INDUSTRY-ORIENTED COMPETENCY REQUIREMENTS FOR MECHATRONICS TECHNOLOGY IN TAIWAN

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ABSTRACT
This study employed a three-phase empirical method to identify competency indicators for mechatronics technology according to industry-oriented criteria. In Phase I, a list of required competencies was compiled using Behavioral Event Interviews (BEI) with three engineers specializing in the field of mechatronics technology. In Phase II, the Delphi technique was performed with ten experts in mechatronics, followed by the K-S (Kolmogorov-Smirnov) one-sample test to evaluate the consistency of opinions amongst respondents. In Phase III, these competencies were quantitatively verified by 62 learners studying mechatronics technology, and a nonparametric Mann-Whitney U-test was then performed. As a result, we developed a list of 36 competencies in 9 domains. Our research findings reveal the practical competencies required for mechatronics technology according to industry-oriented criteria.
Keywords: Competency analysis, Mechatronics, Delphi technique

INTRODUCTION

The shift toward globalization and a knowledge-based economy as well as rapid changes in the labor market now mean that hard work can no longer guarantee employment for young people. Students require a quality education to meet the competency demands of the workplace, and technological education is considered effective only if it meets the requirements of the industry in which they seek employment (Yildirim and Simsek, 2001). Technological training should be directed toward the development of key competencies and problem-solving abilities (Yeh *et al.*, 2010). Industry-oriented competency refers to the ability to obtain and keep a job; therefore, the priority of education should be the development of industry-oriented competency (Kuo *et al.*, 2011).

Mechatronics sequences integrate the fundamental elements of mechanical, electrical, engineering, and information systems, to form a powerful, adaptable, interdisciplinary approach to solving practical problems. A broad-based approach to learning involving student-built projects can encourage creativity and enthusiasm for the subject (Siegwart *et al.*, 1998; James, 2004).

Engineers specializing in mechatronics are expected to adapt quickly to trends in technology and the market, and to apply an integrated approach to the development of products and processes. Mechatronics engineers must be able to work effectively in an industrial environment, apply advanced technological skills according to the principles of mechatronics, and coordinate their actions with team members to facilitate concurrent engineering (Gupta *et al.*, 2003). The curriculum employed in educational programs for mechatronics engineering should cover the core technologies and multi-disciplinary background required by future engineers (Geddam, 2003). Industry has repeatedly requested that educational institutions broaden the scope of undergraduate engineering courses (Witt *et al.*, 2006).

Mechatronics is an integrated multidisciplinary approach to product design and therefore differs fundamentally from classical single-discipline engineering programs (Acar, 1997; Alex, 2006). Mechatronics is poised to become the key enabling technology for enhancing competitiveness in the modern era, making it indispensable to the continued competitiveness of national economies.

The teaching objectives of courses in mechatronics should be to enhance student competency, while preparing students for active employment through the interrelated tasks of operating action, taking action, taking continuous action, and stimulating action (McGee *et al.*, 2009). In this manner, graduates would have the skills required to propose innovative ideas as well as to put them into practice (Spencer and Spencer, 1993; Heinonen and Poikkijoki, 2006).

We reviewed a number of previous studies in which competence was considered an external behavior, comprising knowledge, skills, and attitudes (Stout and Smith, 1986; Stasz, 2000; Chen and Chen, 2005; Chen, 2010). Rychen and Salganik (2003) specified that competency is a psychosocial prerequisite (including both cognitive and non-cognitive aspects) required to perform in a particular context. Klein et al. (2004) focused on job tasks and the development of abilities required of an individual to fulfill the duties of a given occupation to the standards expected by the employer. Displays of competence can be diverse and multi-faceted; a number of competencies are considered innate, while others are acquired through learning. Competencies are the behavioral characteristics (both observable and non-observable) required for the successful performance of a given task.

