ASSESSMENT OF ACTIVE LEARNING WITH UPPER DIVISION COMPUTER SCIENCE STUDENTS

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Abstract - *This paper describes the assessment and evaluation of experiments with active learning techniques performed in upper division Computer Science classes at California State University, Northridge (CSUN). In spite of the traditional views of Computer Science as an individualistic subject matter that attracts introverted, non-social students, the authors used active learning techniques in their classrooms for several semesters with encouraging results. In addition to an improved attitude and stated increased satisfaction, students' test results seemed to show increased comprehension and improved critical reasoning abilities. However, the authors felt the need to further evaluate their experiments for a more objective assessment. As an initial step, the authors conducted a survey of CSUN graduates, now working professionals. The goal of the survey was to determine how well the active learning experiments met the objectives of improved critical analysis abilities that were needed on their jobs, as well as improved communication and collaboration skills.*

Index Terms - Active learning, communication skills, cooperative learning, teamwork, assessment.

INTRODUCTION

The goals of assessment are to better understand and improve student learning, and it is an ongoing process. It involves systematically and continually collecting, analyzing, and interpreting evidence to determine how well the performance of a program matches the standards and expectations for the program. This paper describes the assessment and evaluation of experiments with active learning techniques performed in upper division computer science classes at California State University, Northridge (CSUN).

The authors used active learning techniques in their classrooms for several semesters with encouraging results. In addition to an improved attitude and stated increased satisfaction, students' test results seem to show increased comprehension and improved critical reasoning abilities. However, the authors felt the need to further evaluate their experiments for a more objective assessment. The active learning experiments include field related discussions of current events, entry and exit surveys with feedback, cooperative learning, and other problem based group activities. In addition to a general evaluation of the program, the authors wanted to know which of these techniques were perceived to be the most useful by the students. This is especially important since upper division computer science students are stereotypically considered to be introverted and therefore poor candidates for an active learning curriculum even though the requirements of their field demand skills in critical analysis and evaluation, as well as communication and collaboration skills. It is well known that these skills are not easily acquired in the traditional classroom environment where students maintain a basically passive role.

To assess these student perceptions, the authors initiated a survey of CSUN computer science graduates, now working professionals, to determine how well the experiments met their goals of improved critical analysis, as well as the improved communication and collaboration skills that they would need as computer science professionals. In addition, they did a study of similar exams taken by students who had experienced active learning, and those who had not, in order to compare comprehension and critical reasoning abilities. The results and outcomes of these and other evaluation techniques are described in the paper.

BACKGROUND

Active learning in the classroom includes nearly every activity other than merely passively listening to an instructor's lecture. Short writing exercises, sharing information in student pairs or groups, and complex group problem solving exercises are all examples of active learning. Cooperative learning is a subset of active learning that usually involves formally structured groups of three or more students assigned multi-step exercises, research or development projects, or presentations. According to social psychological theories, learning is more effective when the process is an active rather than a passive one [1]. Many studies have been done including Ruhl, Hughes, and Schloss [2] that have demonstrated the dramatic improvement on long term retention of course information by the introduction of active learning techniques into the classroom. In a more directly relevant result, McConnell has shown a statically significant correlation between the use of active learning exercises and final exam scores for students in a theory of computation course for computer science majors [3].

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Characteristics of CSUN that would seem to present challenges for active learning are cultural diversity within the student population and the large number of students with disabilities, especially the hearing impaired. In one software engineering class of 32 students there were 14 different languages specified as the student's native language on an end of semester survey. Fewer than 35% students specified English as their native language. Since English is the second language for nearly two thirds of most classes at CSUN there can be some inherent communication problems in group discussions and projects. Although students with disabilities are not present in such large numbers, there are typically one or two such students in each class. Students who are deaf or hearing impaired are the most common although blind students and students with other physical or learning disabilities are also often present. CSUN is deeply committed to meet the educational needs of students with disabilities and it was the first mainstream university in the nation to provide full-time professional interpreters in the classroom.

Despite these challenges, however, efforts to use active learning in upper division computer science classes have been very successful. Care has been taken to choose exercises that are well suited to the learning styles that are typical among engineering and computer science students and are sensitive to the cultural diversity and disabilities present within the classroom. The following section briefly describes the specific forms of active learning used.

