AC 2010-1290: ENHANCING STUDENT LEARNING AND PROBLEM SOLVING SKILLS THROUGH SELF-REGULATED LEARNING ASSESSMENT FOR COMPUTER ENGINEERING

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Introduction

The research reported in this paper reflects an effort to enhance student self-awareness and to self-regulate their learning in a Special Topics Course taught during the fall semester at Jackson State University. The students were introduced to the concepts of software engineering, systems engineering and problem solving in support of a semester level project based upon small team dynamics. Emphasis was placed on monitoring the students' feedback on a number of issues related to self-regulated learning concepts of motivation, study techniques, self awareness and metacognition. The primary purpose of the research was to attempt to understand and mentor junior and senior level students in computer engineering in regard to their learning and study strategies and habits. Furthermore, the research provided insight into how the curriculum could be improved at the freshman and sophomore levels that would foster student success and retention.

Self-Regulated Learning – Overview

Self-regulated learning focuses on the development of set of skills that aid the student in managing his/her own learning and study skills. In particular, the student learns to evaluate their own study and learning strategies, to evaluate and implement critical thinking and to regulate their learning environments outside of the classroom[1]. Certainly, many students come to the university without adequate study experience or not having been introduced to self-regulated learning concepts. In fact, it has been my experience in teaching both freshmen in a university success course and upper class students in computer engineering courses, that their study and learning skills are often based on ad hoc processes centered on assignments and examinations and the mimicking of their peers, not always with success. Peer emulation has its pros and cons, particularly if the student identifies with the wrong set of peers, those students who have not developed a strong sense of self and have not developed an organized, productive set of study skills.

Researchers and educators recognize the important issues surrounding the concept of self-regulated learning[2,3]. The characteristics of self-regulated learning focus on the ability of the individual to employ a series of cognitive skills which include the use of repetitive learning techniques, organizational skills focusing on information and time management, and the ability to acquire, enhance and recover critical information. Each of these individual skills is essential to the success of the university student, in particular when being introduced to new topics and information built upon previous courses and experiences.

Metacognition, the ability to understand one's own learning and thinking processes, is vital to the setting and achieving of goals[4,5]. Here the students must be able to recognize and project the value of new subjects to their potential worth in either continuing education or the students' careers. Without this ability then the student is likely to focus only on the immediate value of the material, the impact on the next examination or project to be completed, in order to achieve a satisfactory grade in the course.

Additional characteristics of self-regulating learners are their ability to control their learning environments and to avoid internal and external distractions that can affect their concentration and effectiveness while focusing on academic tasks. Such students have the ability to 'Just Say No' when nonacademic opportunities, such as entertainment outings, present themselves. For many focused learners their peers may see them as driven.

Pintrich[6] developed a theoretical framework which has application in the case of classifying the self-regulatory process. In this framework he identified four phases: planning, self-monitoring, control and evaluation. Each of these areas is critical to the development of strategies for becoming a successful student at the university level, particularly in one of the engineering disciplines. When defining success, it can be measured in a number of different ways, but for graduate schools and many employers, success has a meaning directly related to one's GPA: 3.0 or higher. Developing the proper skills and techniques to become a truly self-regulated student can certainly aid in the establishment of the minimum GPA. Students must recognize that there are more requirements than just meeting the minimum curriculum for the degree. Furthermore, they must also acknowledge and internalize that fact that they are in control of their futures and can make adjustments to their performance by making changes in their study habits. Those changes, however, must be in a form that reinforces the concepts of self-regulated learning. Simply desiring to make modification is not sufficient; one must make a conscientious effort to establish a plan, implement and monitor that plan and utilize the feedback to continuously improve one's efforts. Self-regulated learning requires the monitoring and continuous evaluation of the outcome of one's effort, identifying the tasks that can improve one's learning and those that limit or negatively affect it. For example, if one establishes a schedule for studying in the library after class for 4 hours each day. Initially the environment is acceptable and there is measured improvement in the retention of the materials being studied. However, once the outside temperature begins to fall, the library environment becomes uncomfortable. For this reason, study times are reduced to only one hour. The student must be recognize that reducing one's study time to only one hour is not sufficient and an immediate change must be made to provide to a better environment. Two possible approaches are 1) to ask the librarian in charge if there are ways to modify the inside temperature or 2) find an equally suitable location that has a more acceptable temperature. Students must recognize that in this and other cases they have the responsibility for making changes.

Method

The sample for this initial work included 15 upper-class computer engineering students in a special topics course. The university is a historically black university (HBCU). The ethnic makeup of the course was 86% African-American, 7% Hispanic and 7% Caucasian, with gender breakdown as 27% female and 83% male. The concept that directed the data collection and feedback was the use of multiple questionnaires that focused on student anticipation, study habits, basic knowledge and problem solving skills.