This study sought to identify the practical competencies required by individuals studying mechatronics technology and confirm the structural features of these competencies using empirical data. We began with a review of the literature and behavioral event interviews (BEI). The feasibility and accuracy of the proposed competency requirements were analyzed using the Delphi technique. Descriptive analysis was adopted to obtain mean, standard deviation, and Z-values for the K-S (Kolmogorov-Smirnov) one-sample test (Wen and Shih, 208) and the nonparametric Mann-Whitney U-test. Scholars in engineering education and experts in mechatronics technology were also engaged to assess the fitness of the competency requirements (Chou *et al.*, 2010). These results could be used by educational institutions for the development of training regimes and testing standards.

COMPETENCY ANALYSIS

The concept of competency was first proposed by McClelland in 1973, and since that time, the term has been widely interpreted. According to Lysaght and Altschuld (2000), competency is the external behavior of an individual according to his/her knowledge, skills, and attitude. As such, competency is reflected in one's values, attitudes, and judgment. Weinert (1999) considered performance competency to be the knowledge, sentiment, and skills required to undertake and complete a task. Competencies can be categorized into general and professional.

Analysis of competency involves the identification of the behaviors required by professionals to perform job-related tasks. These behaviors include motives, characteristics, and skills; or knowledge of the fundamental characteristics. Specifically, competency refers to the ability of employees to work effectively and perform the role they have been assigned (Shang, 2000). Thus, competency is more than an aggregation of knowledge, skills, and attitudes, but also a dynamic concept of putting theory into practice.

Competency refers to the ability to achieve an outcome in a specific situation (Chao *et al.*, 2003). To meet the industrial requirements for mechatronics technology, competencies must be examined to ensure the validity of the items and standards used in the measurement of competency. The curriculum should be implemented according to industry requirements, and the process of analyzing competency should determine whether students have attained the required standards. The main purpose of analyzing competency is to verify whether an individual possess the knowledge, attitudes, and skills required in the workplace (Heitmann *et al.*, 2003; Rebolj *et al.*, 2008).

McClelland (1973) suggested the term competency as a criterion for judging the success of performance. Competency frameworks have been applied in various settings, including the assessment of managers, as training and recruitment tools (Rifkin *et al.*, 1999; Foxon *et al.*, 2003), and for educational professionals recruiting and developing staff as well as designing curriculum (Russ-Eft *et al.*, 2008; Ball, *et al.*, 2012). So (2006) characterized these as attempts to define the human resource needs of a knowledge-based, capitalist society and subsequent researches have published papers dealing with competency levels (Dinçer and Sahinkayas, 2011; Zorba, 2011).

BEHAVIORAL EVENT INTERVIEW (BEI)

Several methods have been developed for defining and developing competency. The most commonly applied of these is the Behavioral Event Interview (BEI), which provides definitions of related competencies by comparing the performance of outstanding experts with that of ordinary individuals. McClelland (1998) explained that BEI is an adaptation of the critical-incident interview used to note differences between outstanding and typical performance. Competencies are defined through structured interviews in which highly successful and typical performers describe what they did, said, and thought. This is followed by content analysis to compare the statements and identify the critical competencies within the setting being investigated. The collection of empirical data and the analysis of systematic content are considered the main advantages of BEI (Hong and Jung, 2011).

Several alternatives to the BEI method have been proposed. Gregory (2008) conducted interviews on the subject of competency with highly regarded communicators to identify the competencies associated with practitioners in public relations. In the context of education, Marrelli (1998) and Marrelli *et al.* (2005) suggested applying BEI only to superior performers. This approach appears to be a useful means of identifying the competencies required in formal education where goals are usually predetermined, specific, and subject to assessment and evaluation.

METHODOLOGY

This study employed a three-phase method for the collection and analysis of data. Phase I involved the application of BEI to define competencies associated with the tasks of three engineers involved in mechatronics. Phase II employed involved the Delphi technique on ten experts to examine the consistency of the BEI findings. Phase III involved quantitatively verifying the results of Phases I and II with a group of individuals currently mechatronics learners.

