THE DEVELOPMENT OF A WEB-BASED SELF-REFLECTIVE LEARNING SYSTEM FOR TECHNOLOGICAL EDUCATION

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ABSTRACT

One obstacle to industrial technology education is that the difficulties or problems students encounter during experiments are not easy to detect. Students are often unaware of their flaws, and some will not notify the teacher of these flaws even if they are aware of them. Consequently, many opportunities to rectify these flaws and improve teaching methods are lost, and students who are falling behind are deprived of instant guidance and cannot catch up. Therefore, this paper aims to develop a web-based self-reflective learning system to enhance students' learning of industrial technology.

This study applied sensor network technology to develop a web-based self-reflective learning system based on a self-reflective learning approach. The system was integrated into a micro-fabrication technology course for empirical study. Subsequently, the influence of the web-based self-reflective learning system on students' learning performance and technical skills was investigated. Analysis of the data obtained from learning cognition, skill assessment, and learning satisfaction following education indicated that the web-based self-reflective learning system could effectively improve the learning performance of students falling behind, thereby allowing these students to catch up in their cognitive and skill achievements by the end of the semester.

INTRODUCTION

Dewey (1933) was the first scholar to propose the concept of reflection, which he defined as the behavior of repeated thinking and searching upon encountering problems; combined with observations of the surrounding environment, understanding of the causal relationship stimulates deeper thinking. Kemmis (1985) believed that reflection was a process of internal and external dialectics. Through reflection, individuals are able to increase comprehension of their own thinking process. Reflection is a psychological activity that extracts and forms meaning from experience, which contributes to reorganizing and restructuring perceptions. This further enables gained knowledge to become refined and differentiated gradually. Consequently, this study considers reflection distinctive from thinking. Reflection is the process of integrating experience or past perception with newly received perspectives before further internalization into personal knowledge. Therefore, reflection is thinking with the additional components of reflection and action. Paris and Ayres (1994) pointed out that reflective thinking motivates students to learn; applying strategies to accomplish specific objectives is very useful. Reflection may occur before or after the action, which indicates that personal knowledge is progressively formulated during actual working action. Regarding the relationship between personal action and reflection, Elliott (1991) stated that reflection originates from action, which suggests that reflection is generated from collected information during personal action. From a teaching perspective, Schon (1983) divided reflection into two major frameworks: reflection-on-action and reflection-in-action. Reflection-on-action indicates that reflection occurs in the interval after teaching and before planning and thinking. Reflection-in-action is an attempt to adjust personal teaching and deal with responses during the process of teaching. Carver and Scheier (1998) identified self-reflection as individualistic survey, evaluation, and comprehension of personal thoughts, feelings, behavior, and self-awareness. Davis (2000) requested learners to perform self-reflection during the process of learning; the action of reflection allowed the learners to re-survey, test, and modify existing thoughts and knowledge, which further achieved improved and more structured comprehension. Costa and Kallick (2000) believed that students who could conduct self-reflection were more able to gain cognitive structure among teachers and classmates as they had a clearer understanding of their own steps in reasoning.

Paris and Ayres (1994) suggested that applying learning portfolios and authentic assessment could effectively induce reflective learning. The creation of learning portfolios is a continuous process from the beginning to the end of the learning activity. Prior portfolios can provide learners with a reference for reflection, allowing the learners to focus their reflection on the learning objectives. This approach is more effective and directional. E-portfolios are primarily a development of traditional portfolios, and only secondarily result from the process of digitizing; data that are collected, stored, and managed digitally before being placed on the Internet are called web-based portfolios. The main functions of the web-based student portfolio system developed by Younes (2004) was to provide storage, display, and reflection of students' learning processes from admission to graduation. In the structured web-based portfolio assessment system established by Chang (2008), one of the functions was composition and assessment of reflection. This system provided students with a reflection outline for them to compose their reflections; the teacher assessed the compositions and responded with feedback. Students could assess their own reflections as well as assess and give feedback on the reflections of their peers. E-portfolios assist students in evaluating their own learning processes and performing reflections (Liu, E. Z. F., 2010, and Chang, C. S., et al., 2011). Through observing and emulating each other, the students'mutual understanding among peers is increased along with the opportunity for competitive learning processes; teachers are thereby aided in observing the learning circumstances of the students and can assess accordingly. However, how to combine modern technology and construct a web-based learning system based on a self-reflective learning approach to enhance learning performance is an issue requiring further examination.