Course Content

The course, CPE 493 Special Topics, focused on the development of a wireless Linux cluster to be used in the creation of intelligent wireless sensor networks and for advanced computing among a group of rovers involved in planetary exploration. Specific topics examined during the semester included the following:

- Engineering concepts related to system engineering and software engineering
- Operating systems and the Linux OS
- Parallel computing and parallel programming, focusing on the use of MPI and Open MPI
- Wireless communications and wireless networks
- Problem solving techniques
- Enhanced self-regulated learning
- Wireless sensor networking
- Software and systems engineering
- Project management

A number of the topics were new to the students or were extensions of subjects that they had already studied in their undergraduate curriculum such as operating systems, programming and software development, and networking. None of the students had ever created a Linux cluster and only a limited number were familiar or had even worked with the Linux OS.

Two of the topics, software engineering and system engineering, presented the students with a new approach to how these two fields of engineering could be applied to their study of computer engineering. In addition, it was pointed out to the students that all fields of engineering focus primarily on the issues surrounding problem solving. Though each of the students had encountered the need to solve problems throughout their undergraduate education, they have not

formally studied different ways in which problems can be analyzed and solutions proposed. Building upon the process of problem solving: analysis, requirements elicitation, design, implementation, testing and feedback, the students were charged with using these different techniques to find solutions to the individual OS installations and software development, as well as the creation and testing of the Linux cluster.

The goal of the course was to introduce the students to advanced topics that had the potential of being directly applicable to potential career choices they would be making after graduating in the near future, whether that decision regarded graduate school or full-time employment. Many of the students reported that they were pleased that the course involved Linux since their knowledge/experience of Linux was questioned on some of their recent job interviews.

Since the class was composed of 15 students, it was easy to create 5 teams of 3 students each. Each team was assigned a common set of tasks required to create a wireless Linux cluster. The cluster was to be composed of 4 nodes and a server.

Initially, the students were given an overview of the concepts of software and systems engineering, problem solving, and how project management related to each of these topics. The purpose of this introduction was to illustrate to the students common principles of project management that they would encounter in their careers. In addition, they were encouraged to utilize many of the concepts in the management of their sub-teams and in the final integration of the individual Linux computers into a wireless cluster where they would have to work together to solve a common problem, in this case a parallelized application written in C.

To facilitate the development of the wireless cluster, a set of 5 Intel Atom-based computers were provided. Each team was assigned one of the computers with the responsibility of installing the necessary software components, including the Linux OS, and assisting in establishing the wireless Linux cluster and verifying its operation.

Lectures

The course lectures were designed to provide emphasis on both the subject matter being covered, as well as encouraging students to actively engage themselves in self-regulated learning by developing a set of tools and techniques for problem solving. Additionally, subjects related to career choice, financial management and decision making, and time management were introduced throughout the course. Since the students enrolled in the course were either seniors or juniors, many soon to graduate, it was essential they have a solid understanding of career and personal finance management. These topics also lend themselves to the use of self-regulated learning where the student learns from their mistakes and is able to improve their decision making process, even after either employment or financial missteps. It is important that engineering education include topics related to career planning, ethics, financial management, time management, community service and lifelong learning. Many of these students have little

or no experience in any of these topics since they entered college directly out of high school and have not been faced with the issues surrounding one's living on their own. There are certain students who have been employed throughout their college careers and have a better sense of the issues of budgeting and financial responsibility. Still, it is recognized that all of the students, including their instructor, can always benefit from improved budgeting practices and financial responsibility.

Aiding Self-Regulated Learning – Instructor lead motivation

To aid the individual students, without overwhelming them, assignments required both classroom participation and team-based lab work to be performed outside of the classroom. Furthermore, a research paper, related to the course content, was assigned to be completed by the end of the semester. The final exam was designed to support both an in class portion, as well as a take home portion related to applying self-regulated learning strategies. The results of their projects and assignments were to not only measure the student's knowledge of the subject matter but to also aid them in enhancing their self-regulated learning strategies.