There were two primary reasons for adopting this method. First, BEI was seen as the best way to identify the competencies of field engineers required for the initial investigation. Second, we believed that the best way to ensure that the results were valid and generalized was to have the data from Phases 1 and 3 verified by a group of students actively engaged in learning mechatronics technology (Gayeski *et al.*, 2007).

Delphi technique

The Delphi technique is widely used for gathering data from respondents within a specific domain of expertise. This approach is a process of group communication meant to achieve a convergence of opinion regarding a specific real-world issue. The Delphi process has been used in various fields of study, including program planning, needs assessment, policy determination, and resource utilization to develop a comprehensive range of alternatives, explore or expose underlying assumptions, and correlate judgments in many disciplines. The Delphi technique is well suited to consensus building through its use of a series of questionnaires delivered through multiple iterations to collect data from a panel of selected subjects. Any staff member who assigns a rank deviating by 10 or more points from the corresponding first Delphi median rank is requested to state the rationale for the dissenting opinion in the space provided (Dalkey and Helmer, 1951). The number of subjects used to perform the Delphi technique should be kept to a minimum as determined by a representative pooling of judgments and the information processing capability of the research team. However, previous studies provide no consensus as to the optimal number of subjects. Researchers have suggested that 10-15 subjects could be sufficient if the background of the subjects is homogeneous. Nonetheless, results should be verified through follow-up investigation. Delbecq et al. (1975) suggested that 10-15 subjects could be sufficient if the background of the subjects is homogeneous.

The Delphi technique avoids many characteristics of traditional decision-making processes, in which participants discuss issues face to face in order to reach an agreement. By filling out questionnaires individually, experts have a sense of full participation and remain free from interruption (Rowe *et al.*, 1991). Thus, this study recruited ten participants, included six experts in the mechatronics industry and four professors in a technological university.

Questionnaire design

The questionnaire was designed to collect data regarding competency indicators in nine domains: (1) sensor techniques, (2) electrical machinery control techniques, (3) PLC techniques, (4) pneumatic control techniques, (5) mechatronics techniques, (6) graphical monitoring and control techniques, (7) computer control techniques, (8) remote monitoring and control techniques, and (9) system integration techniques. Thirty-six professional competencies associated with the industrial aspects of the mechatronics technology were identified. Each competency was rated according to its importance in terms of job performance using a Likert scale: 5 for 'very important', 4 for 'more important', 3 for 'somewhat important', 2 for 'less important', and 1 for 'least important'.

Participants

Based on the results of literature review, Kayaoğlu *et al*. (2011) and Aktaş *et al.* (2011) adopted a small sample size to compare two different groups in statistical analysis. Kayaoğlu *et al.* (2011) investigated whether a difference exists between learning vocabulary via animation and via traditional paper-based method. This small scale study was selected as the experimental group (n=17), and control group (n=22). Aktaş *et al.* (2011) investigated that teaching of different pattern types by using computer animations and activities. The sample of this study was 28 eighth grade students.

Three field engineers in mechatronics technology oversaw the BEI in Phase I. The ten participants in the Delphi technique in Phase II included four professors and six field experts with an average of 8 years experience in teaching, research, and the development of mechatronics technology. Four of these had doctoral degrees in educational technology or engineering. The participants in the survey in Phase III included 62 students studying mechatronics technology at a technological university in Taiwan.

Instruments

The content of the BEI in Phase I was verified with regard to content validity. Thirty-six questions were examined using the Delphi technique in Phase II. The content validity of these questions dealt mainly with the thoughts and experiences of experts in teaching and researching mechatronics. The survey instrument used in

Phase III was used to assign an importance rating to each of the 36 competencies related to the instruction of mechatronics and its relationship to their own studies.

