Development of an inventory of problem-solving abilities of tertiary students majoring in engineering technology

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ABSTRACT: Problem-solving ability increasingly is becoming important for students in meeting their future career demands. Training for problem-solving ability, one of the high level cognitive skills, for tertiary students may help them face complicated developments in future society. Providing assistance for practical training at a factory with an actual position in collaboration with the university may enhance the professional experiences and abilities of the students. However, the actual enhancements of the abilities of the students during the practical training of such a *sandwich programme* are unknown. A problem-solving inventory for sandwich programme students was constructed to assess the variation of ability after the practical training period. The cycle of pre-testing, statistical analysis, expert consultation, and assessment provides feedback on the variations in ability of students on the fundamental science courses. This enables the construction of appropriate teaching modules for this special sandwich programme. This study provides a model that enhances the assessment of problem-solving ability in higher technical education.

INTRODUCTION

One of the most influential models of learning, Kolb's experiential learning model (ELM), has been widely used by educators for a variety of different purposes in higher and in professional education [1]. Students studying at technological universities in Taiwan receive vocational training that differs from the general university curriculum. Constructing the learning environment for practical training on the basis of Kolb's ELM is, therefore, very important. Many schools have been adopting sandwich programmes containing practical training to help their students acquire professional know-how. Obviously, sandwich programmes are a useful part of a practical learning environment and minimise the gap between theory and practice. The implementation of sandwich programmes at a university may comprise a half year or a full year in a company. Basically, learning alternates between school and factory. Therefore, seeking a suitably instructive company is very important.

Not all sandwich programmes can be successful. Intrinsically, factory practice is a process of *learning by doing*. If cooperating companies cannot provide instructive learning environments, the students in such practical training may just become low-cost labour. Therefore, *how to grade the student's achievements and discriminate the qualification of factories* is the principal concern of the faculty administering the sandwich programme. Ming Chi University of Technology, funded by the Formosa Plastic Group, has run their sandwich programme for more than 40 years in Taiwan. The students graduating from the school must complete one year of factory practical training. During the year, the faculty of the university and the supervisor of the cooperating company guide the student by the practical training plan assigned by the previous supervisor. The current and previous supervisors also grade the student on their contribution, and profile in the company, as well as quarterly reports. However, it is not easy to assess students' achievements only by the seasonal reports because the students' learning is based on Constructivism [2].

The University's sandwich programme needs to be revised to adapt to the changes in industry and society. As a part of engineering education accreditation, the Faculty needs a standardised procedure to supervise the implementation of sandwich programmes and to assess the learning achievement of students. Assessment for learning should be used to enhance all learners' opportunities, especially practical training on the sandwich programme, one that can ensure all learners achieve their best, with their efforts recognised. Problem-solving ability is at the forefront of educational goals. Especially in this decade, most senior high school students gain access to a university in Taiwan. The curriculum of each department is formulated to help students achieve their career goals.

Assessment enables students to improve their skills provided they understand the learning aims. This understanding is where they are in relation to the aims and achieving the aims. Students' learning assessment raises the standard of a course. Bransford, Brown and Cocking reveal that an effective teaching environment is assessment-centred [3]. Formative assessment provides feedback for the students. The ongoing feedback monitors the learning status of students and reflects the linkage between course and students [3]. Brown and Knight state that the purpose of formative assessment is learning feedback given to the student to close the gap between actual and desired levels of performance [4]. Timely formative feedback is much more important in increasing the learner's knowledge and skills, given that there is clear feedback on required standards.

Generally, the student constructs knowledge from experiences, mental structures, and beliefs that are used to interpret objects and events. Developing higher cognitive ability of problem-solving is the most important of all education goals. The assessment of enhanced ability is, therefore, vital and students should give more attention to this in colleges [5]. By studying the educational approach, a problem-solving inventory for the senior student of higher technological education is constructed to assess ability. Accordingly, the university conducted a study to build a standard procedure for portfolio assessment of students' performance and evaluated the cooperating companies.

Based on Constructivism, the construction process of intellectual skills is the main concern. Therefore, the student's growth in problem-solving and cognitive strategy, before and after the sandwich programme, was observed and analysed. Students' test results in mechanical engineering are summarised in this article.

The circle of pre-testing, statistical analysis, expert consulting and assessing indicate the students' problem-solving abilities, which may provide feedback on the abilities emphasised during the fundamental science and technology courses studied to construct the proper teaching modules for the sandwich programme in the Ming-Chi University of Technology.

