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A spiral-ADDIEE&R industry-oriented automatic measurement technology

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ABSTRACT: A spiral-ADDIEE&R model was introduced and utilised to develop, implement and evaluate an industry oriented technology course in automatic measurement technology. A process was built to develop teaching material and training devices. Practical competence indicators for automatic measurement technology were found using a Delphi questionnaire answered by industrial supervisors, engineers and university scholars. The teaching material contains six chapters and 27 sections for developing a multi-functional automatic measurement platform that includes over 20 kinds of sensors and measurement devices, designed and constructed for use by students in their professional training. An experimental class is exposed to an assessment performed for examining the flaws in this course development process.

Keywords: Industry-oriented technology, course development, automatic measurement, experimental class, assessment

INTRODUCTION

Automatic measurement technology meets specific requirements and manpower needs in industrial circles. This study has examined automatic measurement technology competence indicators to assist students with effective learning by fitting automatic measurement technology for industry oriented needs [1]. The implementation of software is one of the major issues to address in automatic measurement technology classes' design. Teaching material and training devices are additional problems that need to be resolved.

LabVIEW is the most often used software in the automatic measurement field in industry [2]. It provides powerful functions for instrument control and measurement. For example, it is used to connect computers using GPIB, IEEE-488, RS-232 communication interface, etc, or Local Area Network (LAN), to carry out signal measurement, analysis, data storage and data acquisition functions [3]. The LabVIEW system also supplies analogue-to-digital (A/D) and digital-to-analogue (D/A) converter functions. For instance, analogue signals acquired via data acquisition are transformed into digital signals, and conveyed to a computer that reads the digital signal for data acquisition (DAQ) interface system processing and storage. LabVIEW manages external loads using a D/A converter to gain signal acquisition and automatic control. Therefore, LabVIEW has many applications in engineering, including agriculture, biomedical technology, quality control testing, etc.

Furthermore, the application of automatic measurement technology is widespread in the automobile industry. Previously, conventional manpower was used to carry out vehicle measurement and inspection. This was extremely time-consuming. LabVIEW is presently used for automotive electronic control units (ECUs) and mechanical components to proceed with simulation, measurement and inspection of related functions. LabVIEW supplies test products with particular input or output states, the chassis and related controllers to integrate and strengthen existing test systems through a combination of software and hardware for virtual instruments.

RESEARCH METHODOLOGY

Some scholars' research has produced generalised results about curriculum planning and teaching material development models. The proposed spiral-ADDIEE&R model is divided into six processes. Figure 1 shows the flow chart of the development process, Spiral-ADDIEE&R Method.

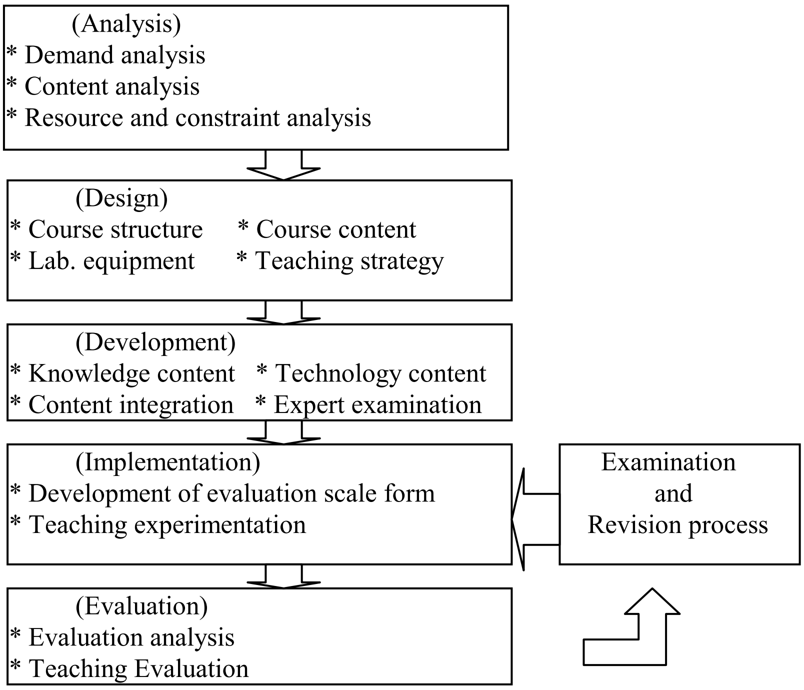

Figure 1: The flow chart of the development process, Spiral-ADDIEE&R Method.