Procedure
The three phases of the study were performed between September and November 2011. In Phase I, the three experts were first sent emails explaining the purpose of the study, the nature of the interview process, and the questions they would be asked. Actual face-to-face interviews took an average of one hour per engineer. During these interviews, the interviewees were asked to respond to questions and provide detailed accounts of how they handled critical study situations. The interviews were audio-recorded with the permission of the learners.

In Phase II, emails were first sent out to the ten participates explaining the purpose of the Delphi technique surveys. Surveys were then conducted to determine the competency items for working in the mechatronics industry.

Phase III was a validation survey involving sixty-two individuals studying mechatronics technology. The respondents were volunteers who had learned about the survey primarily from their instructors. Figure 1 illustrates the three-phase process of competency analysis.

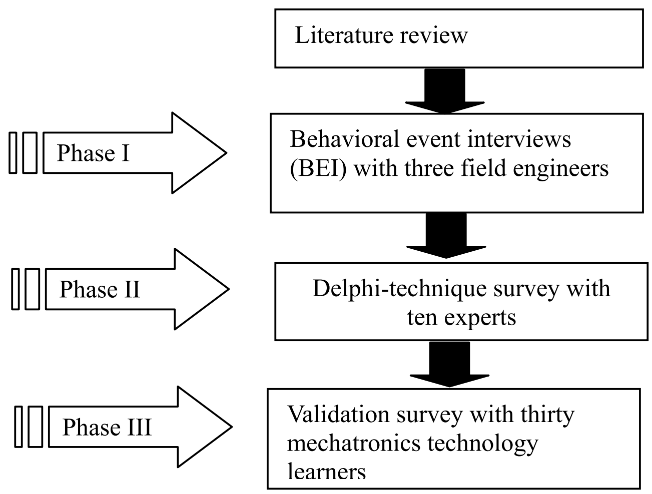

Figure1. Three-phases of the competency analysis process

Data analysis
For data analysis in Phase II, descriptive analysis was adopted for the mean (M), standard deviation (SD), and Z-value of the K-S Test. After the questionnaires were received, correlation analysis was performed to determine relationships between two sets of the second and third rounds of the Delphi technique.

For data analysis in Phase III, since the sample size is small, the non-parametric Mann-Whitney U-test was used to confirm the importance of the 36 competencies in this study (Shyr, 2009).

RESULTS
Results of the Delphi survey of experts are shown in the Table 1. The nine domains for industry-oriented competency requirements for mechatronics technology include the following: sensors, electrical machinery control, programmable logic control, pneumatic control, mechatronics, graphical monitoring and control, computer control, remote monitoring and control, and system integration. For the K-S test, a value equal to 0.05 was considered statistically significant, indicating that participants considered these indicators more important and consistent. Regarding the importance of job performance, the mean score for the 36 working competencies in nine domains of the mechatronics industry was above 4.4, which indicates that the Delphi group considered the competencies listed in the questionnaire to be ”more important” and the items that participants considered important and consistent.

Table 1. Analysis of the consistency in data of the professional competency items for the K-S test

Competencies Indicators	Z-value
1.Sensor Technique	
1-1.Can understand the basic principles of sensors	1.897*

