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Using AHP method to construct a practical ability index of mechanical engineering students in technical and vocational schools

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ABSTRACT: This study analysed the dimensions of practical ability of mechanical engineering students in technical and vocational schools in Taiwan. The results may serve as a critical reference for schools when developing their curricula in order to ensure that students are equipped with the skills required by engineering industry. Through content analysis and interviews, the practical ability of mechanical engineering students in technical and vocational schools was divided into the following four dimensions: professional knowledge, skills, attitudes and situational ability in mechanical practice. Using these four dimensions, the authors developed a hierarchical weight-based analysis questionnaire and surveyed it on experts in education. The results of a data analysis show that among these four dimensions, *professional attitude toward mechanical practice* was the most critical practical ability, whereas *professional situational ability* was the least critical. Finally, among the 13 items of the four practical ability dimensions, *general skills of fundamental mechanical practice* was the most crucial, whereas *individual motor skill* was the least crucial.

INTRODUCTION

Achieving a competitive advantage in any industry depends on the technical skills and professional ability of the workforce. The quality of Taiwan's technical education has been severely diminished, with students' academic qualifications and practical ability becoming highly irrelevant to industry conditions, and the professional skills required by various industries have gradually disappeared [1].

The main purpose of technical and vocational education is to equip students with the knowledge and practical ability they need to succeed in their industry of choice [2]. Thus, technical and vocational schools worldwide are focused on preparing students for employment after graduation and developing professional abilities required by relevant industries, demonstrating the importance of practical ability [3]. Practical ability is an important factor for measuring the overall quality of students [4]. Du et al maintained that engineering students must have a comprehensive understanding of theory and a certain level of practical ability to meet the current demands of engineering industries [5].

A survey conducted by the Small and Medium Enterprise Administration of the Ministry of Economic Affairs of Taiwan revealed problems, such as wide discrepancies between students' programme of study and subsequent employment, as well as the delay between graduation and entry to the workforce. This implies that the relevance between the skills learned through school education and the skills required for entry into the job market is low; therefore, the government, corporates and schools must accept responsibility for facilitating a smoother transition from school to the workforce and reducing the involved social cost. Industry demand for adequate practical ability has become increasingly high. Consequently, current technical and vocational education systems also have higher demands for students to demonstrate greater practical ability [6].

In recent years, higher education has been focussing on teaching theory of knowledge, while ignoring the practical aspects of education [7]. In the engineering industry, the consensus is that mechanical engineering students generally have poor practical ability and their skills are irrelevant to the industry. Because students can acquire practical ability through modular training [8], the dimensions and importance of the practical abilities taught to technical and vocational school students and those needed by the professional industry must first be clarified before attempting to redevelop such abilities. Understanding the aforementioned situation may serve as a critical reference for relevant personnel in technical and vocational education systems and schools when designing mechanical engineering courses.

PRACTICAL ABILITY

Sternberg believes that practical ability is the process of translating theoretical problems into practical solutions (i.e. from abstract ideas to actual outcomes), which can be used to convince others of the validity and value of theoretical knowledge [9]. Practical ability-oriented education primarily involves change, discovery, operation and usage. In a classroom setting, practical ability-oriented education focuses on students' gaining hands-on operation of various types of equipment, through which students discover, and become familiar with, new knowledge. *Practice* is a process through which people conceptualise and realise concepts, whereas *ability* is the combined psychological and physiological characteristics that a person must possess to successfully complete a specific activity [8]. Therefore, *practical ability* refers to the formation of a practical concept and the sum of the psychological and physiological characteristics that a person must possess to realise the concept; thus, practical ability is a person's system of physical and mental capacities. In summary, practical ability is ultimately embodied in the level of quality with which an individual completes his or her tasks; it is the foundation of innovation, which relies on the practice of various means and skills [10]. Hence, in this study, practical ability is defined as the thinking and behavioural patterns that are derived from life experiences and are directed toward solving problems.

According to Fu and Liu, practical ability is a physiological and psychological characteristic that a person must possess to apply his or her knowledge and skills to solve practical problems [11]. In addition, they assert that practical ability can be divided into general, professional, and situational practical abilities, and that these three abilities can be further divided into sub-abilities or skills. *General ability*, which influences a person's problem-solving ability, is divided into situational awareness, language and communication skills and physical ability. *Professional ability*, which is the ability demonstrated when solving problems, comprises professional operational skills, professional awareness and professional communication skills. Finally, *situational practical ability*, which is the core ability for solving problems, is divided into analytical judgment, decision-making, and monitoring and evaluation abilities. Situational practical ability is focused on the timely adjustment of activity plans, procedures and methods in solving real-life problems [11].

Practical ability was divided into general, professional and situational practical abilities. Similarly, these three abilities were further divided into the following subsets of abilities and skills: general ability, which is a factor influencing one's problem-solving abilities, includes basic literacy knowledge, foreign language skills, communication skills, self-management skills, situational awareness and physical ability. Professional ability, which is the ability to solve problems, is divided into workflow planning, professional equipment operation, professional awareness, professional communication, and the ability to use resources and communications technology. Finally, situational practical ability, which is the core element of critical thinking and one that leads to a person's involvement in problem solving, is divided into problem-solving, analytical judgment abilities, and decision-making abilities, as well as monitoring and evaluations abilities.

