Lab-based Approach to Teaching Knowledge-based Systems in High School

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Abstract

The research reported in this paper is a suitability and effectiveness study on lab-based approach to teaching knowledge-based systems in high school. The experiment was conducted at a rural high school. One hundred fifty-five first year high school students in four classes participated in this study. Two of the classes were designated as the control group and the other two classes as the experimental group. After three in-class lectures on topics in AI and KBS, a test was given as a pre-test for the experimental stage that is to follow. The achievement test was given after three more weeks of in-lab (experimental group) or in-class (control group) enhanced study about knowledge based systems. The ANCOVA results indicate that the students in the experimental group learned significantly better. The ease of understand the worksheet problems and ease of use of the software tool all contributed to this success.

Keywords:

Lab-based, CS education, knowledge-based system

1. Introduction

In Taiwan, the high school CS curriculum [MOE, 1996] mandates basic computer science concepts be taught in the computer course. Furthermore, the curriculum calls for an introduction of Artificial Intelligence (AI) as part of the computer course. However, most students graduate from high school without basic understanding of Artificial Intelligence. Some high schools in Taiwan use the computer course to teach computer programming. Other schools use the course to teach operational skills of selected commercial software. For those that do adhere to the curriculum guideline, teaching of AI concepts is minimal at best. The result is that students entering a CS-related degree-granting program have little or no prior knowledge of about computer science. Therefore, it is our goal to find a way to teach AI and its various subtopics in which students can have some understanding about this field while in high school.

Ever since the Computing Curricula 1991 [ACM/IEEE Task Force, 1991] and its sequel Computing Curricula 2001 [ACM/IEEE Task Force, 2001], recommended that laboratories be an integral part of undergraduate computing curricula, labs have become a major topic for discussion in the ACM SIGCSE Technical Symposium. Many research results have been reported on the design, implementation, and the instructional effectiveness of labs [e.g., Thweatt, 1994; Parker and McGregor, 1995; Lin, Wu and Liu, 1999; Lee and Wu, 1999]. We have also noticed that more and more textbooks for computer science courses, especially the introductory courses, have been providing lab manuals and exercises as a necessary supplement in recent years. All of these point out the fact that labs have gradually gaining ground in computer science education.

Ever since Aiken (1991) promoted teaching of AI, many researches have been reported. Aiken (1992) developed individual AI related lab modules for teaching at the college level; Stern and Sterling (1997) have students learn about AI algorithms through the use of interactive programs; and Kumar and Meeden (1998) taught AI through the use of robotic labs. In high school, Pilgrim (1995) had experimented with the teaching of expert systems through a tic-tac-toe game based lab. All of the above have reported positive results in some way. Therefore, in this study, we have also taken the similar lab approach. The teaching objective is to cover some introductory AI subtopics while allowing full understanding of the working nature of a knowledge-based system.

2. Research Methods

2.1. The KBS Lab Package

A lab-package containing classroom teaching slides, an in-house software tool, and the lab-worksheet are developed. The teaching slides are for teachers to use during the lecture. The software tool allows the students to experiment with the built in knowledge-based system, as well as to create their own deduction rules and inference methods. The work sheets provide students with lab procedures and with questions to entice thoughtful responses.

- In-class lecture slides. The lecture slides are used by the teacher to prep the students with fundamental concepts and knowledge on AI and KBS in general. The topics covered are given in Table 1.

Table 1. Topics and contents of the in-class lectures.

Topics	Contents
Introduction to AI	Definition Examples
Knowledge Representation	Logic representation Semantic networks Scripts Production rules
Logical Inference	Forward chaining Backward chaining Conflict resolution

- KBS lab software and worksheets. The KBS lab worksheets lead the students, step by step, in building a knowledgebase system. The students would have to practice knowledge extraction and representation from the given facts, to deduce logical rules, to prioritize rules, and to construct decision trees. The accompanied software allows students to realize their KBS and see the reasoning process using the facts and rules that they have identified. In this experiment, the KBS lab software and worksheet are used by the experimental group only.

- In-class exercise worksheet. The in-class exercise worksheets are used by the control group to enhance their understanding of KBS with the teacher as the facilitator. Just as with the KBS lab worksheets, the in-class exercises allow students to work through the KBS construction process and to hand trace through the KBS that they have constructed.

In addition to the KBS lab package, two achievement tests are developed in association with this research.