1-2.Can understand the functions and characteristics of sensors	1.897*
1-3.Is familiar with the application of sensors	2.214*
1-4.Possesses the ability to design simple circuits with sensors	1.581*
2.Electrical Machinery Control Technique	
2-1. Can understand the basic principles of electrical machinery	1.897*
2-2. Can understand the characteristics and control of electrical machinery	1.897*
2-3. Is familiar with the application of electrical equipment	1.897*
2-4. Possesses the ability to maintain electrical equipment	1.897*
3.Programmable Logic Control (PLC) Technique	
3-1. Can understand the commands and syntax for PLC	1.897*
3-2. Is familiar with the applications of PLC	2.846*
3-3. Is familiar with the communication methods for PLC	1.581*
3-4. Possesses the ability to debug for PLC	2.530*
4.Pneumatic Control Technique	
4-1. Can understand the basic characteristics and principles of pneumatic components	2.530*
4-2. Is familiar with the selection and placement of pneumatic components	1.897*
4-3. Is familiar with the application of pneumatic control components	1.897*
4-4. Possesses the ability to control pneumatic components	2.214*
5.Mechatronics Technique	
5-1. Can understand the concepts of mechatronics	2.214*
5-2. Is familiar with the operation of mechatronics module	2.530*
5-3. Is familiar with the control technique of mechatronics	2.214*
5-4. Possesses the ability to design mechatronics	2.530*
6.Graphical Monitoring and Control Technique	
6-1. Can understand the concepts of graphical monitoring and control	1.897*
6-2. Is familiar with the use of graphical monitoring software	1.581*
6-3. Is familiar with the planning of graphical monitoring and control	1.897*
6-4. Possesses the ability to integrate graphical monitoring control and peripheral devices	2.846*
7.Computer Control Technique	
7-1. Can understand the use of various computer control techniques	1.897*
7-2. Is familiar with the computer control technique using software	1.897*
7-3. Is familiar with the computer control technique using hardware	1.897*
7-4. Possesses the ability to integrate computer control technique with mechatronics systems	2.530*
8.Remote Monitoring and Control Technique	
8-1. Can understand the concepts of remote monitoring and control	2.214*
8-2. Is familiar with the planning of remote monitoring and control	2.214*
8-3. Is familiar with the operation of remote monitoring and control	1.897*
8-4. Possesses the ability to integrate remote monitoring control with mechatronics equipment	2.530*
9.System Integration Technique	
9-1. Can understand the concepts of system integration	1.897*
9-2. Is familiar with the assembly with automation equipment	2.214*
9-3. Possesses the ability to system integration	2.530*
9-4. Possesses the ability to construct a set mechatronics control system	2.214*

*p<0.05

As shown in Table 2, the industry-oriented competencies for mechatronics technology comprise 36 indicators. These include understanding the basic principles of sensors, understanding the functions and characteristics of sensors, familiarity with the application of sensors, the ability to design simple circuits using sensors, understanding the basic principles of electrical machinery, understanding the characteristics and control of electrical machinery, familiarity with the application of electrical equipment, the ability to maintain electrical equipment, understanding the commands and syntax for PLC, familiarity with the applications of PLC, familiarity with the communication methods used in PLC, the ability to debug PLC, understanding the basic characteristics and principles of pneumatic components, familiarity with the selection and placement of pneumatic components, familiarity with the application of pneumatic control components, the ability to control pneumatic components, understanding the concepts of mechatronics, familiarity with the operation of mechatronics modules, familiarity with the control of mechatronics, the ability to design mechatronics, understanding the concepts of graphical monitoring and control, familiarity with the use of graphical monitoring software, familiarity with the planning of graphical monitoring and control, the ability to integrate graphical monitoring control and peripheral devices, understanding how to use various computer control techniques, familiarity with computer software in control techniques, familiarity with the hardware used in computer control techniques, the ability to integrate computer control techniques with mechatronics systems, understanding the concepts of remote monitoring and control, familiarity with the planning of remote monitoring and control, familiarity with the operation of remote monitoring and control, the ability to integrate remote monitoring control with mechatronics equipment, understanding the concepts of system integration, familiarity with the process of assembly using automated equipment, the ability to perform system integration, and the ability to construct a set mechatronics control system.

Further analysis was conducted to confirm whether the ten experts and sixty-two learners differed in the mean ratings regarding the importance of the competencies. The nonparametric Mann-Whitney U-test was used and the results are presented in Table 2. The level of significance α was selected to be 0.05 and the corresponding two-tail critical value was ±1.96. The mean ratings of the experts regarding the importance of the competencies did not significantly differ from those of the learners.