METHODOLOGY

To determine the dimensions of practical ability for mechanical engineering students from technical and vocational schools, this study used research methods, such as content analysis, interviews and the analytic hierarchy process (AHP).

Content Analysis

This study performed a content analysis on textual data, such as related literature and mechanical programme courses currently taught at technical and vocational schools in Taiwan, to derive the dimensions of practical ability for mechanical engineering students at technical and vocational schools.

Interview

To understand the various perspectives people have regarding developing practical abilities, the authors conducted a semi-structured interview with 10 experts and scholars in mechanical engineering to evaluate the dimensions of practical abilities of mechanical engineering students from technical and vocational schools.

Analytic Hierarchy Process (AHP)

To identify the importance of the various dimensions and related ability indicators, the results drawn from the interviews and content analysis were used to design a hierarchical weight-based analysis questionnaire for measuring the discussed dimensions of practical ability. A total of 10 experts and scholars in mechanical engineering were recruited to complete the questionnaire. Subsequently, the AHP was applied on the quantitative results to identify the weights of the dimensions and to determine the level of importance of the various ability indicators. Finally, the dimensions of practical ability and weights of the ability indicators were derived.

ANALYSIS AND RESULTS

Interview Data Analysis

To determine the dimensions of practical abilities of mechanical engineering students and compare them with those expected of professionals working in the industry, this study interviewed members from the engineering industry, winners of national engineering skills competitions, and national experts in mechanical device control and computer numerical control. Records of the interviews were repeatedly reviewed, and the dimensions of practical ability were coded and aggregated before comparing them with the results derived from the literature. This process provided detailed structural information regarding the dimensions of practical ability (Figure 1).

