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Implementation of a Web-based e-learning course with a simulation laboratory in a fuzzy expert system course

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ABSTRACT: This study proposes the implementation of a Web-based course together with a simulation laboratory for fuzzy expert systems. This course is a three-week e-learning course attended by thirty junior and senior students from the National Kaohsiung Normal University in Taiwan. Six learning topics related to the fuzzy expert system are covered in the course. In addition, a simulation laboratory to implement a fuzzy expert application is required for each student. After finishing the learning topics and the simulation laboratory, a learning satisfaction survey was conducted. The questionnaire comprised 20 questions, each question to be answered according to a Likert 5-point scale. A one-way ANOVA and *t*-test were used to analyse the learning satisfaction with respect to the learners' backgrounds. The statistical results are thoroughly discussed and explanations of the results are provided. Concluding remarks and research findings are also provided at the end of this article.

INTRODUCTION

Due to the fast promotion of network infrastructure and the fast development of information technologies, more and more learning activities are conducted through the Internet. Numerous Web-based learning environments are then developed for Internet learning. Multimedia learning materials have been widely employed in Web-based applications. Designing a course within a multimedia environment has become an important issue. Many studies have discussed multimedia-related issues from several viewpoints such as role [1], efficiency [2] and cognitive load [3-6]. The animation effect in multimedia learning has also been studied in [7]. Some studies suggested adding learners' experiences and auditory presentations in designing multimedia courses [8][9].

A traditional crisp set uses a binary value (0 or 1) to indicate whether or not an element belongs to a certain crisp set. However, this cannot be applied to solve problems involving situations of uncertainty. People then use fuzzy logic to solve the uncertainty problems with a matching degree μ ($0 \leq \mu \leq 1$) to describe the degree of certainty. The procedure of mapping a crisp input to a matching degree is called *fuzzification*. A membership function is a function to describe the mappings for crisp inputs to matching degrees. A fuzzy rule is constituted by two parts: an *IF* part (the antecedent) and a *THEN* part (the consequent). The process to conduct a fuzzy consequent from the antecedent is called *fuzzy inference*. After using fuzzy inference, a fuzzy conclusion (antecedent) is obtained, but it cannot solve real-world problems since real-world problems need crisp values to solve them. Therefore, the procedure of using a crisp value to represent a fuzzy conclusion is called *defuzzification*.

Based on fuzzy logic, a fuzzy expert system is a very popular method for solving real-world problems in many areas. It mimics the thinking process of human beings and expresses the process with fuzzy *IF-THEN* rules. Basically, a fuzzy expert includes three parts: graphic user interfaces, an inference engine, a rule base. The user interfaces allow user to define membership functions and, then, to establish fuzzy rules. The inference engine performs fuzzy inference and finally gets the defuzzification results from inputs. The rule base stores fuzzy rules generated by users.

This study proposes the implementation of a Web-based course together with a simulation laboratory for fuzzy expert systems. This course is a three-week e-learning course attended by thirty junior and senior students of the Department of Software Engineering at the National Kaohsiung Normal University, Taiwan. Six learning topics related to the fuzzy expert systems are covered in the first two weeks. In the last week, a simulation laboratory to implement a fuzzy expert application is required for each student. After finishing the learning topics and the simulation laboratory, a learning satisfaction survey was conducted. The questionnaire comprised 20 questions, each answered according to a Likert 5-point scale. A one-way ANOVA and *t*-test were used to analyse the learning satisfaction with respect to the learners' backgrounds.

COURSE DESIGN AND CONDUCT

The major learning topics for a fuzzy expert system include the basic concepts of fuzzy logic, fuzzification and matching degree, membership function, fuzzy rule and inference, and defuzzification [10].

Table 1: Learning objectives of the six topics and the simulation laboratory.

Topic	Title	Objectives
1	Introduction to fuzzy theory	• Learning the definition of fuzzy logic. • Learning the original fuzzy idea from Zadeh, the founder of fuzzy logic. • Learning the areas to which fuzzy logic can be applied.
2	Fuzzification	• Learning the fuzzy control process. • Learning the fuzzification process and the fuzzy meaning in verbal expression. • Learning the difference between traditional crisp sets and fuzzy sets.
3	Membership function and fuzzy rule	• Learning membership functions, and types of membership functions. • Learning fuzzy IF-THEN rules.
4	Fuzzy inference	• Learning how to conduct an overall matching degree from a fuzzy rule. • Learning the basic fuzzy inference methods. • Learning the Mamdani-style inference process.
5	Defuzzification	• Learning the meaning and the necessity of defuzzification in a fuzzy expert system. • Learning the COA defuzzification method. • Learning the MOM defuzzification method.
6	Case study	• Learning the entire procedure of a fuzzy expert system. • Demonstrating an air-conditioning example of fuzzy expert system step by step.
Lab.	Implementing a fuzzy expert application	• Introducing the laboratory environment step by step. • Creating a real-world scenario of a fuzzy expert application. • Implementing the fuzzy expert application based on the created scenario.

