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Rearrangement of mobile wireless sensor nodes for coverage maximization based on immune node deployment algorithm

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Abstract - Teamwork is recognized as an important skill for engineering and computer science professionals. Both potential employers and accrediting agencies, such as ABET, expect students to gain proficiency in teamwork skills through experiential learning. Teamwork based projects challenge the student to apply the technical knowledge they gain in school to solve meaningful and complex problems. However, to be trulyproficient in teamwork, a student must also learn and practice a large number of peripheral skills. These include planning, estimating, tracking progress, taking corrective actions, managing change, controlling and managing risks, maintaining ethical and professional conduct, communicating complex ideas clearly and concisely, using design automation tools, leveraging web-based tools for team collaboration, and most importantly participating effectively as team members. It is essential that students should be taught these important skills. It is unlikely that without adequate faculty guidance students can pick up these skills through ad-hoc project experience. Yet, many engineering and computer science programs expect the students to do just that. We feel strongly that we need toemploy a more pragmatic approach in teaching students the skills necessary to function as effective and productive team members. Additionally, we need to develop criteria for assessing the effectiveness of teachingteamwork and the tools to measure learning outcomes. Among the problems contributing to this situation are the following: engineering and computer scienceinstructors themselves often have had little or noexperience operating in teams; training or guidance in effective ways to teach teamwork is seldom provided; and tools and effective approaches to assist in the teaching and assessment of teamwork are lacking. Another problem is that, it takes a great deal of faculty time, effort and energy to guide groups of students in doing effective teamwork. We will describe an approach that we have used to teach team collaboration skills using free and freely available web-based tools. Students learn to use tools for design automation, metrics collection, project management, and web-based collaboration. Our approach encourages students to learn teamwork skills and improves levels of collaboration among team members while reducing demands on faculty time and effort. Use of web-based collaboration tools allows students to participate without the need for frequent face-to-face meetings; this our
students love. In an effort to maximize the use of techniques like the ones described in this paper, we hold regular informal sessions of interested faculty to share ideas on improving teaching teamwork and to develop methods and tools for assessment. The paper and the conference presentation will describe both our approach and the results we have obtained.

Index Terms – Teamwork, experiential learning, assessment, agile process, web-based collaboration

INTRODUCTION

Few would dispute the importance of teamwork as a learning outcome for students in engineering and computer science. Engineering is by nature a collaborative process, and most production systems are designed by teams working over long periods of time. Those who employ the graduates from these programs look for these skills, and the Accreditation Board for Engineering and Technology (ABET) demands them [1]. In a recent article in *IEEE-USA Today's Engineer Online*, Ben Amaba, a worldwide executive for IBM Complex Systems, was asked what employers are looking for in today's software engineers [2]. He responded bysaying "Software engineers need good communication skills,both spoken and written. They need an analytical capability,and they need to be able to manage a project from end to end while working well with their colleagues." Communication and teamwork skills are increasingly being sought when hiring engineering and computer science graduates.

Unfortunately most programs do little to teach theseskills. Typically, they give students many opportunities to participate in team projects, but they do little to help students develop or improve specific teamwork skills. The assumption is that experience is the best teacher, that students when given sufficient opportunity to participate in team activities will learn how to be effective team members on their own. This is not the case. In fact, studies have shown that being members of ineffective teams actually negatively affects student's attitudes about the benefits of teamwork [3]. There is a need to be more proactive in the teaching of teamwork skills.

Through assessments conducted to measure the extentto which our students are exhibiting effective teamwork skills, we have discovered specific areas where improvementis needed. This paper explains the assessment results and describes a promising approach we have taken to improve student learning with respect to teamwork skills. In

addition, we discuss an ongoing effort in the college to allow faculty members to share successes and challenges with respect to the teaching of teamwork.