With recent advances being developed in the fields of micro-electro-mechanical systems (MEMS) and wireless communication technologies, wireless sensor networks have emerged from being utilized in laboratories to being ubiquitous, potentially changing our lives on a daily basis. Wireless sensor networks are more attractive and useful than traditional wired sensing systems because of their ad-hoc and easy means of deployment. This new technology expands our sensing capabilities by connecting the physical world to the communication networks and making a broad range of applications possible (Akyildiz, Su, Sankarasubramaniam, and Cayirci, 2002). Sensor networks are the integration of sensor techniques, distributed computation, and wireless communication techniques. They are embedded in our physical environment and are used for sensing, collecting data, processing information of monitored objects, and finally, transferring the processed information to users. The sensor node's hardware consists of five components: sensing hardware, processor, memory, power supply, and transceiver (Tubaishat and Madria, 2003). For numerous applications, a sensor network operates in three phases. In the first phase, the sensors take measurements that form a snapshot of the signal field at a particular time, and these measurements are stored locally. The second phase is the information retrieval, during which data are collected from individual sensors. The last phase is information processing, during which data from sensors are processed centrally with a specific performance metric (Dong, et. al, 2007, and Shyr, 2011). Such a network is composed of numerous tiny low-power nodes, each consisting of actuators, sensing devices, and a wireless transceiver. These sensor nodes are deployed in significant numbers in a region of interest to gather and process environmental information.

WEB-BASED SELF-REFLECTIVE LEARNING SYSTEM

The new technology of a wireless sensor network expands sensing capabilities by connecting the physical world to the communication networks. To support learning in micro-fabrication technology, numerous sensor devices must be deployed in the laboratory to collect real-time information of students' motions and machine operation conditions. This study used the Zigbee modules to build a wireless sensor network. The proposed architecture of the sensor network system is shown in Figure 1. The overall system architecture is comprised of a Web camera, a Zigbee dongle (base node), a server, and wireless sensor nodes. The wireless sensor nodes consist of two key parts referred to as the static and the mobile nodes. The static sensor nodes are scattered in the laboratory, forming a multi-hop mesh networking topology. A couple of the defining roles of the static node is to transfer all the data packets from the mobile node to the dongle, while the other role is to provide sufficient anchor points for the localization. Each sensor nodes is capable of collecting data and routing data peer-to-peer to the Zigbee dongle, which is then used to bridge the sensor network to the Internet to provide a serial interface and wireless connection for node programming and data transferring. The server is connected to the Internet to enable remote users to access the laboratory monitoring system. The mobile node, comprised of an accelerometer, is worn by the students and it monitors student motions and positions in an indoor environment.

Since students need to rotate handles manually, operate machines, and adjust machining parameters simultaneously, and while some of the machines also require students to have the machining parameters adjusted by stepping on pedals during experiments and practice, this study has intended to incorporate ultra-thin force sensing units (0.127mm) into the Zigbee node. To ensure that the students are able to use the tools correctly, training during experiments and practice is necessary; hence the connection between the Zigbee node and the PIR325 infrared sensing unit to make a wireless infrared sensor that will then be installed in the toolbox. In this study, a Zigbee node is connected to a three-axis micro electro-mechanical system (MEMS)-based accelerometer to make a wireless accelerometer, which is a device that measures acceleration and detects the acceleration magnitude and direction as a vector quantity. The sensor is worn by the students, and it not only detects and records the students' position inside the laboratory but also senses their movements.