- In-class lecture achievement test. The in-class lecture achievement test is used to measure students' understanding of AI and KBS subtopics after the first three weeks of in-class lectures. The test consists of 13 true-false questions and 4 short-answer questions. The true-false questions are to measure student's basic understanding of AI, where as the short-answer questions are to measure student's knowledge about the inner working of KBS. The maximum possible score for this test is 37.
- Lab Work Achievement test. This achievement test is a written exam that contains two types of questions: eight multiple choice questions and four short answer questions. The multiple choice questions are to measure student's basic understanding of the "conflict resolutions" and "logical reasoning" subtopics. The short answer type questions test students' understanding of the "forward/backward chaining" and "decision trees" concepts. The maximum possible score for this test is 24.

2.3 Participating Classes

The teaching experiment was conducted at a typical rural high school. The participating teacher has had eight years of teaching experience, all at the same school. She is responsible for teaching most of the "Introduction to Computer Science" classes, which is a required course for first year high school students at this school. For this experiment, two classes were randomly chosen as the experimental group and two other classes were chosen as the control group. Since at this school, students were randomly assigned into different classes, there should be no bias as to which classes were chosen for the experiment. There are 76 students in the control group and 79 students in the experimental group.

2.4 Experimental Procedure

The entire experiment lasted eight weeks, including time for the pre- and post-tests. Figure 1 depicts the flow of the experiment. Both the experimental and the control groups attended in-class lecture on AI subjects for three class periods, one class period per week. For the next three weeks, the experimental group used the KBS lab package for self-study, whereas the control group met in the class for reinforcement lectures. A lecture achievement test (pre-test) on the in-class lectured material was administered to both groups at the end of the first three weeks. Lab work achievement test (Post-test) was also administered to both groups at the end of the experiment (8^{th} week) to determine how well have the students learned about the knowledge-based systems.

2.5 Data Collection

The In-class lecture achievement test and the post-experiment achievement test were administered and the scores were collected. The one-way Analysis of Covariance (ANCOVA) was performed to test the difference among the achievements of the experiment and the control group. Student questionnaire and teacher interviews were also conducted at the end of the semester. The questionnaire contained both open- and close-ended questions.