DESCRIPTION OF ACTIVE LEARNING EXPERIMENTS AT CSUN

One of the computer science classes for which it seemed most natural to employ active learning techniques was the course on "Societal Issues in Computing". This course is a senior level course required of computer science majors. The course examines ethical issues such as privacy, copyright, and free speech as well as the impact of computers on education, productivity, and health and safety. Group discussions, debates, and team presentations seem to be natural ways to promote learning of the material. Some early attempts, however, met with difficulties. For example, when the *think-pair-share* technique was used as a learning mechanism, the results were mixed. In this technique students were first asked to write down their thoughts, then they talked about them with one other person, and finally shared them in a group, which presented the consensus response to the question or problem to the rest of the class. A typical question might be "Why are their so few women and minorities majoring in computer science?"

Although appropriate reading assignments were given, if the specific discussion questions were not known until class time, many students were not adequately prepared to participate in the discussion. Students accustomed to the traditional lecture course often feel that they need not do the assigned reading ahead of time, if at all, since they will

probably be able to get what they need to know from the instructor's presentation. Students who are, conatively speaking, fact-finders, according to Kolbe [4], have difficulty participating in such discussions if they are not prepared. Previous studies have shown computer science students to be predominately of this type [5]. Many such students will just sit and listen to the rest of the group, reluctant to participate. To maximize the effectiveness of this technique for computer science students, the instructors found it advisable to announce the specific questions that would be discussed in advance. In that way the fact-finders were able to prepare and be more likely to participate in group discussions. An added benefit of this approach was that more students actually did the assigned reading before the material was covered in class.

Another active learning technique used in this class was the use of *group presentations* where a group of students must research a topic and prepare a presentation for the rest of the class. The topic to be discussed might be the issue of "privacy of personal information". The presentations were organized by the group, but each panelist was expected to make a short presentation. The floor was then opened to questions from the rest of the class. This exercise works fairly well for computer science students since the group is given adequate time to do research (fact find) before making their presentation although the thought of questions being asked can be stressful. A variation of this technique, debates, was also used. In this case there are two groups and each presents a different side to an issue, such as "Should there be laws to control pornography on the Internet?" The debate was controlled by letting each group present arguments in support of its position, and then letting each group rebut the arguments of the others. If time permitted each group would then respond to the rebuttals.

Another computer science class that seemed like it would benefit from the use of active learning techniques was "Computer System Security". This is a senior and graduate level course and is part of the cores of the Computer Network and Operating Systems Concentrated Studies Packages. Any study or implementation of computer security requires a good deal of critical thinking and evaluation on the part of students. Currently daily articles and other items on these subjects appear in all forms of news media. This makes it very easy to present the pertinent issues of each of the courses in their historical and real world context by starting each class with a discussion of current events in computer security or societal issues involving computers. Students were encouraged to bring in articles and share them with the class. Some of the more introverted students participated particularly well in these sessions. Possibly this was because they had time to prepare in advance and felt more confident. With the articles in their hands, they were the experts on the issue being discussed. Another technique that was used was the groups discussed and reported on news items the students brought to class and

kept journals of these items. The students knew that the journals were to be collected at the end of semester.

As part of cooperative learning the students were divided into groups in order to discuss the issues raised during the 15 or 20-minute lectures that preceded the group sessions. Some important essentials for successful groups that the instructor has to be aware of are: appropriate grouping; individual accountability; instructor as facilitator; and an end product. Each group session has to end with the group producing something [6].

A technique called *key words* was used during cooperative learning sessions where the students separated into groups of four or five for discussions and reports to the class on the groups' conclusions made from the discussion at the end of the session. Group discussion questions that were assigned during the sessions contained key words recommended by Moss and Holder [7] such as *evaluate, contrast, explain, describe, define, compare, discuss, criticize, prove,* and *illustrate.* These words were chosen to help them develop their critical thinking skills as well as their writing skills. These same key words were used on exams to give them additional practice and to assess the improvement in their writing skills.

An active learning technique that was found to be valuable for assessment was *entrance* and *exit survey*. These had two applications. The instructor used them for ongoing assessment and evaluation as discussed in the next section and they became a powerful tool to help the student become involved in the learning process. An important feature of the survey method is that the students receive feedback on the results of the surveys. A survey would ask questions about the course material or ask the student to evaluate the class or the instructor. It was observed by the instructors that the students took these surveys very seriously and were very attentive when the results of the surveys were reported back to them.

A third course that used active learning techniques extensively was "Introduction to Software Engineering." Since software engineering is almost always a team activity, it seemed important to involve students in team projects and other team oriented exercises to the greatest extent possible. It has long been recognized that engineering and computer science students need to learn communication and collaboration skills. In his 1992 article on "Educating a New Engineer," Peter Denning observed that employers felt that new hires did not know how to communicate and that they had insufficient experience and preparation for working as part of a team [8].