TEAMWORK ASSESSMENT RESULTS

In an effort to better understand what teamwork skills our students seemed to be learning and which ones they were not mastering, we conducted peer reviews among the students participating in team projects. Students were asked to rate their fellow team members with respect to the following list of team skills. The survey was done anonymously and all team members were asked to rate each member of theirteam, including themselves, as to whether that member:

- Attended meetings and arrived promptly Completed individual assignments on time
- Performed research and gathered information whennecessary
- Completed tasks with high quality Accomplished a fair share of the work Communicated clearly with other team
- membersIntroduced new ideas
- Openly expressed opinions Shared opinions and knowledge
- Listened to views and opinions of othersConsidered the suggestions of others
- Adopted suggestions of others when appropriateProvided help to others on the team
- Asked for help from others on the teamWas committed to team goals
- Showed respect for other team members Distinguished between the important and the trivial
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(The details of the creation of this assessment instrument andan analysis of the assessment results are documented in an earlier paper [4].)

The table below shows the three items that scored the highest and the three that scored the lowest at the time this peer assessment was done. The score indicates thepercentage of all ratings of all students who achieved that outcome. While the items at the top of the list suggest that students complete their individual tasks well, those at the bottom suggest that students are challenged when it comes tocollaboration skills. They tend not to help one another or to ask for help when they needed it, and they often fail to communicate with each other when required. The academic environment that has long encouraged students to work independently, and not to "cheat" by asking for help or sharing answers with another student, might be partially responsible for this tendency. Whatever the reason, students need to develop these collaboration skills in order to becomeeffective team members

The following sections describe an approach we developed using Yahoo/Google groups and other freely available tools to encourage or, more precisely, demand,greater student collaboration. This approach has proven to have promise in improving students' abilities with respect to collaboration. Additionally, it facilitates the assessment of these skills.

REGULAR CLASSES

We maintain that teamwork should be used not just in capstone classes, but in any class involving analysis, design, implementation, and testing. In industry, teamwork is the norm; most engineers must adapt to working as members of a team. In contrast, college students often prefer working alone rather than in a team. Students view team projects as risky assignments, where the individual has little control over the final outcome, leading to potentially lower grades. Our observation is that there are good reasons for this concern. We have observed team projects degrade to anarchy, devoid of plans and schedules. In some teams, a small subgroup emerges that does most of the work. Disorganized, non-functioning teams have a tendency to fail simply by floating, producing no work products. When the due date looms, faltering projects exhibit a tendency to form tiger teams that work long hours over days and weekends in an attempt to produce some marginally acceptable work products to salvage the project. Students do not learn team collaboration skills in any of the cases described above.

From the faculty perspective, introducing team projects in a lecture-discussion class can appear to be a daunting prospect. Teaching principles of teamwork in a class discussion is easy. On the other hand, managing multiple teams of students actually engaged in different projects could be overwhelming. Giving quizzes or assigning term papers seem far more attractive than managing teamwork assignments.

SUCCESS FACTORS FOR SUCCESSFUL TEAMWORK

Over the years we have found that there are certain key factors that are important for achieving student success in team projects. These are:

1. Agile, self-organizing teams.
2. Well defined project objectives.
3. Cohesive teams.
4. Project asset library.
5. Team communication.
6. Project planning, execution, and tracking.
7. Engaging all members of the team.
8. Avoiding ceremony.

AGILE, SELF-ORGANIZING TEAMS

Our experience is that a process framework based on the agile development practices works best in the classroomenvironment [5]. It is very difficult for a single faculty member to manage five or six teams. Therefore, it is essential to encourage teams to follow the agile principles and be self organizing, self managing and self motivated for success.

In keeping with the Agile philosophy each team takes total responsibility for both developing the project work products and for managing the development process.

We deviate somewhat from the rigid Agile Manifesto [6] in two important ways. First, we do not overemphasize the role of working code. We consider the various analysis, design and test work products as legitimate deliverables. Examples of such work products are: use-case models, static models (class/object diagrams), dynamic models (sequence diagrams), and test descriptions. Second, we require the teams to use a modern CASE tool to capture all work products, rather than using a collection of ad-hoc tools or producing hand drawn artifacts.