DISCUSSION

This study makes three important contributions. First, the results add to the literature by presenting a set of working competency requirements and their relative importance is based on empirical data. Second, the working competencies identified in this study can contribute to the development and improvement of learner support programs. Third, the findings improve the methodology of determining competency by piloting a three-phase method involving both qualitative and quantitative approaches.

The findings indicate the kinds of industry-oriented competencies as well as intrinsic and extrinsic motivations required by institutions to promote the efficient learning of mechatronics. As indicated in other studies (Simpson, 2003; Johnson and Onwuegbuzie, 2004), comprehensive, ongoing learner support systems are required to help students in their studies. We demonstrate the value of the three-phase method as a systematic and reliable methodology for identifying working competencies associated with mechatronics technology. Various methods were applied individually and in combination to identify and validate the competencies of various professionals (Lucia and Lepsinger, 1999; Simpson, 2003; Klein *et al.*, 2004). The proposed three-phased method integrates three carefully selected methods – a behavioral event interview, the Delphi technique, and a validation survey using the synergetic method. These competencies were then clarified, elaborated on, validated, and classified by experts in the field and experienced researchers. Finally, the defined competencies were validated by surveying a group of mechatronics technology learners to finalize the competency list.

It is worth noting that the selection of Taiwan participants who are well-versed in mechatronics technology use and accustomed to instructor-led classes may limit the generalized ability of our findings.

CONCLUSIONS

The industry-oriented competency indicators for mechatronics technology cover nine domains, including the following: sensors, electrical machinery control, programmable logic control, pneumatic control, mechatronics, graphical monitoring and control, computer control, remote monitoring and control, and system integration. These provide a reference for the planning and revision of core courses at the university level. Future studies may include task analysis to determine the expertise, knowledge, and types of assignments required for each competence, as a reference for the development of instructional materials.

Table 2: The results of Mann-Whitney U-test

Competencies Indicators	Experts (n = 10)		Learners (n=62)		U-test (*p* value)
	M	SD	M	SD	
1.Sensor Technique					
1-1.Can understand the basic principles of sensors	4.60	0.516	4.71	0.458	-0.694(0.488)
1-2.Can understand the functions and characteristics of sensors	4.60	0.516	4.74	0.441	-0.923(0.356)
1-3.Is familiar with the application of sensors	4.70	0.483	4.69	0.465	-0.041(0.967)
1-4.Possesses the ability to design simple circuits with sensors	4.40	0.699	4.65	0.482	-1.083(0.279)
2.Electrical Machinery Control Technique					
2-1. Can understand the basic principles of electrical machinery	4.60	0.516	4.73	0.450	-0.807(0.420)
2-2. Can understand the characteristics and control of electrical machinery	4.60	0.516	4.60	0.495	-0.019(0.985)