This study developed a suitable inventory of problem-solving abilities of the technological university students and then tested the students against the norm of previous abilities. From every student's assessment results, an evaluation can be performed on whether the training position provided by the cooperating corporation is suitable for increasing the problem-solving abilities of students provided by the sandwich programme.

METHODS AND IMPLEMENTATION

All junior students enrolled in the sandwich programme practised in companies, factories and academic institutions. In this problem-orientated investigation, a class of 38 students at the Department of Mechanical Engineering, Ming Chi University of Technology, was assessed before proceeding to the practical training of the sandwich programme for developing the problem-solving ability norm of the students.

The focal point of the assessment tool is to develop a measure of the problem-solving used by students in the completion of their technology education learning activities. The tasks include: 1) developing a procedure for identifying the mental processes as they were used by students; 2) creating an inventory to analyse the mental processes used by students; and 3) proving the inventory for consistency and reliability.

Table 1: Inventory for attitude to problem-solving ability.

Attitude A: Never, B: Seldom/Rarely, C: Sometimes, D: Often/Frequently, E: Always		A	B	C	D	E
1.	I face the obstacles during my learning without escape.					
2.	I am always active and positive in daily life.					
3.	I am learning to be more passive, and often need guidance from others.					
4.	I can make an independent decision by myself.					
5.	I cannot do well in nervous situations.					
6.	I will try the other methods if I find my approach is a failed one.					
7.	If the method is no use in solving the problem, I will leave it out.					
8.	I admit being responsible for the consequences of failure.					
9.	Faced with it, I can make persistent efforts, and not be discouraged.					
10.	I am confident that I can do everything well.					
11.	I would forget the failure that made me comfortable.					
12.	When I solve the problem, I would not want to try to find out the reasons.					
13.	When I do not understand the problem, I search the information to make it clear.					
14.	When I solve the problem, I doubt the problem cannot be solved by myself.					
15.	I will always think of ways to solve the problem, until no idea occurs.					
16.	I solve the problem, and do not spend enough time to think carefully about it.					
17.	When successfully solving the problem, I have confidence in myself.					
18.	As long as there is sufficient time and effort, I believe I can solve most problems.					
19.	When I face a new (training) environment, I can control any potential problems.					

20.	I believe that I am able to solve novel and difficult issues.					
21.	In the course of practice, I can harmoniously take care of my partners.					
22.	I can act according to circumstances and properly handle meeting difficulties.					
23.	In the course of practice, I hold a high degree of interest in everything.					
24.	I can consistently reach the target.					
25.	I will respect the different opinions and views of others.					
26.	I will accept criticism from others, and reflect on their actions.					
27.	When I have a lot of things to be dealing with, I often do not know where to start.					
28.	When I have a lot of important issues pending.					
29.	I think that to solve a new problem is the most satisfying thing.					
30.	In my learning process, I encourage myself to my desired goal.					

Table 1 outlines the initial inventory on attitude toward problem-solving ability. This inventory has a five-point scale (A: Never, B: Seldom/Rarely, C: Sometimes, D: Often/ Frequently, E: Always). Students were instructed to read 30 items and to circle the answer that best described the way they were trying to solve a problem they might see during pilot testing. The other inventories for the approach and quality of the problem-solving abilities are not introduced in this article, but the processing schemes are the same as the attitude inventory in pilot testing.

It is relevant to note that although the term *assessment* is often used within a context where a value judgment is made and one thing is determined to be better than another, the process described in this study uses the term *operationally* to describe procedures for identifying particular activities, determining how long these activities last, and how frequently activities are repeated in practice.

The procedure would enable an observer to determine whether a learning activity accomplished objectives related to use of mental processes in problem-solving. It was not, however, designed to directly measure the products or outcomes of the activities involved. Preliminary testing of the observation procedure was done using a timer to record the duration and frequency of each mental process observed. The field-testing phase demonstrated that agreement could be achieved between observers independently viewing videotaped technology education activities.

The data for the research have been collected through several stages. First, sample descriptive statistics, such as arithmetic means and standard deviations on the study scales have been computed and reported in tables. Subsequently, the relational solutions determined in alignment with the objectives of the research have been computed. The statistical solutions of the data have been tested by the SPSS package program.