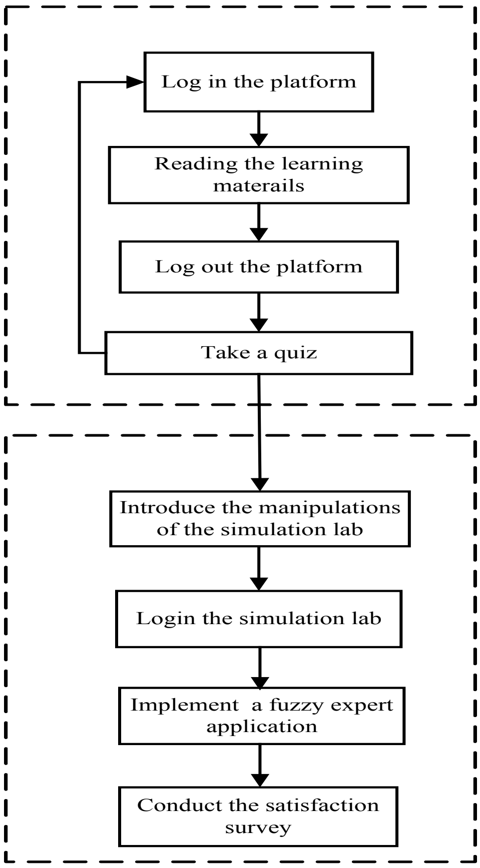

Figure 1: The implementation flowchart for the three-week course.

The duration of the e-learning course is three weeks. The participants were 30 junior and senior students who took an artificial intelligence course at the Department of Software Engineering, National Kaohsiung Normal University, Taiwan, during the autumn semester of 2010. During the first two weeks, six topics were covered, including introduction to fuzzy theory, fuzzification, membership function and fuzzy rule, defuzzification and case study. In addition, during the last week of this course, a simulation laboratory to implement a fuzzy expert application was conducted. Table 1 shows the learning objectives of the six topics and the simulation laboratory. Figure 1 shows the implementation flowchart for the three-week course.

SATISFICATION SURVEY AND RESULTS

After completing the e-learning course, the 30 students' opinions were surveyed with a satisfaction questionnaire. There were 20 questions in the questionnaire, each answered according to a Likert 5-point scale from 1 to 5. The higher the value of a student's answers, the higher their satisfaction. Table 2 shows the descriptive statistics of the students' backgrounds and Table 3 summarises responses to the 20 questions by providing means. These questions are divided into three dimensions: learning material and platform, simulation laboratory, and overall opinion. This study analyses the differences in learning satisfaction among students from different backgrounds. The *t*-test and ANOVA methods were used as the statistical analysis tools. The independent variables are the students' background, and the dependent variables are the 20 questions in the questionnaire.

Table 2: Descriptive statistics of the students' background.

Background	Item	Freq.	Percent
Gender	Male	22	73.3%
	Female	8	26.7%
Previous e-learning experience	Yes	24	80%
	No	4	13.3%
	Missing value	2	6.7%
Hours of previous e-learning	7 hours or less	16	53.3%
	8-21 hours	5	16.7%
	22 hours or more	3	10%
	Missing value	6	20%
Hours spent on the Internet per week	14 hours or less	4	13.3%
	15-21 hour	6	20%
	22 hours or more	20	66.7%
Commonly conducted Internet activities (can choose more than one item)	Capturing software	16	53.3%
	Searching data	30	100%
	Using e-mail	20	66.7%
	Playing on-line game	9	30%
	Charting and making friend	16	53.3%
	Browsing leisure information	25	83.3%
	Reading news and magazine	15	50%
	shopping	3	10%
Average hours spent in the e-learning per week	Less than 1 hour	16	53.3%
	1-2 hours	11	36.7%
	3 hours or more	3	10%
Course loading of the e-learning course	Light	8	26.7%
	Heavy	22	73.3%

Table 3: The 20 questions in the questionnaire with satisfaction means (based on a Likert 5-point scale).

Dimension	Question Number	Item	Mean
Learning material and platform	Q1	I am more satisfied with the displaying way of interactive materials than with that of text materials.	3.87
	Q2	Interactive learning materials are more vivid and more diverse than text learning material.	4.03
	Q3	Interactive learning materials are more abundant in content than text learning materials.	3.67
	Q4	E-learning can sustain more attention than traditional classroom learning.	3.71
	Q5	The property of repeatability of the e-learning is helpful to my learning.	4.30