A graphical user interface (GUI) enabled remote users to carry out the operations desired, such as sending commands and parameters to activate the sensor nodes, as well as having the measurement results visualized. This thesis used ASP.NET and Microsoft Visual C# to write an internet program that enabled swift and convenient processing of information. Figure 2 displays the Web GUI of a user monitors the laboratory environment at the remote client side. By clicking on the mouse, a remote user is able to adjust the camera's viewing angle to acquire video data. This interface accepts remote client-side to acquire information on which node to monitor though clicking the buttons and checkboxes on the panels. Upon clicking the sensor installed on the node, the sensors' signal can be observed, and then the data from the selected sensors are collected and sent to the Web GUI at the specific time intervals. In Figure 3, the top-left corner displays the information measured by the force sensor at various intervals, while the bottom-left corner displays the force sensor's instant information. Additionally, the top-right corner displays information measured by the IR sensor at various intervals, while the bottom-left corner shows the student's current position in the laboratory.

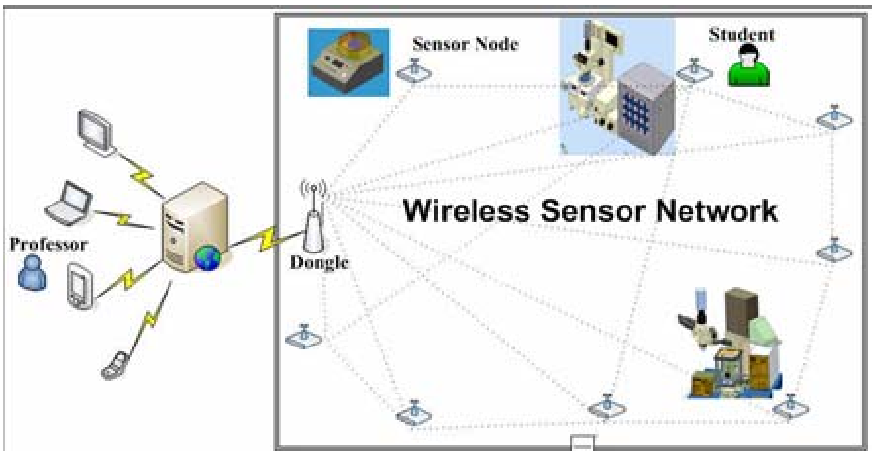
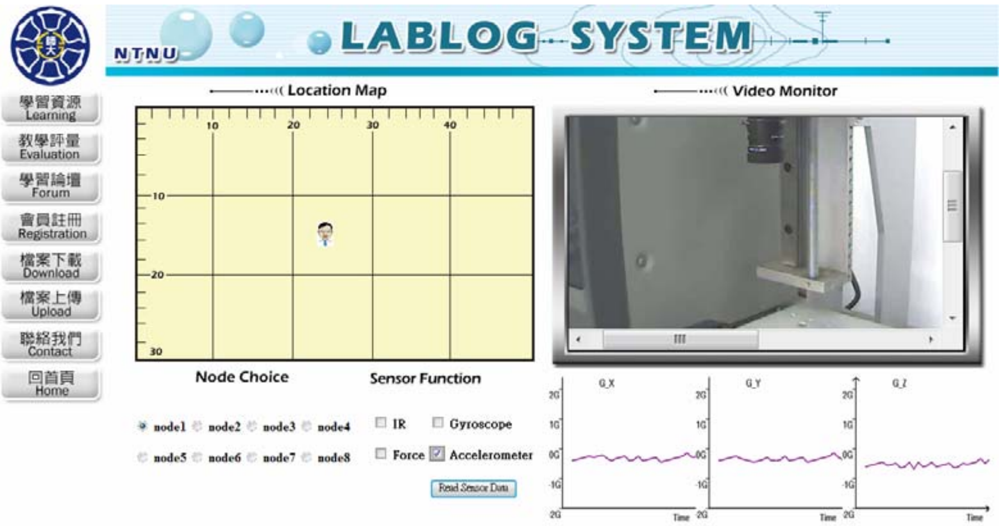