If the distributions showed normal distribution characteristics, parametric analysis techniques such as independent group *t*-test have been used. To determine whether there is a significant relationship between the students' problem-solving skills and self-confidence points, Pearson product-moment coefficient has been calculated. In addition, for finding relationships between problem-solving skills and self-confidence scores, coefficient analysis was used.

The initial questionnaire has 90 items for assessing the problem-solving abilities of the students for pilot testing on the population of 36 students. The analysis by SPSS shows that the reliability of the inventory by Cronbach's Alpha was 0.696, whereas the normalised one is 0.773. Removing the items of the initial questionnaire, based on the conditions of the item dependence lower than 0.3 and Cronbach's Alpha lower than 0.696 without the evaluated item, the final items of the questionnaire number 76 culled from the previous pilot testing and analysis.

RESULTS AND DISCUSSION

After pilot testing, review, expert discussions, and revision of the inventory, the inventory was acceptable for students in the sandwich programme at Ming Chi University of Technology. Surveys of pilot-testing analysis and comparisons with the inventory published by publication of psychology have shown that the test results confirm the proposed scale and height of commercial quantity of expression was related to other pre-test reliability.

Cronbach's Alpha coefficient is 0.696 and standardised Cronbach's Alpha coefficient is 0.773. The proposed inventory for the three dimensions of the total 76 items shows reliability testing of 0.773, which demonstrated good validity.

A total of 456 questionnaires were returned, as against 534 initial ones. Respondents included 154 (34%) females and 295 (66%) males. A total of 137 (30.4%) of the respondents did not have any service-learning experience, and a total of 141 (31.5%) of the respondents had no part-time work experience during tertiary education and senior high school. As a result of the analyses, the students' problem-solving skills show an insignificant variability across gender and department variables.

It was concluded that no significant difference was present in terms of classroom variables. As a result of the *t*-test conducted, it was concluded that problem-solving ability scores of students from the groups showed significant differences in the part-time work experience, learning achievement ranking in the class, and service experience during tertiary education and senior high school.

Table 2: Norms of the problem-solving attitude, approach, quality, and ability of students in each department.

Mean./Std. dev.	Attitude	Approach	Quality	Ability
Norm (Whole student)	90.2/10.1	76.1/10.8	102.9/16.1	269.2/34.3
Dept. of Mechanical E.(A)	90.8/9.6	76.7/9.6	103.7/11.8	271.2/29.8
Dept. of Vehicle E.	88.1/11.1	71.6/12.6	99.6/117.4	259.3/40.8
Dept. of Electronic E.	91.4/12.5	77.9/11.6	105.4/17.9	274.8/39.5
Dept. of Electrical E.(A)	94.4/7.1	78.0/9.98	104.6/14.1	276.9/27.1
Dept. of Chemical E.(A)	87.6/11.3	71.4/12.4	97.1/16.2	256.1/38.7
Dept. of Environment E.	90.8/7.8	76.2/9.2	105.3/16.7	272.3/31.0
Dept. of Materials E.	86.6/6.7	72.4/8.7	93.2/20.2	252.2/29.6
Dept. of Industrial E.	92.0/10.6	78.6/12.9	107.7/18.3	278.2/39.1
Dept. of Industrial Design	86.9/12.4	74.7/10.2	100.2/14.3	261.7/35.7
Dept. of Business Adm.	90.7/6.7	77.2/7.2	102.7/14.3	270.6/23.7
Dept. of Visual Comm.	89.7/9.6	77.4/10.5	104.5/16.3	271.6/33.0
Dept. of Mechanical E.(B)	91.8/9.8	77.8/10.1	105.1/14.3	274.7/33.1
Dept. of Electrical E.(B)	90.7/12.2	77.1/10.8	102.5/18.1	270.3/36.9
Dept. of Chemical E.(B)	90.5/11.1	77.3/10.8	105.5/14.6	273.3/34.7

The results of analysis on the assessment of problem-solving ability are shown in Table 2. It can be seen that the mean scores of total students is 269.2 and standard deviation is 34.3. The mean scores/standard deviations of attitude, approach, and quality dimensions are 90/10.1, 76.1/10.8, and 102.9/16.1, respectively.

According to the results obtained at the end of research, it is proposed that tertiary students have different variations in terms of problem-solving skills according to various variables, which differ statistically. As well, it has been observed that education received has made differences in sub-dimensional levels of problem-solving. It was concluded that the students' levels of problem-solving abilities in terms of attitude, approach and quality show significant differences as a result of the part-time working experience, learning achievement ranking in the class, and service experience during tertiary education and senior high school.