RESULTS

The methods used in this study included literature analysis, expert consultations, the Delphi technique, experimental classes and bloom evaluation theory. The following steps were taken: A) Literature analysis method; B) Expert consultations; C) Delphi Technique; D) Course design; E) Automatic measurement platform establishment; F) Develop evaluation forms; G) Experimental class implementation; H) Experimental class evaluation; and I) Examination and revision process [1][4][5]:

A. Inquire into recent domestic and overseas documentary data. Data were collected on automatic measurement, curriculum planning and practice teaching material. The author used the teaching material principles and development models to produce a Delphi questionnaire and expert consultations for literature analysis and generalisation.

B. Conduct expert consultations for initial interview guide. This study seeks to understand practical competence indicators for automatic measurement technology course (AMTC), developing a Delphi questionnaire using interview results answered by industrial supervisors, engineers, and university scholars. The following procedure was carried out for expert consultations: 1) Send out interview invitations and identify a list of interviewees; 2) Develop initial interview guide; 3) Carry out the interviews seeking practical competence indicators for AMTC; and 4) Modify and confirm the practical competence indicators for AMTC.

C. Execute the survey using the Delphi Technique about industry needs. A Delphi questionnaire that adopted a 5-point Likert-type scale, ranging from *Not Important* to *Most Important* and open-ended questions that allowed experts to provide opinions was designed and developed using the literature review analysis and generalisation, and the expert interviews. Ten experts agreed to complete the Delphi survey. They were sent e-mail messages to invite them to offer opinions about practical competence indicators [6-9].

D. Course design. The Kolmogorov-Smirnov one sample test was carried out using the third Delphi questionnaire for data analysis. The author identified the degree of consistency of ten expert opinions regarding practical competence indicators for the AMTC. In order to improve the teaching syllabus and teaching material unit design, the spiral-ADDIEE&R instructional design model was adopted.

The Delphi survey results divided the practical competence indicators into six dimensions for AMTC:

1. Virtual instrument with four competence indicators.
2. LabVIEW programming design with eight competence indicators.
3. Interface of signal transmission with four competence indicators.
4. Sensing and measuring devices with four competence indicators.
5. Automatic measurement with three competence indicators.
6. Automatic measurement applications with four competence indicators.

A total of 27 competence indicators were developed using the constructive method, leading to a set of suitable teaching materials. An automatic measurement platform was also constructed for practical training use based on dimension five. Table 1 shows the content and the allocated lessons projected for each unit.

Table 1: Scheme of thematic unit, content outline and lessons/time.

Unit	Subject	Content Outline	Lessons/Time	Note
1	The introduction of virtual instrument and LabVIEW related knowledge	1-1.The introduction of virtual instrument related knowledge 1-2.The introduction of LabVIEW related knowledge 1-3.The operation of LabVIEW 1-4.The combination of LabVIEW and other software and hardware	1wk/3hrs	
2	LabVIEW programming design	2-1.LabVIEW programming 2-2.The programme establishment and test for various loop structure 2-3.The program establishment and test for array and data clustering 2-4.The programme establishment and test for graphics and charts 2-5.The programme establishment and test for string and file I/O function 2-6.The combination and test for PLC 2-7.The combination and test for MATLAB 2-8.The combination and test for C Language	4wks/12hrs	
3	The interface of signal transmission	3-1.The principle, property and test for USB communication interface 3-2.The principle, property and test for RS232 communication interface 3-3.The principle, property and test for DAQ communication interface 3-4.The principle, property and test for remote network	2wks/6hrs	
4	Sensing and measuring devices	4-1.The application of sensing and measuring devices for industrial circles 4-2.The sensor was in common use for industrial circles 4-3.The measuring device was in common use for industrial circles 4-4.The application of image acquisition devices for industrial circles	3wks/9hrs	
5	Automatic measurement platform	5-1.The system structure of automatic measurement platform 5-2.The hardware structure of the external circuit for automatic measurement platform 5-3.The software structure of automatic measurement platform	3wks/9hrs	
6	Automatic measurement applications	6-1.Diode manufactures in automatic quality measurement system 6-2.Motor monitoring and control system 6-3.Indoor environment monitoring and control system for the flower nursery 6-4.Irregular heartbeat detector in wireless remote monitoring and control system	3wks/9hrs	

Note: There were 18 weeks of teaching schedule deducted from the midterm and the final examination for this semester courses, and the number of teaching lessons and time totalled 16 weeks/48 lessons.