Figure 1. Architecture of the wireless sensor network system



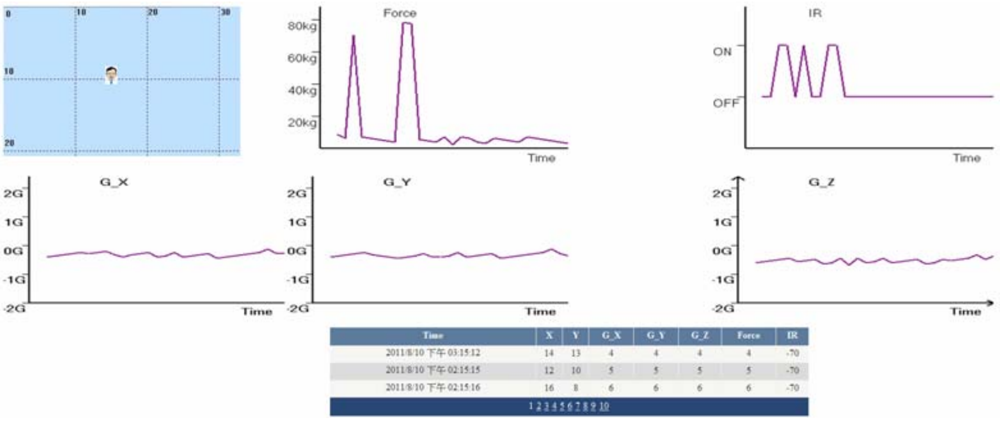
Node Choice

● node1 ○ node2 ○ node3 ○ node4
○ node5 ○ node6 ○ node7 ○ node8

Sensor Function

☐ IR ☐ Gyroscope
☐ Force ☑ Accelerometer

Figure 2. GUI of the wireless sensor network system at the remote client side



Time	X	Y	G_X	G_Y	G_Z	Force	IR
2011/8/10 下午 03:15:12	14	13	4	4	4	4	-70
2011/8/10 下午 02:15:15	12	10	5	5	5	5	-70
2011/8/10 下午 02:15:16	16	8	6	6	6	6	-70

Figure 3. Real time monitoring of force and IR sensors at the remote client side

RESEARCH PURPOSE

The objectives of this study are as follows:

1. Investigating the influence of a web-based self-reflective learning system on student learning performance and technical micro-fabrication Technology skills.
2. Investigating the influence of a web-based self-reflective learning system on student satisfaction of micro-fabrication technology learning activities.

Based on the preceding research motives and research purposes, this study formulated the following hypotheses:

Research Hypothesis 1-1: Students' micro-fabrication Technology cognitive aptitude test scores before and after experiencing the web-based self-reflective learning system demonstrate no significant differences.

Research Hypothesis 1-2: The micro-fabrication Technology technical skills test scores from different raters after implementation of the web-based self-reflective learning system show no significant differences.

Research Methods and Instruments

The study population is comprised of students taking courses in micro-fabrication technology; the sample size was 54 students. The curriculum contains a series of formal lectures and laboratory sessions. Besides the scientific fundamentals and the technical subjects presented in the classroom, the students were required to complete practical work that is basing on problem-based learning (PBL) approaches, and assignments as such aim to increase the theoretical understanding of the subjects presented and the development of practical micro-fabrication and micro-packaging skills.

The experimental tools used during this study include a Cognitive Aptitude Test, a Learning Satisfaction Survey, and a Technical Skills Indicator. Following revision and correction, the Cognitive Aptitude Test had 50 multiple-choice questions. The passing mean and discrimination percentage were 0.58 and 0.35, respectively, demonstrating it to be a reasonable test with a good passing and discrimination percentage. According to the reliability analysis of the study, the Cronbach's alpha value of internal consistency was 0.786. Furthermore, the criterion validity was based on a significantly positive correlation between the semiconductor assembly and the packaging test scores of several comprehensive and technological universities. As a result, the cognitive aptitude test had good reliability and validity.