Unfortunately, as Simon McGinnes states in regard to teaching information technology, "the skills of communication and collaboration . . . have often been undervalued in computing courses." [9] And according to Hilburn and Bagert, "Computer science education too often focuses on individual contributions rather than on managed group efforts that depend on defined standards, methodologies, and software processes; however, such groups are the norm in the software industry." [10]

In the "Introduction to Software Engineering" course an effort was made to emphasize major team activities. Near the beginning of the semester the class was divided into groups of approximately five students each. Although the issue of effective group formation is a complex one, beyond the current discussion, suffice it to say that efforts were made to create teams that were equitably balanced with respect to their probabilities of success [11]. The teams worked on large projects taking several weeks that were typical of those that might be encountered on real software development efforts. For example, one team project was the development of a comprehensive Software Requirements Specification for a proposed software system. Other projects dealt with topics like software design, software implementation, and software testing. These multi-week team projects exposed students to industry like activities. Furthermore, from a learning perspective using small teams of students provided many advantages. As John Bean points out such a collaborative learning approach "promotes student interaction and friendships, develops leadership skills and celebrates diversity." [12]

ASSESSMENT

We were initially concerned about assessing our efforts, but found that many accepted assessment techniques were appropriate for our experiments. Angelo and Cross describe fifty Classroom Assessment Techniques (CATs) that have been proven to be useful in class assessment [13]. These techniques have been successfully adopted by faculty throughout the United States and are well recognized for their value for individual courses. Their use in program assessment is less well documented.

Simple techniques were chosen for initial and ongoing assessment. These include *minute paper*, *muddiest point*, and *one-sentence summary*. These classroom strategies were used to improve learning because they helped the authors to evaluate the classes' progress towards their defined objectives and they let them know if they needed to change directions. The minute paper was assigned to answer the following questions: What was the most important thing you learned today? What questions remain uppermost in your mind as we conclude this session?

The muddiest point simply asks the question: What was the muddiest point in today's class session? This was best done as an exit survey. Exit surveys were good indicators of students' satisfaction and their current opinions. They were used to track opinions over the semester. M. J. Allen advises the use of simple clear cut questions in an exit survey [14]. The authors followed his advice and got the best results when they avoided compound questions, vague questions, or confusing or biased questions. The one-sentence summary could be used during a break in the lecture. A sample question might be in the following form: Encryption might

be installed in a computer system by *whom*, in order to mitigate *what*, by *whom*, *where*, *how*, and *why*?

The midterm and final exams in the Computer System Security classes used a method of evaluation suggested by Jacobs and Chase [15]. Essay questions containing the key words mentioned above were used in the exams. Some examples of exam questions are: "Contrast the substitution method for data encryption with the transposition method."; "Present arguments for and against mandatory access control."; and "What are the relevant parts of system security auditing?" The pilot testing was done with students of Computer System Security who were taught with the lecture method. The results of these students' tests were compared with the results of the students in classes that were exposed to the active learning techniques described above. Though all classes were given the same or very similar tests, the students exposed to active learning gave answers that were more correct, more comprehensive, and an average of 50% longer, showing that the students were not only more confident, but felt they had more to say about the subject. One weakness with this method is that even though it was recommended and was useful to us, its reliability and validity is generally unknown [15].

Another assessment technique that we used was the observation method suggested by Babbie [16]. Observation is considered to be able to provide more valid data about social processes than some other data collection strategies. The classes were evaluated by observing the students interacting during their group sessions. In this case, the observers, the instructors, were usually not part of the social process that was being observed. However, the instructors frequently had to answer questions and act as facilitators for the groups, and this is acceptable for the observer in the method. An improvement was noted in the students' ability to interact as the semester progressed. The method allowed us to observe the subtle nuances of attitude and behavior that are difficult to measure quantitatively.

Of particular interest was the observation of the deaf and hearing-impaired students who made up about 5% of the groups. Though communicating with the other students with the assistance of an interpreter, either signing or using a closed-caption monitor, was awkward at first for all involved, the hearing impaired students, the rest of the groups, and their interpreters were observed to quickly adjust and become comfortable groups.

ASSESSMENT SURVEY

The authors felt that more assessment was needed. They wanted to hear from the students who had graduated to see if they felt that the active learning techniques used in their classes were helpful in their careers, which had been one of the main goals of the active learning experiments. A list of all computer science graduates for the last 5 years was compiled (a total of 416 graduates).