E. Establishment of automatic measurement platform. The multi-functional device measurement platform provides over 20 kinds of sensors and measurement devices for users. The DAQ-Card acquires data from every sensor and converts it into physical signals for further processing by NI LabVIEW. The sensors and measurement devices are classified and interface easily with the corresponding function. They contain: 1) Infrared joules switch; 2) Weight sensor; 3) PD100; 4) AD590; 5) Humidity sensor; 6) Solar cells; 7) V/F converter; 8) Pressure sensor; 9) LVDT; 10) Rotary angle sensor; 11) Hall current; 12) Light type switch; 13) Machinery; 14) Ultrasonic; 15) Magnetic sensor; 16) Proximity switches; 17) Metal sensing; 18) Resistance class; 19) Microphone; 20) Liquid level controller; 21) Gas/Fumes concentration sensor; and 22) Alcohol sensor.

F. Develop evaluation forms. A cognitive test, affective scale form and psychomotor scale form were developed for experimental class assessment. The cognitive pilot test comprised 90 questions. The examination assesses expert validity containing dimensions for knowledge, comprehension, application, analysis, synthesis and evaluation. Students who take the test have basic LabVIEW programming ability, and are juniors in the Department of Industrial Education and Technology, National Changhua University of Education, Taiwan. Thirty-six questions were deleted with 54 questions remaining in the difficulty and discrimination analysis index. Applying distraction and inspecting the questions using a two-way specification table, 50 questions were chosen to construct a cognitive examination index. Utilising KR-20 to inspect reliability achieved a value of 0.864, which is very reliable.

In assessing skill performance, a programmable virtual instrument skill ability assessment designed by Kai-Chao Yao and Hsiao-Mei Cheng in 2008 was used [10]. Its reliability was 0.865. There are four dimensions in the assessment form: equipment assembling ability, virtual instrument operation ability, circuit wiring ability and programming ability. A 5-points Likert scale was used in every dimension for assessment.

An affective scale form was developed using expert opinions for the affective domain. The content has four dimensions: learning demand, cognitive development, skill performance and self-exploration. There are seven questions in each dimension for a total of 28 questions. After item analysis, these 28 questions were all kept. The Cronbach α reliability test was applied in the pilot test, and produced a value of α = 0.928.

G. Experimental class implementation. The class was offered as a requirement in the 2011 Fall and 2012 Spring semesters in the Department of Industrial Education and Technology, National Changhua University of Education, Taiwan. This course is named Automatic Measurement Technology. It lasts for three hours and is worth three credits. A total of 43 students enrolled.

H. Experimental class evaluation. A quasi-experimental design was applied in the teaching experiment because the teaching materials and equipment were newly developed. Pre-test and post-test design methods were used in this course evaluation [11]. Bloom proposed a taxonomy for educational objectives in 1956 [12]. According to this theory, the evaluation involved three domains. The evaluation forms that were developed and designed were the cognitive test, affective scale form and psychomotor scale form. Figure 2 shows the schedule for formally evaluating the three domains. These three evaluation tools can be designed and developed during the Develop and Implementation phases.

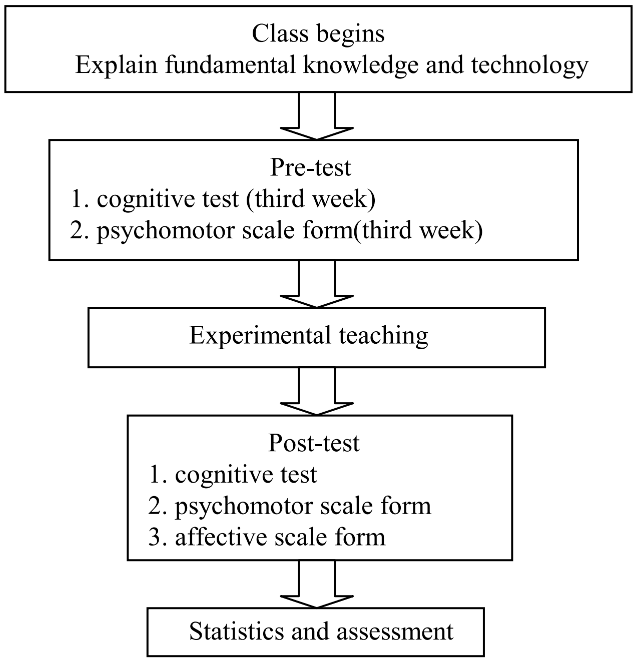

Figure 2: The schedule of formally evaluating the three domains.