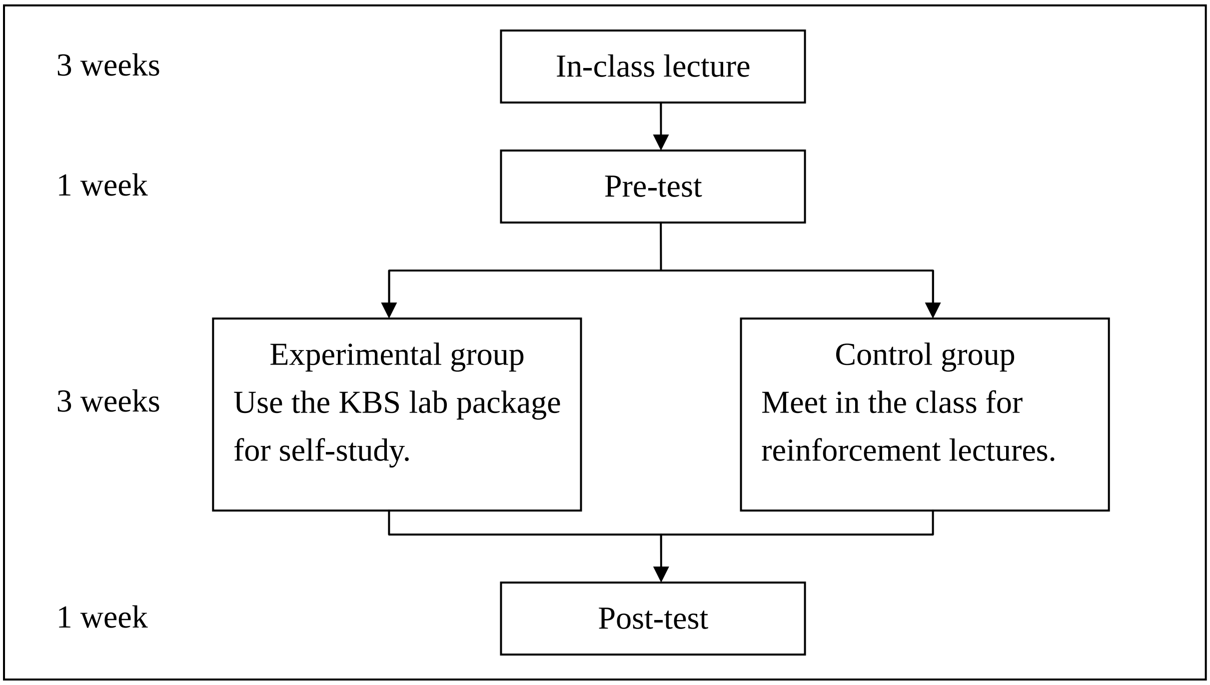

Figure 1. Experimental Procedure

3. Results and Discussions

The ANCOVA was performed to test the difference among the achievements of the experiment and the control group. The in-class lecture test (administered at the 4^{th} week) scores were used as the covariate in the analysis. Tables 2 and 3 present the results of the statistical analyses of the study. The descriptive statistics for the ANCOVA analysis are depicted in Table 2, whereas Table 3 presents a summary result of the ANCOVA analysis on the overall post-experiment achievement test. The ANCOVA results ($F=4.70$, $p=0.032$) indicate that the experimental group scored significantly higher than the control group on the post-experiment achievement test. It can be concluded from the study that lab-experiment can better improve students' understanding of concepts relating to knowledge based systems as oppose to the traditional lecturing approach.

Table 2. Descriptive statistics of the achievement test scores. Maximum scores are 37 for the in-class lecture test and 24 for the post-experiment achievement test

Group	*n*	Post in-class lectures test scores (covariate) Mean	SD	Post experiment achievement test scores Mean	SD
Experiment Group	79	25.03	3.10	16.85	3.15
Control Group	76	24.66	3.04	15.74	3.04

Table 3. Summary results of the ANCOVA analysis on the achievement test score

Source	SS	d.f.	MS	*F*	*P*
Between groups	45.14	1	45.14	4.70*	.032
Error	1459.39	152	9.60		

P<0.05

Student questionnaire was also collected at the end of the experiment. The questionnaire contained seven close questions and three multiple choices and open questions. The result is summarized in Table 4, in which "strongly agree" and "agree" statistics are grouped together and "strongly disagree" and "disagree" statistics are grouped together. The results are discussed below.

From the questionnaire, 50% of students indicated that the lab software was easy to use, while only 13% indicated the opposite (Q1). On the clarity of the instructions on the lab worksheet, 79% of students indicated that the lab instructions were clear while only 1% of the students have difficulty following the instructions. Therefore, we can conclude that the effectiveness of the study is not adversely affected by the experimental tool.

As for the problems presented in the lab worksheet, slightly more than half of the students had no difficulty understanding the questions posed (Q3, 54%), while 13% of the students needed help interpreting the questions asked. Once the students understood the questions, most students were able to answer them eventually (Q4, 40% + 54%), while only

Table 4. Post-lab experiment questionnaire and results (n=79).

Problem	(Strongly) agree	neutral	(Strongly) disagree
1. The lab software is easy to use.	50%	37%	13%
2. The instructions on the lab worksheet are clear.	79%	20%	1%
3. The questions on the lab worksheet are understandable.	54%	32%	13%
4. I am able to answer the problems at the end of each experiment.	40%	54%	6%
5. There is enough time to complete the lab worksheet.	11%	11%	78%
6. The lab exercise enhanced my learning interest.	37%	48%	15%
7. Overall, the lab exercise helped me reinforce the concepts taught in class.	70%	23%	7%
8. When encountered a lab software operational problem, I _____ for help.	♦ discuss with group members (84%) ♦ discuss with other classmates (63%) ♦ read the instructions on the worksheet again (56%) ♦ ask the teacher (52%) ♦ look up on-line help (9%)		
9. When working through the lab worksheet, I would	♦ discuss with group members (82%) ♦ work along (56%) ♦ copy other's answers (18%)		
10. When I have difficulty answer a worksheet question, I ___.	♦ discuss with group members (90%) ♦ ask the teacher (55%) ♦ discuss with other classmates (55%)		
11. Which learning method do you like better, the in-class lecture or in-lab experimentation? Why?	♦ Like in-class lecture better (34%) ♦ Like in-lab experimentation better (50%) ♦ Either way is fine (16%)		

a small number of students (6%) were not able to answer the questions. Since more than half of the students (54%) responded neutral to this question, this indicates that the problems in the worksheet were not trivial and that it requires the students to think and to experiment with the lab tool to arrive at a possible answer.

The last three questions (Q5 ~ Q7) gather students' impression about the experiment in general. It is interesting to note that most of the students thought that the time allotted for completing the lab worksheet was not enough (Q5, 88%). Although students wished for more time, most still managed to complete the worksheet in time. However, only about a third (Q6, 37%) of the students agreed that the use of lab enhanced their learning interest, and more than two third of the students (Q7, 70%) thought that the lab did help them reinforce the concepts learned in class. Therefore, the use of lab can indeed forester students' learning but only aroused students' learning interests in a limited way.

In the multiple choices questions, we wanted to know how the students go about resolving different type of problems encountered during the experiment. Since students were allowed to have multiple checks, the percentage for each question does not add up to 100%. From the responses, it is clear that students do discuss among their partners when encountering a problem. When students are unable to resolve the problem then they turn to the teacher or other classmates for help. Only a few would take the easy way out in copying others answers (Q9, 18%).