In addition, the satisfaction survey for this study was based upon a Likert-type five-measurement scale. By administering a pre-test satisfaction survey, this study had participants answer questions regarding observations and thoughts, and then analyzed each question's effectiveness and reliability according to the received result. Following evaluation of the survey's effectiveness and reliability, the questions were carefully revised and edited to produce the final and official questionnaire.

To better understand the technical skills of students, this research developed a technical skills indicator based on E. J. Simpson's Seven Levels of Taxonomy, and to avoid subjective judgment, the teaching assistants joined the researchers in monitoring and evaluating the testing groups during the examinations. Upon reviewing the results using Spearman's Rho rank order correlation, the correlation coefficient was 0.889, indicating that the researchers' and the teaching assistants' evaluations were consistent.

DATA COLLECTION AND DISCUSSION

The data collected in this study include the scores from the two cognitive aptitude tests, the learning satisfaction questionnaires of technical activities, and the technical skills tests. The adopted methods for statistical analysis were mean, standard deviation, and a t-test, conducted using SPSS12.0.

This study examined the relations between pre-course cognition, post-course cognition, satisfaction, and the technical skills test. Pearson's correlation coefficient was applied to investigate the correlation and strength among the variables. As shown in Table 1, significant linear correlation exists between pre-course cognition and post-course cognition ($r = 0.812$), between post-course cognition and the technical skills test ($r = 0.320$), between satisfaction and pre-course cognition ($r = 0.657$), and between satisfaction and post-course cognition ($r = 0.604$). The correlations are all positive, indicating that: 1) pre-course cognition is proportionate to post-course cognition; 2) higher scores in the technical skills test represent greater post-course cognition; and 3) satisfaction is greater in students with higher pre-course cognition or post-course cognition.

Table 1: Summary of correlation analysis

Item	Pre-course Cognition	Post-course Cognition	Technical Skills Test
Pre-course Cognition			
Post-course Cognition	.812**		
Technical Skills Test	.137	.320*	
Satisfaction	-0.061	-0.151	-0.031

*p<.05; **p<.01

This study adopted an independent t-test to determine whether significant differences exist between students with higher and lower learning achievement. Students scoring in the top 27 % in pre-course cognition were in the high achievement group, while the bottom 27 % comprised the low achievement group, and the statistics from these two groups were compared. As indicated in Table 2, a t-test presented significant difference (p<.05) between the high and the low achievement groups in the pre-course cognition test, indicating a difference between the two groups in pre-course cognition. In post-course cognition, a t-test also showed a significant difference (p<.05) between the two groups. In terms of progress, the difference between the two groups was also significant (p<.05); the margin of progress was greater in the low achievement group than in the high achievement group. The above results indicate that receiving web-based self-reflective learning causes the learning cognition of students to differ.

Table 2: Comparison of t-test results for course cognition of high and low achievement groups

Group	Low Achievement Group (n = 16)		High Achievement Group (n = 18)		*p*	t
	Mean	SD	Mean	SD		
Pre-course Cognition	44.50	11.74	68.00	3.43	.000**	-7.72
Post-course Cognition	54.38	12.48	71.78	5.69	.000**	-5.12
Improvement Score	9.88	6.55	3.78	5.04	.004**	3.06

*p<.05; **<.01

Table 3 presents the t-test results for technical skills in the two groups of students. Excluding the perception and set constructs, the t-tests produced statistically significant results (p<.05), indicating that considerable differences exist in the technical skills test of both groups. The total score of the technical skills test was derived by summing up the mean number of times in the achieved items of each construct, and that sum was then converted to a percentage. Analysis revealed that the majority of the constructs reached significance (p<.05), indicating considerable differences being in existence in the technical skills of students in the high and low achievement groups upon receiving web-based self-reflective learning.