I. Examination and revision process. Three assessment tests were conducted during the experimental class. The cognitive test results explain how effective the developed teaching materials and teaching equipment were in enhancing students' cognitive ability. The psychomotor test result shows how much growth occurred in student skill. The affective questionnaire reflects how students feel about the course in learning demand, cognitive development, skill performance and self-exploration. Based on the assessment of these three dimensions, the teaching material, teaching equipment, teaching method, and so on, can all be adjusted to meet the students' needs.

CONCLUSIONS

Following the time schedule shown in Figure 2, the cognitive, psychomotor and affective scale tests were formally conducted with the results shown below:

A. Cognitive Test Differential Analysis

At the beginning of the course, the basic automatic measurement technology concept is introduced. The cognitive examination pre-test is given. The post-test is given in the final week. Table 2 shows the paired-sample cognitive *t*-test results. Table 3 shows the difference between the two tests and the *t*-test results. The differential mean value of the two tests M = -29.8. Moreover, *t* = -41.244, df = 39 and reaches 0.001 significance level. In other words, after taking this class, the students' cognitive ability was greatly enhanced.

Table 2: The paired-sample cognitive *t*-test statistical results.

Paired variables	N	M	SD	SE	*t*
Pre-test	40	54.45	9.82	1.55	-41.244***
Post-test	40	84.25	9.50	1.50	

***p < .001

Table 3: Paired-sample *t*-test.

Item		Paired difference					*t*	df
		M	SD	SE	95% CI			
					UL	LL		
Paired Sample	Pre-test Post-test	-29.80	4.57	0.72	-31.26	-28.34	-41.244***	39

Note: CI = Confidence Interval; UL = Upper Limit; LL = Lower Limit
***p < .001

B. Differential Analysis of Skill Performance

In order to establish how effective the teaching material and equipment that were developed are in enhancing students' skill performance, pre- and post-tests were given to measure the difference using paired-sample *t*-test. In the psychomotor scale form, the maximum and minimum scores are 50 points and 10 points, respectively.

Table 4 shows the paired-sample *t*-test for skill performance statistical results. Table 5 shows the difference between the two tests and the *t*-test results. It shows the differential mean value of the two tests M = -21.83. Moreover, *t* = -39.222, df = 39 and reaches 0.001 significance level. In other words after taking this class the students demonstrated greatly enhanced skill performance.

Table 4: The paired-sample cognitive *t*-test results.

Paired variables	N	M	SD	SE	*t*
Pre-test	40	19.10	2.22	0.35	-41.244***
Post-test	40	40.93	4.26	0.67	

***p < 0.001

Table 5: Paired-sample *t*-test.

Item		Paired difference					*t*	df
		M	SD	SE	95% CI			
					UL	LL		
Paired Sample	Pre-test Post-test	-21.83	3.53	0.56	-22.95	-20.70	-39.111***	39

Note: CI = Confidence Interval; UL = Upper Limit; LL = Lower Limit
***p < 0.001

C. Affective Scale Test

In order to understand the reactions and thoughts of this class of students, an affective scale form was filled in by the class students. The affective scale was developed according to literature research, and the expert consultation contains four dimensions: learning demand dimension, cognitive development dimension, skill performance dimension and self-exploration dimension.

The affective scale form was designed as a 5-point Likert scale: *strongly agree*, *tend to agree*, *neither agree nor disagree*, *tend to disagree* and *strongly disagree*. The pilot test shows the reliability of this developed affective scale form possesses $\alpha = 0.928$. In the final week of the class, this form was completed by the whole class of students. The statistical results are shown below:

1. Learning Demand Dimension

Table 6: The mean value and standard deviation in the learning demand dimension.

No.	N	M	SD
1. The teaching material content is correct and easy to read	40	4.45	0.60
2. The content amount and difficulty are appropriate	40	4.25	0.59
3. The teaching material content is logical and well organised	40	4.30	0.76
4. The teaching material has good connection with the teaching	40	4.20	0.65
5. The teaching material contains enough knowledge and practices	40	4.33	0.69
6. The experimental parts of the teaching material can clearly explain the experimental process	40	4.13	0.56
7. The teaching material can integrate other related professional knowledge to solve the problems	40	4.18	0.68

2. Dimension of Cognitive Development

Table 7: The mean value and standard deviation in the cognitive development dimension.

No.	N	M	SD
1. The goal of each chapter clearly expresses the key points of learning points	40	4.45	0.64
2. The teaching material can help me to learn more new professional concepts in this field	40	4.18	0.64
3. The quiz properly assesses the learning	40	4.18	0.78
4. The teaching material can enhance my application ability	40	4.18	0.68
5. The teaching material and experimental equipments stimulate personal learning motivation and interest	40	4.15	0.86
6. The teaching material corresponds with the experimental equipment	40	4.43	0.67
7. The teaching material and experimental equipment inspire me to develop new products	40	4.35	0.70

3. Skill Performance Dimension

Table 8: The mean value and standard deviation in dimension of skill performance.