The assignments, along with associated readings, were designed to provide the student with the base knowledge for a given topic. Students were encouraged to expand their knowledge by seeking additional research articles and technical information. As expected, the students with the higher GPAs tended to not only apply self-regulated learning principles and practices, but they also exhibited a higher level of interest in the overall technical aspects of the projects. During the semester it was noted that several of the students with the lower GPAs tended to avoid the outside reading assignments and chose to rely upon the efforts of the stronger members of their teams. Of course, this decision making process was reflected in both their knowledge of the subjects and the results on their examinations. Their research papers, also, were an important effort to aid the students in enhancing their self-efficacy through completing research and producing a professional paper that could be presented at a regional or national conference. Though there was much anticipation at the beginning of the class, many of the students were interrupted in their efforts due the fact that a number of the students were completing their senior design projects. Instead of using their time management skills in this situation, where they had multiple assignments and tasks to complete, they returned to the more comfortable habits they had developed in their time at the university. In interviews with the students at the end of the semester several admitted that they had prioritized their work, with this course being considered the less important than their senior design projects. When making such decisions it is reasonable that they would select a required course over an elective, particularly with their capstone project.

Every student at Jackson State University, save for transfer students with a minimum number of hours, is required to complete a freshman course titled, "University Success." Many of the topics covered in that course are directly related to the development of self-regulated learning.

In teaching that course it has been observed, though not measured to any degree, that the students who succeed in University Success come to the university already possessing an acceptable degree of self-regulated learning skills. Other students, though they are introduced to the concepts, often fail to incorporate those new techniques into their daily lives. Though it was late in their academic careers a concerted effort was made to re-introduce the concepts to the upper class engineering students and to attempt to have the 'weaker' students reevaluate and hopefully adopt these practices. From simple observation, the level of adoption was not very high. However, to verify this non-scientific observation a series of post-tests were administered that were designed to measure the same elements as the pre-test for the semester.

By allowing the students to record their responses anonymously it was easier for the students to be honest in their reporting without fear of repercussion. However, this fact did allow for them to over report / underreport their grade point averages. Discarding the potential for slight discrepancies in their GPAs, the students showed a high level of self evaluation in the answers to their questions. Without a doubt, the students reporting higher GPAs also reflected a higher sense of self-confidence. In particular, even on the post-course questionnaire, students with lower GPAs again responded to the questions regarding their potential success in the class as being 'Not Very True' for them. This type of self reporting contains more information than just a sense of reality regarding their potential grade in the course; it shows that they did not gain more self-confidence during the course, even though there was a concerted effort to encourage all of the students to apply the concepts of self-regulated learning throughout the course.

An important aspect of the course that should have aided the weaker students in developing more confidence was the use of teams. Students were allowed to select their own teams. As expected, the more dominant students, and often the students with the highest GPAs, self-selected to server as team leaders. This behavior has been observed in a number of instances in the Senior Design classes. The students with weaker self-confidence often participate in the teams by remaining on the side-lines, contributing only when given specific assignments.

In the case of the Special Topics Course, the same response was observed by the different team members. When one student was queried about their team and its makeup, he responded by reporting that no one selected him and he ended up joining the remaining team which contained only two members at the time.

Questionnaires

A series of questionnaires were used during the semester to gather data about the students in the course, their feelings about the course, how they were reacting to the subjects, and their knowledge base as related to the course. The questions ranged from how they compared themselves to other students in the class to their own self-confidence about learning the material and applying the concepts to the semester project. A second set of questions solicited responses

from the students regarding their anxiety and issues with examinations. Finally, the third group of questions focused on the students' study skills and motivations.

These instruments were administered at the beginning and end of the semester in an effort to access the impact of the instructional methods employed during the semester on the development of self-regulated learning.

A short survey was use to gather feedback from the students at the beginning and end of the semester on their self-reflection on both learning and time management. The questions centered on:

- Their feelings regarding availability of time for study
- Effective learning strategies they are using
- Ability to apply self-reflection on their work
- Lack of time for studying and how that affects homework and exams
- Success on homework as correlated with paying attention in class
- Self-regulated learning assessment and reflection on their success or failure in problem solving

Results and analysis

The initial data collection effort was able to illustrate the lack of knowledge, among the students, of key concepts to be covered in the course. The questionnaires were divided into three different focus areas: 1) questionnaire regarding their self concepts, 2) a questionnaire about the software engineering focuses of the course and 3) a questionnaire regarding the semester long project in which they would be engaged.

Semester Project Questionnaire

The students were asked a series of questions that related to their feelings toward being assigned a challenging project in which they would have to learn new material in order to be successful. The specific questions were related to how they felt when faced with challenging topics

Results of the initial questionnaires

All of the students at the beginning of the semester expressed excitement about both the project's content and the opportunity to learn new topics which may be related to their future employment.

A 5-point Likert scale was used on the majority of questions, the responses were to be rated as 1 – unable to 5 – being very able. Additional open-ended questions were used to collect the

students' responses to opinion related questions regarding the feel for the course, their self confidence and related efforts in meeting the requirements of the course. Table 1 presents some of the results of that questionnaire.