	Q6	E-learning can provide me with instant learning opportunity for the topics I do not understand.	3.93
	Q7	E-learning can provide me with the opportunity for auto-learning.	3.97
	Q8	The e-learning platform is easy to manipulate and to use.	3.97
	Q9	In general, the interactive learning materials are easier to understand than the text learning materials.	3.93
	Q10	In general, I am satisfied with e-learning.	3.90
Simulation laboratory	Q11	The graphic user interfaces (GUIs) of the simulation laboratory are vivid and diverse.	3.93
	Q12	I am satisfied with the flow design of the fuzzy expert system in the simulation laboratory.	3.80
	Q13	I can implement my fuzzy expert application with the simulation laboratory.	4.27
	Q14	Using the simulation laboratory helps me to achieve a more deeply understanding in fuzzy expert system.	4.17
	Q15	The simulation laboratory is easy to manipulate and to use.	3.90
	Q16	In general, I am satisfied with the design of the simulation laboratory.	4.03
Overall opinion	Q17	I hope other courses can be conducted with e-learning.	3.90
	Q18	The e-learning course provides me with the means to overcome problems.	3.73
	Q19	With e-learning, I have more understanding of fuzzy expert systems.	4.07
	Q20	The e-learning course is suitable to me.	3.80

To understand if there is a difference in satisfaction according to students' backgrounds, this study used the *t*-test method to analyse the independent variables within two groups. They are gender, previous e-learning experience and course loading of the e-learning course. Table 4 presents a summary of the *t*-test results.

Table 4: Results of *t*-test analysis (Only the questions with significant difference are listed).

Independent Variable	Question Number	*t*-value	Means by groups	Note
Gender	Q6	-2.195*	Male:3.73; Female: 4.50	Female > Male
Course loading of the e-learning course	Q16	-2.121*	light:3.63; heavy: 4.19	heavy > light

The statistical result shows that only for Question 6 is there a significant difference in gender where female students (mean = 4.5) have more satisfaction than male students (mean = 3.73). The other questions did not demonstrate any significant difference according to gender. In addition, the statistical result also shows that only in Question 16 did a significant difference in course loading of the e-learning course exist. The students with a heavy loading (mean = 4.19) have more satisfaction than those with a light loading (mean = 3.63). The possible reason for this is that the students with a heavy loading might pay more attention during the course and, thus, be more satisfied with it. Responses to the rest of the questions did not indicate any significant difference in the course loading of the e-learning course. Of the 20 questions, none of them indicated a significant difference based on previous e-learning experience.

Similarly, this study used the one-way ANOVA method to analyse the independent variables with three groups or with more than three groups. These variables are hours of previous e-learning, hours spent on the Internet per week, commonly conducted Internet activities, and average hours spent in e-learning per week. Table 5 summarises the one-way ANOVA results. The statistical results show that only some of the questions have significant differences according to commonly conducted Internet activities. The other independent variables did not suggest any significant difference in the 20 questions. This study divided the independent variable (commonly conducted Internet activities) into three categories: Category 1 (c1): two or fewer activities, Category 2 (c2): three activities and Category 3 (c3): more than three activities. The statistical analysis shows that in commonly conducted Internet activities, Q4 and Q12 have significant differences (Q4: $F = 3.446$, $p<0.05$; Q12: $F = 5.036$, $p<0.05$). The study then used the Scheffe post-hoc test to further analyse the results and found that only Q12 has significant difference in the three categories (c1 > c2; c1 > c3). This implies that the students engaged in fewer Internet activities have higher satisfaction levels than those undertaking more Internet activities.

Table 5: Results of the one-way ANOVA (Only the questions with significant difference are listed).

Independent Variable	Question Number	F-value	Scheffe post-hoc	Note
Commonly conducted Internet activities	Q4	3.446*		
	Q12	5.036*	c1>c2; c1>c3	c1: Two activities or less c2: Three activities c3: Four activity or more

CONCLUSIONS

In this research, a case study related to a Web-based e-learning course is reported. This course is a three-week course for fuzzy expert systems. Thirty junior and senior students of the Department of Software Engineering at the National Kaohsiung Normal University, Taiwan, attended the course. Six learning topics related to the fuzzy expert system course were covered in the first two weeks. During the last week, a simulation laboratory was conducted to implement a fuzzy expert application for each student. The learning objectives and the implementation flowchart of the e-learning course is presented and explained. After finishing the learning topics and the simulation laboratory, a learning satisfaction survey was conducted. There were totally 20 questions in the questionnaire. Each question was answered with a Likert 5-point scale. A one-way ANOVA and *t*-test were used to analyse the learning satisfaction with respect to the learners' backgrounds. The statistical results were also discussed and explained for the results provided.

The findings of this study can be summarised as follows:

- Female students are more satisfied than male students in Question 6 (*E-learning can provide me with an instant learning opportunity to learn the topics I do not understand*).
- Students experiencing heavy course loading in the e-learning course have higher satisfaction levels than those with light course loading in Question 16 (*In general, I am satisfied with the design of the simulation laboratory*).
- Students engaging in fewer Internet activities are more satisfied than those having more Internet activities in Questions 12 (*I am satisfied with the flow design of the fuzzy expert system in the simulation laboratory*).

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