No.	N	M	SD
1. The course helps to increase LabVIEW programming and analysis ability	40	4.25	0.71
2. The course and teaching materials excite me to apply myself to LabVIEW programming	40	4.40	0.63
3. The course promotes personal knowledge and skill in understanding the computer measurement instrument structure	40	4.38	0.54
4. This course and teaching materials can improve practical skills on circuit failure detection and removal	40	4.15	0.92
5. This course promotes personal innovative ability in this profession	40	4.10	0.81
6. The teaching material and experimental equipment provide a opportunity to learn a different technical profession	40	4.20	0.79
7. This course promotes personal multi-dimensional professional skills	40	4.03	0.70

4. Self Exploration Dimension

Table 9: The mean value and standard deviation in the exploration dimension.

No.	N	M	SD
1. The skill training in this course matches industry needs	40	4.25	0.90
2. This course contains professional skill and knowledge on automatic measurement technology	40	4.25	0.63
3. This skill training in this course matches the skill needs of industry automatic measurement technology	40	4.35	0.74
4. This course can help me to understand the current trend in industry automatic measurement technology	40	4.20	0.65
5. This course helps me to understand if I am fit for this professional field.	40	3.88	0.88
6. This course increases my practical experience in automatic measurement technology.	40	4.05	0.90
7. The course offers a personal professional advantage for future jobs	40	4.45	0.96

Table 10 shows the mean value and standard deviation of four dimensions. The mean values are 4.26, 4.27, 4.21 and 4.13, individually. The results show that these 4 dimensions tend to agree and reach a 4.22 average.

Table 10: The mean value and standard deviation of four dimensions.

Dimension	Question numbers	N	M	SD
1. Learning Demand	7	40	4.26	0.37
2. Cognitive Development	7	40	4.27	0.47
3. Skill Performance	7	40	4.21	0.50
4. Self-Exploration	7	40	4.13	0.58
Total	28	40	4.22	0.44

Further discussion is shown below in three domains:

1. Professional cognitive domain: In the cognitive post-test performance, utilising constructive teaching material, the post-test was a lot better than the pre-test. According to the *t*-test results, the teaching material and teaching equipment that were developed help students perform well in the cognitive test. The analysis showed an obvious difference between the pre-test and post-test results.

2. Skill performance domain: In the psychomotor post-test performance, with the teaching material and training equipment, utilising constructive teaching strategy, the post-test was a lot better than the pre-test. According to the *t*-test results, the constructive teaching strategy helped students perform well in the psychomotor test. The analysis showed an obvious difference between the pre-test and post-test results.

3. Affective domain:

   a) In the learning demand dimension, the teaching material content is correct and easy to read. It presents a well organised, logical arrangement with enough knowledge and practices. The experimental parts of the teaching material clearly explain the experimental process.
   b) In the cognitive development dimension, the goal of each chapter clearly expresses the key learning points. The teaching material corresponds with the experimental equipment and both inspire to develop new products.
   c) In the skill performance dimension, the course and teaching material inspire students to learn LabVIEW programming and promote their knowledge and skill in understanding the computer measurement instrument structure.
   d) In the self-exploration dimension, most of the students who take this course think the course contains professional automatic measurement technology skill training. This course matches the skill needs of the automatic measurement technology industry. Moreover, this course offers a personal professional advantage for future jobs.

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BIOGRAPHY

Yao Kai-Chao was born in Changhua, Taiwan on 4 November 1971. He entered the Electrical Engineering Department of the National Taipei Institute of Technology in 1990. In 1994, he went to the USA to study in electrical engineering at the University of New Haven between 1994 and 1998. He obtained his Bachelor's degree and a Master's degree in 1997 and 1998, respectively. In 1998, he was offered a fellowship and PhD admission by Wichita State University in the Electrical and Computer Engineering Department and completed his doctoral degree in December 2000. He came back to Taiwan at the end of 2000 and began to teach as an Assistant Professor in the Electrical Engineering Department of Chien-kuo Institute of Technology. In August 2001, he was appointed to teach in the Electrical Engineering Department of the National Chinese Naval Academy in Kaohsiung. In February 2004, he obtained a new position in the National Chungha University of Education, where he is a Professor in the Department of Industrial Education and Technology.