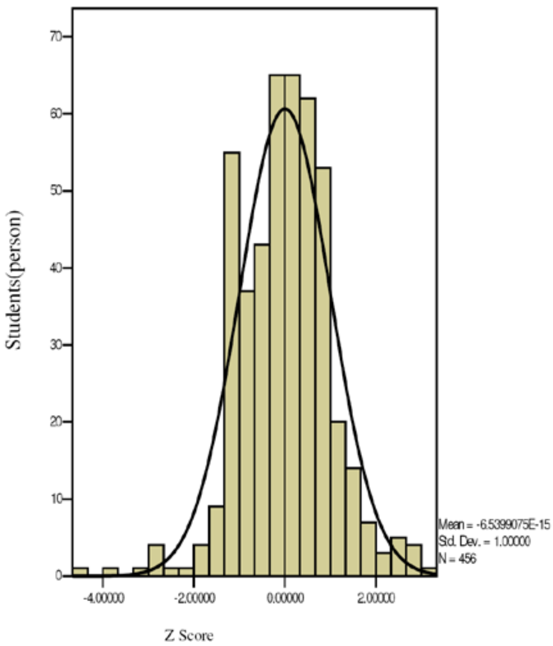

Figure 1: Z scores of the problem-solving attitude of senior students.

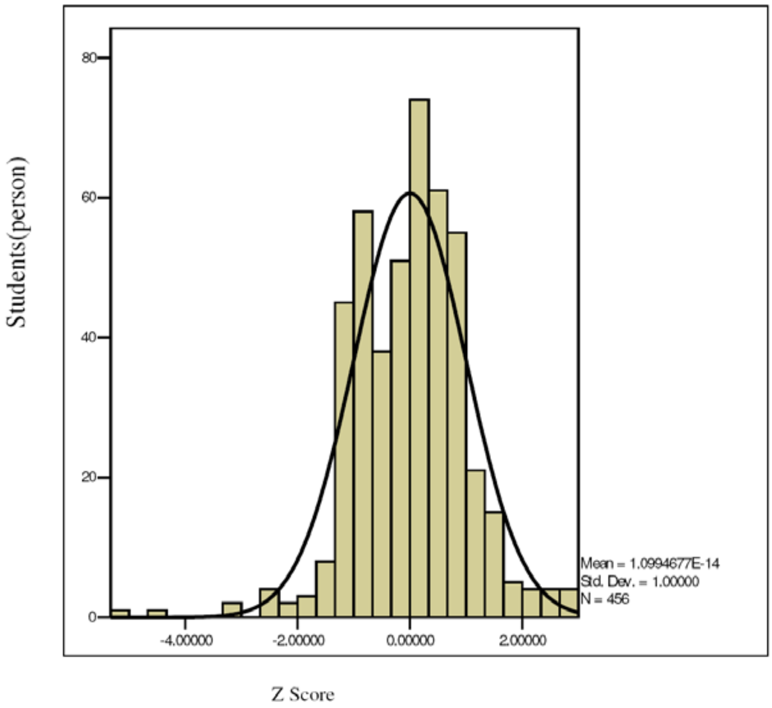

Figure 2: Z scores of the problem-solving ability of senior students.

CONCLUSIONS

The inventory was divided into three dimensions: attitude, approach and the quality of the problem-solving abilities. Each dimension comprised 30 questionnaires for the pre-test administered to the 36 students to derive reliability and validity. The pre-test achieved a higher reliability of Cronbach's Alpha, of 0.696, whereas the standardised Cronbach's Alpha obtained 0.773. Out of 523 questionnaires distributed, 456 were completed and used in this study. Using SPSS, it was found that 1) there were 76 questionnaires in the inventory, which shows a higher interrelatedness of the commercial inventory; 2) the problem-solving abilities have no significant interrelatedness on gender, major or the recent graduates; 3) the problem-solving abilities have significant difference between students with a different score ranking, with part-time jobs, and class cadre during high school and college. Based on the findings of this study, some suggestions were given at the end of the study for the reference of inventory users and future researchers. Feedback of the ability assessments of each student is provided to the concerned teachers in order to improve the teaching modules so they are useful for higher technical and vocational education.

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