WELL DEFINED PROJECT OBJECTIVES

We have found that a set of well defined project objectives is essential for keeping student projects focused and capturing student interest. However, rather than presenting the students with a concrete set of project objectives, we like the idea of letting the students develop the project objectives for themselves. Our practice is to start by giving the students a *straw man* version of a challenging problem. We set homework assignments involving analysis of the problem. Students are encouraged to study the problem; create scenarios and use cases, and conduct trade studies. These initial assignments are done individually because we like each student to comprehend the core problem to be solved. We ask the students to find issues such as essential features that are missing from the straw man version and also identify features that may be too difficult to implement. Additionally, we ask the students to offer suggestions forincorporating features that are commonly available in similar products which they discover through conducting trade studies. All solutions and ideas are posted online for all students to read and discuss with each other. We then hold an informal requirements conference involving all students, where various ideas are discussed, and good ideas are harvested. At this point students jointly create a *tin man* version of the project objectives which is released for general discussion and review. This lasts for a week. At this point another requirements conference is held in which the final project objectives are established and placed under change control. The document describing the revised objectives is called the *iron man* specification.

At this point the class is divided into a number of small project teams, with team sizes varying from 4 to 8 students, the ideal size being 6 students. Each team is assigned to solve the same problem. This arrangement gives rise to a degree of competitiveness within the teams and brings some real-world flavor to the classroom projects. Each team startsby developing a set of testable requirements, traceable to the project objectives. These requirements are peer reviewed, approved by the team as a whole, and placed under change control. As the development progresses, both the project objectives and the requirements are allowed to evolve under change control, however all major changes require agreement of the faculty and other teams. Whenever any such significant change is approved by all stakeholders, all participating teams are required to adopt it in their ownwork; this keeps the teams synchronized.

COHESIVE TEAMS

Completing a challenging teamwork project in a competitive environment and with strict deadlines is not a simple task.

Therefore, it is beneficial to have cohesive teams that can work together under pressure. Unfortunately, there is little opportunity for building team spirit when students meet only one day a week. To overcome this problem we have set up a web based facility that allows students to form cohesive project teams by recruiting team members from within their existing friend circles. We limit the size of each team. Other than that, students have the opportunity to audition various teams and join a team of their choosing. Leveraging team formation on existing friendship pathways facilitates better team communication and also gets the teams up and running quicker.

PROJECT ASSET LIBRARY (PAL)

We set up a Yahoo or Google group for each team and invite members to join the group. Each team creates a PAL for storing the team work products and designates a librarian who administers the PAL. All members have visibility to the PAL, however, only the complete and team-approved work products can be placed in the PAL. Therefore, only the PAL librarian is allowed to write data to the PAL. Although the faculty retains ownership of each Yahoo/Google group, moderator authority is delegated to

two student members within each team, thereby relieving the faculty from ordinary group management chores.

Each team member also has a Personal Product Library (PPL). All products created by an individual team member are placed in his/her PPL. This is the case even when the member might be producing a final deliverable product that is destined to be placed in the PAL. This rule is important because each team member's contribution is evaluated by an examination of the products found in his/her PPL; whereas the overall team performance is evaluated by an examination of the products in the PAL. For conducting peer reviews and for promoting team collaboration, each member within a team has full visibility to PPLs belonging to other members within his/her team.

Both the PPLs and the PAL are created following a well defined folder structure and a strict naming convention. This rule makes it easy for anyone to search and locate specific products within the PAL and the PPLs.

TEAM COMMUNICATION

Almost all agile processes, including SCRUM and XP, call for holding face to face meetings of developers to plan work, discuss issues and find solutions. The popular SCRUM agile process mandates daily short meetings (scrums). We found this particular agile practice difficult to follow, because most of our lecture-discussion classes meet only once or twice a week, making it impractical to hold frequent face-to-face meetings. Therefore, out of necessity, we rely on web-based communications rather than face-to-face meetings. Web-based communications provide several advantages that face-to-face meetings do not provide.

The Yahoo/Google group also serves as the common communication platform. All team members communicate exclusively through messages posted in the group site. External communications via emails and phone calls are possible, however all such conversations are required to be summarized and documented as group messages. This rule allows all team members to view and participate in the discussions.

The trail of the posted messages provides a "permanent" record of all team communications which comes in handy in a variety of situations. Additionally, a quick review of the message logs and PPLs allows faculty to determine if proper team collaboration is occurring and also to provide timely intervention for students who are performing below par.