The survey and an introductory letter were sent to all those on the list whether or not they had taken a class that used active learning techniques. It was determined that the group that had not experienced active learning would provide a good control group. The letter stated that the information requested was useful because as recent graduates of the computer science program, they were the best source of information about how well the program prepares students for the world after graduation. They were asked to participate whether or not they experienced active learning techniques in their classes as their participation in this survey would help the authors to assess and improve the program.

The survey began with some questions about the respondents, including their gender, age, and country of birth. It then asked about their areas of concentration in computer science, their current work status, and about their graduate school plans. These questions were followed by 20 statements that they were asked to rate. The ratings went between 1 and 6, where 6 indicated very strong agreement and 1 indicated no agreement. If the statement did not apply to them they were asked to enter 0. A typical statement was "The Computer Science Program adequately prepared me for my current position." After this section the survey asked about useful classes, and finally asked for comments and suggestions, especially suggestions for improving the computer science program.

About 15% of those surveyed responded. Of the 62 responses 79% were male and 21% were female. Forty-five percent (45%) of the respondents were born in the United States and 55% were born elsewhere. The average current age of those responding was 30.2 years, and 82% indicated that they were currently working in a computer science related job. Many of the respondents included long comments. Two respondents returned three type-written pages of comments.

RESULTS OF THE SURVEY

Perhaps the most noteworthy result of the survey is shown in Figure 1.
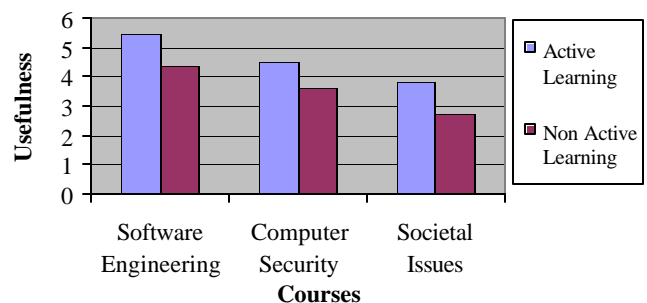

FIGURE 1
COURSE USEFULNESS AS A FUNCTION OF LEARNING TECHNIQUE

Computer science graduates who said that active learning techniques were used in their computer security, software engineering, and/or societal issues classes rated these classes significantly higher (p < 0.005 for software engineering and p < 0.05 for the other two courses) in terms of helpful preparation for their careers than the students who said they did not experience active learning in these classes. It is interesting to note that when graduates were asked to rate the overall value of the Computer Science Program in as preparation for their current positions, there was no significant difference between these two groups.

In the main most students agreed that active learning was beneficial, but they did not approve of all aspects of it equally. While more graduates felt active learning was more helpful than lectures, even more felt a combination of active learning and lectures was more helpful than straight lectures as shown in Figure 2.
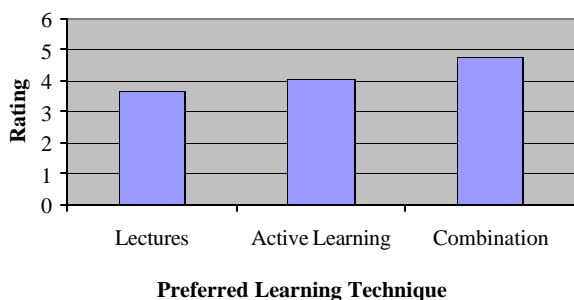

Preferred Learning Technique

FIGURE 2
RATINGS OF LEARNING STYLES

While high ratings went to class discussions, small group discussions, group projects, and presentations, the graduates universally gave much lower ratings to classroom-writing assignments. (See Figure 3.)
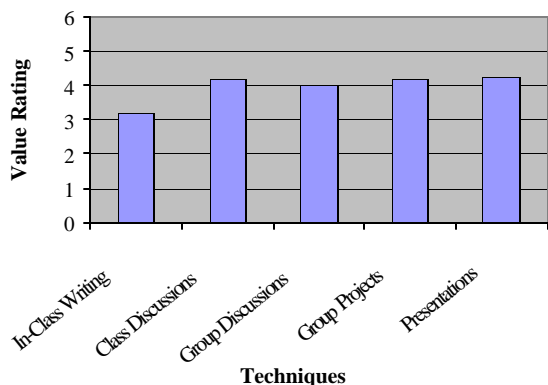

