishing the problems to solve	5.60	0.55	2	0.894
	19. Possess the general knowledge when solving problems	5.00	0.71	9	1.342
	20. Be capable of adapting to the environment	5.60	0.55	2	0.671

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

- The significance rank of *knowledge*

According to Table 6, the most significant index for standard of *knowledge* is *possess substantial content knowledge*, and the second significant index is *possess the knowledge of new technologies*.

Table 6: Mean, standard deviation and significance rank of knowledge.

Standard	Index Connotation	Mean	SD	Significance rank	Kolmogorov-Smirnov test
Knowledge	21. Possess the knowledge for solving problems	5.20	0.84	3	1.342
	22. Possess the knowledge of new technologies	5.40	0.55	2	0.894
	23. Possess the knowledge of relevant industries	5.00	0.71	5	1.342
	24. Be capable of adapting to the environment	5.20	0.84	3	0.671
	25. Possess substantial content knowledge	5.80	0.84	1	0.894

- The significance rank of *skills*

According to Table 7, the most significant index for standard of *skills* is *possess implementation capacity of school subjects*, and the second significant index is *be capable to deliver the solution when solving a problem*, as well as *be capable to conduct the solution when solving a problem*.

Table 7: Mean, standard deviation and significance rank of skills.

Standard	Index Connotation	Mean	SD	Significance rank	Kolmogorov-Smirnov test
Skills	26. Be capable of delivering the solution when solving a problem	5.80	1.30	2	0.894
	27. Be capable of conducting the solution when solving a problem	5.80	0.84	2	0.894
	28. Be capable of evaluating the performance of a solution on solving a problem	5.60	0.55	4	0.894
	29. Possess implementation capacity of school subjects	6.00	0.71	1	1.342
	30. Be capable of collecting information when solving a problem	5.00	0.71	5	0.671
	31. Be familiar with the problem-solving process	5.00	0.71	5	0.671

- The significance rank of *environment*

According to Table 8, the most significant index for standard of *environments* is *encouragement for solving problems*, and the second significant index is *sufficiency of social resources*.

Table 8: Mean, standard deviation and significance rank of environment.

Standard	Index Connotation	Mean	SD	Significance rank	Kolmogorov-Smirnov test
Environments	32. The parenting emphasises on problem-solving training	5.20	1.10	6	0.671
	33. Atmosphere created for solving family problems	5.60	0.55	3	1.043
	34. A good mentor for directing problem-solving	5.40	0.55	5	1.342
	35. Peer interaction during problem-solving	5.00	0.71	8	1.342
	36. Facilities provided by schools for solving problems	5.60	0.55	3	0.671
	37. School atmosphere of encouraging problem-solving	5.20	1.48	6	1.342
	38. Social environment for solving problems	4.80	1.30	9	0.671
	39. Sufficiency of social resources	5.80	1.10	2	0.894
	40. Encouragement for solving problems	6.20	0.45	1	1.043**

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

CONCLUSIONS

This study aims to explore the indexes of the problem-solving ability in industry-orientated and high-skilled machinery education. According to the study goals and results, two conclusions would be inferred as below. The current study aimed to probe into the problem-solving ability indexes for technicians in industry-oriented higher technical education. Conclusions based on the results of the study were as follows:

- Establishing the nature of problem-solving indices for technicians in industry-oriented higher technical education:

The problem-solving ability derives from various dimensions, such as attitude, intelligence, knowledge and skills. Hence, such ability could be divided into several capacities, including defining the nature of a problem, analysing a problem, collecting information, analysing information, setting up the strategy for problem-solving, managing the process of problem-solving and evaluating the overall effect of a solution. On the dimension of *attitude*, significant indexes include capacities of high-levelled motivation, courageous trying, autonomous learning and independent thinking. On the dimension of *intelligence*, significant indexes include capacities of analysing, logical thinking, issues inducing, solutions evaluating and checking. On the dimension of *knowledge*, significant indexes include professional knowledge, knowledge of new technologies and relevant knowledge of technical industries. On the dimension of *skills*, significant indexes include capacities of technical implementation capacity, collecting information, delivering solutions and conducting solutions.

- Understanding the industrial demand on problem-solving indexes for technicians in industry-oriented higher technical education:

The results revealed that with regard to the core of problem-solving ability, teaching should focus on *instructional goals* while practical application should centre on *policy*. Setting up instructional goals helped teachers to emphasise the cultivation of abilities rather than the teaching contents. Obsession with the teaching contents drives teachers only to control the teaching progress, rather than the cultivation of students' problem-solving abilities. For industrial practices, only if the *policy* drives corporations to support industrial technique creativity could these business demands be truly revealed.

SUGGESTIONS

Suggestions based on the findings and conclusions of the study for future studies are as follows:

- This study only examined the construction of attitude and ability of problem-solving. The inclusion of creative thinking or examination with appropriate questionnaires is highly suggested. Such a study will not only examine the relationship among the three issues, but also systematise problem-solving issues and verify the reliability and validity of the measurement.

- The indexes developed and induced in this study can be integrated into the curriculum, with relevant teaching of problem-solving for further validation and examination, whereby the overall teaching effectiveness of problem-solving ability will be advanced.

- The teaching of problem-solving ability should focus on *instructional goals*, meaning the teaching of abilities rather than the teaching contents. Practical application should centre on *policy*, so that industrial technique creativity could be truly revealed.

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