Table 3: U test results for the technical skills test scores of high and low achievement groups

Group	Low Achievement Group (n = 16)		High Achievement Group (n = 18)		*p*	*U*
	Mean	SD	Mean	SD		
Perception	2.00	0.00	2.00	0.00	1.000	352.0
Set	5.88	0.34	5.83	0.38	.081	291.0
Guided Response	7.25	2.08	8.06	1.63	.001**	175.0
Mechanism	12.94	3.21	13.67	3.36	.000**	149.5
Complex Overt Response	8.19	2.61	8.72	2.89	.022*	226.0
Adaptation	2.50	0.73	2.72	0.75	.000**	122.0
Origination	2.06	1.06	2.28	1.41	.049*	244.5
Total Score	62.19	11.71	64.86	12.73	.002**	174.5

*p<.05; **<.01

According to the data analysis shown in Table 3, a radar chart was created for the percentages converted from the sums of the mean number of times in the achieved items of each construct. Figure 4 exhibits the overall learning performance of both groups of students for each technical skill. Using weighted calculation, the mean comprehensive ability values were derived; these were 1.53 and 1.43 for the high and low achievement groups, respectively. As indicated by the values, the mean comprehensive abilities of both groups of students differ significantly after employing the web-based self-reflection learning system. This result corresponds with that of Table 3. The web-based self-reflection learning system effectively improves the learning performance of students falling behind, enabling the students that are struggling to catch up. Regarding satisfaction, a t-test revealed no significant differences (p>.05) in both groups as shown in Table 4.

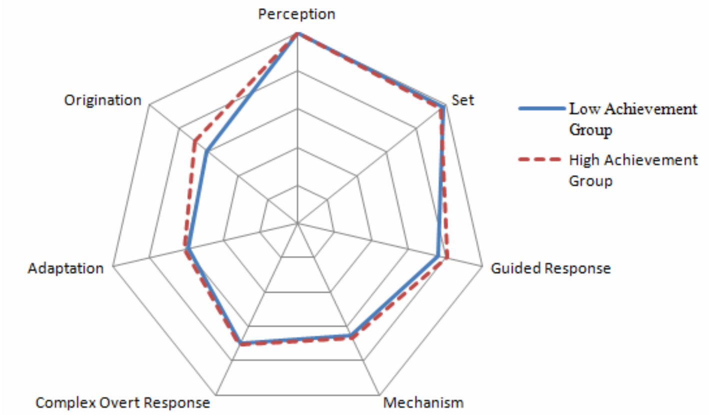


Figure 4. Comparison of Radar Charts for the Technical Skills of Students in the High and Low Achievement Groups

Table 4: T-test results for satisfaction of high and low achievement groups

Group	Low Achievement Group (n = 16)		High Achievement Group (n = 18)		*p*	t
	Mean	SD	Mean	SD		
Satisfaction	4.14	0.59	4.24	0.57	0.623	-.497

*p<.05

STUDY LIMITATIONS

The sensors developed in this study were experimental. One study limitation was that the large sensor size reduced the wearabilty for students. However, this issue will be resolved with future progress in electronics designed to be flexible; sensors may become soft and small like a piece of cloth, which students will barely notice when using. Another limitation of this study was that the precision of the sensor network system's indoor positioning was approximately one meter. Though this affected the positioning of students within the test room, it did not affect the sensing and measurement of data while students operated equipment.

CONCLUSIONS

Practical training is an important teaching strategy to improve students' industrial technology competence. To overcome the obstacles of traditional experiments and practical training courses, and to enhance current e-learning system functions, this study used sensor network technology as the foundation for developing a self-reflective learning system. The system presents with the teachers the students' operational results immediately, thereby enabling appropriate guidance when the students encounter problems during experiments and practical training. Moreover, because this system can record the students' learning processes during experiments and practical training -- where the data can be used to identify the students' learning difficulties -- the teachers are aware of the problems encountered by students during the practice process and can guide students to avoid repeating mistakes, even when practicing in a clean factory room. According to related data, a web-based self-reflective learning system may effectively improve the learning performance of those students who are falling behind, enabling them to catch up by the end of the semester.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support of this study by the National Science Council of Taiwan, under the Grant No. NSC99-2511-S-003-034-MY3

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