Techniques

FIGURE 3
VALUE OF ACTIVE LEARNING TECHNIQUES

It was found that there was a significant difference in responses to two of the questions asked between graduates born in the United States and those born elsewhere. As

shown in Figure 4, non US born graduates felt that a combination of lecture and active learning approaches provided a better learning environment over straight lectures to a more significant degree (p < 0.025) than did US born graduates. They also found group projects to be helpful to a more significant degree than did the US graduates.
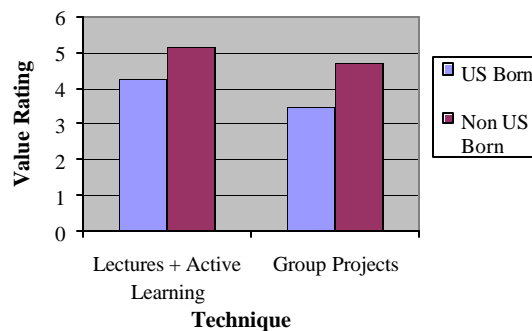

Technique

FIGURE 4
US BORN VERSUS NON US BORN RATINGS OF ACTIVE LEARNING

It was also found that there was a significant difference between males and females in the ratings they gave to the usefulness of the various active learning activities with females rating all group activities and the preparation and presentation of projects significantly higher (p < 0.01 in each case) than men. Also significant was the difference between their ratings of the usefulness of active learning exercises toward improving their communication skills with women again rating active learning much higher than men (p < 0.025) as shown in Figure 5. After further examination of the demographics of the responding graduates it was found that all but three of the female respondents were born outside the USA, and it was decided to study the population further before making any conclusions.
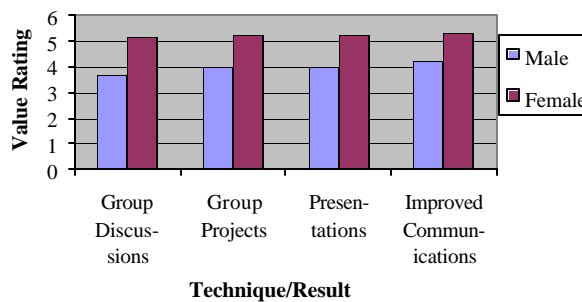

Technique/Result

FIGURE 5
MALE VERSUS FEMALE RATINGS OF ACTIVE LEARNING

On further analysis the survey showed that, for the graduates that were not born in the USA, females rated active learning significantly higher as helpful in improving their communication skills then did males. The females also rated small group discussions significantly as more helpful

than did the males who were not born in the USA (p < 0.025). These results are shown in Figure 6.
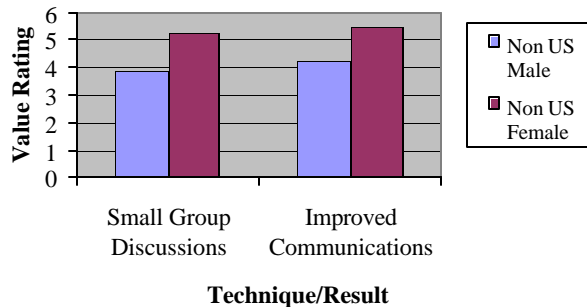

Technique/Result

FIGURE 6
NON US MALE VERSUS FEMALE RATINGS OF ACTIVE LEARNING

CONCLUSIONS

Although this assessment is based primarily on the perceptions of graduates of the computer science program, the results are extremely encouraging. At least from the view of the students, active learning seems to work. The perceived value of three courses in preparing students for their careers was significantly higher when active learning was used. These three courses, Software Engineering, Computer Security, and Societal Issues in Computing, were those in which significant efforts have been made to utilize active learning over the last several years although not all sections are taught in that mode. While other courses utilize active learning techniques, these were the only courses identified by a significant number of the respondents as courses where active learning was used.

One question asked students to rate the extent to which active learning improved their communication skills. This received one of the highest positive responses of all questions asked indicating that this was one of the primary benefits of active learning from the view of the students.

The survey results further provided some interesting insights as to which students might benefit most from active learning and who might be most receptive to such techniques. For example, students not born in the United States rated the value of certain active learning techniques much higher than did non US born students. This was particularly true for group projects. This may be true because the opportunities such activities provide for non-US born students to converse, collaborate and share information with both native born and students from other cultures. It may help them to compensate for many of the obstacles they face resulting from a lack of knowledge of the language and culture of this country.

The survey results also indicate more value given to active learning by women graduates. This is consistent with other analyses. For example, Bean's [12] comments that using small groups is "particularly effective at increasing the leadership skills of female students and for getting male

students used to turning to women for help in pressure situations."

In spite of the valuable information gathered as part of this study, there is clearly a need to do additional assessment in the form of direct measures of student learning. This is necessary to gain a more complete and accurate understanding of the ways and extent to which active learning improves students' understanding of and ability to apply the subject material of the computer science curriculum. Such assessment will be the primary topic of our continuing research in active learning.

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