Table 1 – Post Self Report on Phases 1 and 2

	Question	1	2	3	4	5	Mean
1	When I started the installation of Linux on the computer I felt that I was able to complete the task	0	1 2	1 3	0 0	7 35	4.44
2	After completing the task I felt that I was:	1	0	1	0	8	4.4
3	When I started on the installation of the wireless network I felt that I was able to complete the task.	1	0	3	0	7	4.09
4	After completing the task I felt that I was:	0	0	2	1	5	4.37

As can be seen from Table 1, the students in the class self reported that they felt confident about the installation of Linux, though there was some degree of uncertainty expressed by 5 of the students. For the most part, the students were confident in their ability to complete the task. After the installation of the OS, however, 2 of the students showed less confidence in themselves. In fact, some the teams faced difficulty in getting both their hardware operational, as well as, installing Linux. One of the teams exhibited a strong desire to learn all aspects of the project, assisting the other teams whenever a difficulty was encountered.

The second task performed in the class was the installation of the wireless communications device on each of the computers and the eventual connection of all of the computers via a

wireless router. Again, shown in Table 1, the results were very similar to the installation of Linux, with the exception of the lack of any students reporting that they were unable to complete the task. Though the students reported that their confidence level was higher than average; the strongest student team again assisted the other students in completing this task.

Results of the End of Semester Questionnaires

Two of the students (13%) showed a lack of confidence at the end of the semester. This result may be from the experience they had during their semester, along with their midterm examinations. Developing self-confidence and working knowledge is crucial to aiding such students iimprove both their study/work habits as well as their grades. Failing to complete assignments and not doing well on exams only reinforces the student's lack of confidence.

The students, overall, remained quite positive about both their project and their experience during the semester. The average score on the questions relating to the OS installation were slightly higher than on the wireless project. This result reflects the fact that a number of them had not completed a course on computer networking and had limited or no experience in establishing a network.

In regard to the amount of time available for studying, the students overwhelmingly reported that at times they were overwhelmed and did not feel they had sufficient time for studying. Two students did report that they never were faced with that concern. As for possessing effective learning strategies, 40% of the students were very positive in their responses. The remainder of the class was less certain about that. As for success on homework assignments and examinations, most of the students again reported that any lack of success was a result of not having the chance to read/study the textbook. 80% of the students reported this lacking was either true or very true. This response somewhat contracts the question regarding whether the student felt like that they generally have adequate time for studying. This contraction may reflect that generalized studying does not always involve a textbook but focuses primarily on homework assignments and lecture notes. Related to the understanding and applying of those concepts on homework and exams, the students showed self-reflection when they admitted their success was dependent upon paying attention in class and understanding the concepts during that time. Generally, it can be interpreted from this response that attempting to learn a new concept is more difficult if one has not had the topic explained in detail in a formal lecture environment. Finally, the students reported the effectiveness of self-reflection and self-regulated learning on their success in problem solving and the understanding of engineering concepts. In this case one student reported that self-reflection and self-regulated learning was not very true for him/her; however, the rest of the class did recognize the importance of these concepts in both failure and success in applying learning strategies for learning engineering principles.

In a related topic, use of time for studying, more of the students reported a minimum of 20 to 40 hours per week. One student did report only 12 hours a week. From observation of the work load in the computer engineering department at the university, it is hard to believe that a maximum of only 12 hours could result in success at the undergraduate level.

Conclusions

From this initial effort in the special topics course in computer engineering it is recognized that additional work must be directed toward the integration of self-reflection, self-regulated learning and problem solving technologies into all courses across the engineering curriculum. In addition, an effort will be made to reinforce many of the skills discussed in the freshman university success course which include time management, study techniques, critical thinking, note taking, textbook reading, and examination preparation. The importance of these topics became apparent in the self-reporting by the students and in certain instances their lack of use or understanding of their self-regulated methods.

Since this is the first semester of this research, additional refinements will be made in the data collection instruments, the feedback mechanisms, and the assessment of the effectiveness of both the instruments and the instruction in the important aspects of advance problem solving techniques, self-regulated learning and effective study habits. The students reflected their interest in expanding their knowledge of computer and engineering related subjects while at the same time revealing some lack of trust in their own study habits and practices.

The research and application started during the fall semester will be continued with additional effort directed toward the creation of control groups which will provide move scientific rigor to the data acquisition and analysis. It is hoped that this initial effort will evolve into a standardized methodology for the delivery and monitoring of problem solving skills to computer engineering undergraduates. Included will be the development of a set of metrics than can be used to measure the degree of success.

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