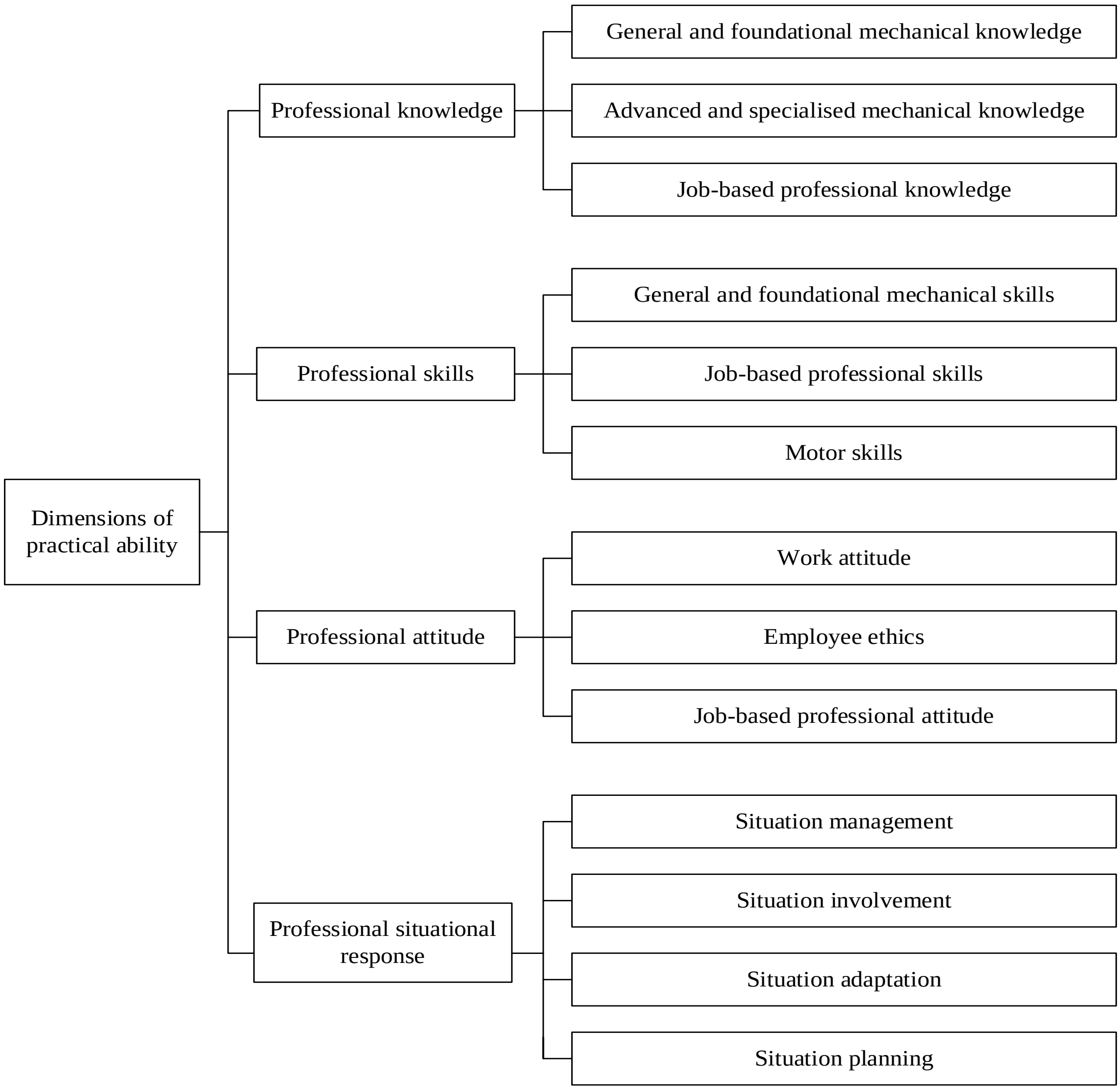

Figure1: The practical ability structure among mechanical engineering students from technical and vocational schools.

Data Analysis Using the AHP

The purpose of the AHP questionnaire was to obtain the relative weights of the item dimensions of the practical ability for mechanical engineering students studying at technical and vocational schools. Ten questionnaires were disseminated to scholars and industry experts in engineering. Subsequently, all 10 questionnaires were retrieved after calling the participants via telephone to confirm their responses to questions that they had failed to answer. With all questions answered in full, the questionnaire response rate was 100%.

Testing the Consistency of the AHP

This study designed a matrix calculation formula to derive the eigenvectors and maximum eigenvalues for the results drawn from the AHP questionnaires. All results were required to attain a consistency ratio (CR) of < 0.1; any questionnaires with a CR of > 0.1 were considered invalid and excluded from the eigenvector calculation. The consistency test yielded a CR of < 0.1 for all 10 questionnaires, satisfying the valid questionnaire requirement and attained a valid questionnaire rate of 100%.

Practical Ability of Mechanical Engineering Students from the AHP Analysis

After the questionnaires were retrieved, they were evaluated to obtain the individual assessment values, which were subsequently used to calculate the geometric mean to be used as the overall weight value. The AHP correlations were then calculated using Choice Maker Version X to determine the weights of the various dimensions of practical ability. The comparative weights of each dimension are shown in Table 1.

Table 1: The eigenvector and ranking generated by AHP.

Dimension	Dimensional eigenvector	Indicator	Indicator eigenvector	Hierarchy eigenvector	Hierarchy ranking
Professional knowledge	0.218	General and foundational mechanical knowledge	0.380	0.083	6
		Advanced and specialised mechanical knowledge	0.340	0.074	7
		Job-based professional knowledge	0.280	0.061	8
Professional skills	0.312	Motor skills	0.136	0.042	9
		Job-based professional skills	0.475	0.149	2
		Professional skills	0.390	0.122	3
Professional attitude	0.323	Employee ethics	0.268	0.086	4
		Job-based professional attitude	0.469	0.152	1
		Professional attitude	0.263	0.085	5
Professional situational response	0.147	Planning in mechanical practices	0.212	0.031	13
		Involvement in mechanical practices	0.262	0.039	10
		Situation management in mechanical practices	0.263	0.039	10
		Adaptation in mechanical practices	0.262	0.039	10

CONCLUSIONS

This study analysed the dimensions of practical ability among mechanical engineering students from technical and vocational schools in Taiwan. The results may serve as a critical reference for technical and vocational schools when developing curricula to ensure that students are equipped with professional skills that meet industry demands. Through interviews and the AHP, the following conclusion was drawn.

In order of importance, the dimensions of practical ability among mechanical engineering students from technical and vocational education are professional attitude, professional skills, professional knowledge and situational ability in mechanical practices. Professional attitude is the attitude that engineers should have when solving job-related problems or completing job tasks. Such an attitude involves employee ethics, identification with their work and career interests.

Engineering industry experts believe that employees without a positive professional attitude tend to lack enthusiasm and overlook responsibilities related to work. Therefore, professional attitude toward mechanical practices is the most crucial attribute of engineers. Professional knowledge and professional skills are the technical aspects of practical skills; without these two aspects, employees would be unable to perform well at work. Finally, situational ability in mechanical practices was considered the least crucial dimension of the four.

In order of importance, the dimensions of situational ability in mechanical practices are management, involvement, adaptation, and planning. Among the 13 discussed dimensions, general skills for fundamental mechanical practices was regarded as the most critical, whereas motor skill was regarded as the least critical. The top five major abilities were general skills for fundamental mechanical practices, work attitude, job-based professional skills, general and foundational mechanical knowledge, and advanced and specialised mechanical knowledge.

The difference between the weighted values of work attitude and general skills for fundamental mechanical practice was marginal, indicating their relatively equal level of importance. General and foundational mechanical knowledge includes the ability to use computers, having skills in sketching and examining mechanical drawings, performing general machine operations (e.g. operating lathes, mills, grinders and drills), operating high-precision measuring tools, and performing basic repairs and maintenance of mechanical equipment (e.g. calibrating and tuning), which are in line with the fundamental skills (i.e. the ability to manufacture, operate and repair machines) the industry professionals require from mechanical engineering graduates.

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