2-3. Is familiar with the application of electrical equipment	4.60	0.516	4.65	0.482	-0.274(0.784)
2-4. Possesses the ability to maintain electrical equipment	4.40	0.516	4.60	0.495	-1.158(0.247)
3.Programmable Logic Control (PLC) Technique					
3-1. Can understand the commands and syntax for PLC	4.60	0.516	4.71	0.458	-0.694(0.488)
3-2. Is familiar with the applications of PLC	4.90	0.316	4.66	0.477	-1.510(0.131)
3-3. Is familiar with the communication methods for PLC	4.50	0.527	4.56	0.500	-0.378(0.705)
3-4. Possesses the ability to debug for PLC	4.80	0.422	4.50	0.536	-1.675(0.094)
4.Pneumatic Control Technique					
4-1. Can understand the basic characteristics and principles of pneumatic components	4.80	0.422	4.61	0.491	-1.135(0.256)
4-2. Is familiar with the selection and placement of pneumatic components	4.60	0.516	4.52	0.620	-0.262(0.793)
4-3. Is familiar with the application of pneumatic control components	4.60	0.516	4.45	0.619	-0.627(0.531)
4-4. Possesses the ability to control pneumatic components	4.70	0.483	4.42	0.615	-1.342(0.180)
5.Mechatronics Technique					
5-1. Can understand the concepts of mechatronics	4.70	0.483	4.58	0.497	-0.709(0.478)
5-2. Is familiar with the operation of mechatronics module	4.80	0.422	4.66	0.477	-0.867(0.386)
5-3. Is familiar with the control technique of mechatronics	4.70	0.483	4.65	0.482	-0.336(0.737)
5-4. Possesses the ability to design mechatronics	4.80	0.422	4.61	0.610	-0.849(0.396)
6.Graphical Monitoring and Control Technique					
6-1. Can understand the concepts of graphical monitoring and control	4.50	0.707	4.66	0.477	-0.580(0.562)
6-2. Is familiar with the use of graphical monitoring software	4.50	0.527	4.74	0.441	-1.551(0.121)
6-3. Is familiar with the planning of graphical monitoring and control	4.40	0.516	4.61	0.554	-1.339(0.181)
6-4. Possesses the ability to integrate graphical monitoring control and peripheral devices	4.90	0.316	4.61	0.491	-1.757(0.079)
7.Computer Control Technique					
7-1. Can understand the use of various computer control techniques	4.60	0.516	4.68	0.471	-0.479(0.632)
7-2. Is familiar with the computer control technique using software	4.60	0.516	4.55	0.502	-0.303(0.762)
7-3. Is familiar with the computer control technique using hardware	4.60	0.516	4.61	0.554	-0.194(0.846)
7-4. Possesses the ability to integrate computer control technique with mechatronics systems	4.80	0.422	4.61	0.491	-1.135(0.256)
8.Remote Monitoring and Control Technique					
8-1. Can understand the concepts of remote monitoring and control	4.70	0.483	4.53	0.503	-0.984(0.325)
8-2. Is familiar with the planning of remote monitoring and control	4.70	0.483	4.58	0.497	-0.709(0.478)
8-3. Is familiar with the operation of remote monitoring and control	4.60	0.516	4.56	0.500	-0.209(0.835)
8-4. Possesses the ability to integrate remote monitoring control with mechatronics equipment	4.80	0.422	4.65	0.482	-0.957(0.338)
9.System Integration Technique					
9-1. Can understand the concepts of system integration	4.60	0.516	4.61	0.491	-0.077(0.939)
9-2. Is familiar with the assembly with automation equipment	4.70	0.483	4.60	0.495	-0.617(0.537)
9-3. Possesses the ability to system integration	4.80	0.422	4.58	0.560	-1.166(0.244)
9-4. Possesses the ability to construct a set mechatronics control system	4.70	0.483	4.45	0.563	-1.301(0.193)

The competencies identified in this study could serve as a basis for the integration of teaching activities in mechatronics technology education dealing with professional subjects or extracurricular activities, school competitions, and the development of skill tests.

Our analysis determined that the consensus-building process of the three-phased method progressed as anticipated and that it was successful in identifying and validating the technological competency items demanded by the mechatronics technology industry. Data analysis revealed a decrease in the standard deviation and an increase in the mean, both of which are indicative of an increase in consensus. In short, the results of this study include: (1) analysis of the competencies required for students in mechatronics technology according to industry-oriented criteria, and (2) the development of working competency indicators for students to enhance the competencies in the application of mechatronics technology.

There remains a need for further research using a larger sample size to validate and generalize the results, as recommended by Johnson and Onwuegbuzie (2004). Standardized methods of measuring the effectiveness of the instructional activities must be designed and implemented. The optimal uses of assessment data to improve programs in mechatronics technology education and assist students in developing competence remain to be identified. Further study with learners with different technology proficiencies and different learning experiences is needed. The three-phased empirical method adopted in this study is found to be a useful method, which can be applied to develop and elaborate competencies in a wide variety of educational and training contexts.

ACKNOWLEDGMENTS
This research was based on work supported by the National Science Council of Taiwan, Republic of China, under contract NSC 100-2511-S-018-008.

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