On the very last question (Q11), we asked the students to compare the in-class lecture-based and the lab-based approach toward learning, 34% of the students liked the lecture-only approach, 50% of the students liked the lab-based approach, while 16% is indifferent to either approach. The overwhelming cited reason for favoring lecture-only over lab-based approach is that it is less stressful to just listen to the lecture in class. Some students wrote:

"*It is more relaxing to just sit and listen to the lecture …*",
"*No need to use my brain in class…*", and
"*I can ask questions anytime …*".

From those comments, we can see that students who lack learning motivation often want to take it easy in class. Simply changing the in-class learning activity to a hands-on approach is not enough to alter those students' learning attitude. On the other hand the most commonly cited reason for those that liked the lab-based approach is that they can learn better with this hands-on approach. One student wrote:

> *"It is easier for me to understand the concepts presented in the lab experiment and easier to discover my misconceptions through those experiments. Doing the experiment by myself allowed me to try out my ideas…"*

Therefore, for those students with some learning motivation and curiosity about the subject or concepts being taught, lab-based approach afford them to learn at their own pace and more importantly in their own way.

4. **Conclusions**

The research reported in this paper is a suitability and effectiveness study on lab-based approach to teaching knowledge-based systems in high school. The experiment was conducted at a rural high school. One hundred fifty-five first year high school students in four classes participated in this study. Two of the classes were designated as the control group and the other two classes as the experimental group. After three in-class lectures on topics in AI and KBS, a test was given as a pre-test for the experimental stage that is to follow. The achievement test was given after three more weeks of in-lab (experimental group) or in-class (control group) enhanced study about knowledge based systems. The following conclusions can be derived from the collected data.

1. Teaching of knowledge based system concepts to high school students is feasible. Furthermore, the ANCOVA results indicated that the students learned significantly

better when lab-based approach was used. The ease of understanding the worksheet problems and the ease of usage of the software tool all contributed to the success of this positive result.

2. The lab-based approach to teaching computer science topics can only stir up learning interest among some students (about 1/3 in this experiment). Students' passive learning attitude is not drastically changed by simply allowing hands-on activities during learning.

Overall, the results showed that the students welcomed the lab-based approach to teaching and learning of higher-level computer science concepts. The hands-on labs resulted in better performance on the achievement test by the experimental group. In all, the lab-based approach to teaching and learning of higher-level computer science concepts is feasible and should be promoted. However, as is in the physical science subjects, suitable lab-packages need be developed to facilitate this practice.

5. References

ACM/IEEE Task Force. (2001). *Computing Curricula 2001*. http://www.computer.org/education/cc2001/index.htm.

Aiken, R. M. (1991). The New Hurrah! Creating a Fundamental Role for AI in Computing Science Curriculum. *Education and Computing*, 1991.

Aiken, R., Allemang, D., and Wehrle, T. (1992). Designing laboratory modules for novices in an undergraduate AI course track: artificial intelligence. *ACM SIGCSE Bulletin, 24(1)*, 76-80.

Kumar, D., and Meeden, L. (1998). A robot Laboratory for teaching artificial intelligence. *ACM SIGCSE Bulletin, 30*(1), 341-344.

Lee, G., & Wu, J. (1999). DebugIt: A debugging practicing system. *International Journal on Computers and Education, 32*(2), 164-179.

Lin, J. M.-C., Wu, C.-C., & Liu, H.-J. (1999). Using SimCPU in cooperative learning laboratories. *Journal of Educational Computing Research, 20*(3), 251-269.

Parker, B., and McGregor, J. (1995). A goal-oriented approach to laboratory development and implementation. *Proceedings of the twenty-sixth SIGCSE technical symposium on Computer science education*, Nashville, Tennessee, 92-96.

Pilgrim, R. A., TIC-TAC-TOE: Introducing Expert Systems to Middle School Students. *ACM SIGCSE Bulletin* , 27(1), 340-344

Stern, L., and Sterling, L. (1997). Teaching AI Algorithms Using Animations Reinforced by Interactive Exercises, *Proceedings of the 2nd Australasian conference on Computer science education,* Melbourne, Australia, 78-63

Thweatt, M. (1994). CS1 closed lab vs. open lab experiment. *ACM SIGCSE Bulletin, 26*(1), 80-82.

Tucker, A. B. (chair). (1991). A summary of the ACM/IEEE-CS joint curriculm task force report: Computing Curricula 1991. *Communications of the ACM, 34*(6), 69-84.