PROJECT PLANNING, EXECUTION, AND TRACKING

In keeping with the agile principles each team creates a loosely defined high-level work breakdown structure and an associated long term schedule. These artifacts are expected to evolve as new requirements and constraints are discovered.

The project work progresses in two weekly sprint cycles as defined in the SCRUM agile process [5]. At the completion of each sprint cycle the team is expected to deliver a set of specified products. To achieve this each team creates detailed plans and schedules for the activities to

be performed and products to be produced within each sprint cycle. Specific responsibilities for the various tasks to be performed and products produced are assigned to each team member.

The team takes full responsibility for planning, executing, and tracking activities within the sprint cycles. Students review progress against the sprint plan and take remedial actions as appropriate. In accordance with the principles of SCRUM, the sprint cycles are time boxed, i.e., the two weekly sprint cycles are never extended. Tasks that remain incomplete in a given sprint cycle have to be completed in a future one. When problems like this develop, all related communications are automatically logged in Yahoo/Google group message trails; faculty can review these messages to get early warning of potential problems.

The long term schedule and the project objectives are reviewed at the end of each sprint cycle. Any significant deviation from the approved project objectives requires faculty approval, and agreement of all teams. Given that all teams are expected to complete the iron man project objectives, our experience is that teams rarely agree to make any major changes that introduce schedule risks.

ENGAGING ALL MEMBERS OF THE TEAM

Emergence of *Team Heroes* is a phenomenon that often develops in uncontrolled and unsupervised teams. Team heroes consist of a small number of capable alpha *students* who take over the project, make all the technical and management decisions, and perform all the tasks. Other team members find it a daunting task to question the decisions made by the apparent super heroes and go along for a free ride. To the non-participating student this arrangement looks like a win-win arrangement because from the outside, s/he appears to be a member of a team that completes the project and gets good grades. To avoid this problem we require that each team member assume responsibility for a significant task in each sprint cycle. At the start of a sprint cycle each member is assigned a task that involves some amount of development activity such as analysis, design, implementation, or testing. Each member is also assigned responsibilities for peer reviewing work produced by other team members. All products, including peer review comments are preserved in folders that all members can see. We actively discourage team members from doing the same type of work in each sprint cycle. The very nature of this process ensures that all team members are engaged in the project tasks and also mitigates the risk of the *Team Hero* syndrome taking hold.

AVOIDING CEREMONY

Most classroom team projects have to be completed within a strict deadline that leaves little time for making formal presentations or writing long documents. Our observation is that when such tasks are assigned, students spend entirely too much time in preparing fancy presentations or writing detailed documents. While both written and oral communication are extremely important, these activities can

detract from doing team-based technical work which is the primary objective of team projects. Given that the team members get a good exposure to the work products through peer reviews and discussions, we avoid formal presentations. All technical work products are captured in a CASE tool that can generate some types of reports automatically. Therefore, we do not ask for long technical reports as part of the project deliverables. Many other opportunities are provided within the program for students to develop their formal communication skills. In particular, when the department or the college wants to showcase student achievements, we help students produce presentations and demonstrations. However, these activities are not considered part of the team project tasks.

ASSESSMENT OF STUDENT COLLABORATION SKILLS

One of the advantages in using Yahoo/Google groups as a teaching tool for student collaboration is that it results in well-documented evidence of the extent of communication among team members. The faculty can easily monitor the degree and quality of student collaboration during a team project, and after the project is completed, the documented record of team activities can be analyzed to assess the achievement of student learning outcomes with respect to teamwork. Assessing teamwork skills has usually depended primarily on the subjective opinions of the faculty, often based on the assumption that the production of a successful product meant that all team members exhibited good teamwork skills. The approach we have outlined produces a recorded account of the collaboration among team members from which a more accurate assessment of each team member's collaboration skills can be determined. Furthermore, this assessment can be done by faculty or others not directly associated with the class in which the team projects were assigned. This adds a much more object flavor to assessment process.

This paper has presented one idea for improving the learning of teamwork skills. As we have discovered, many faculty members in the college have developed approaches for addressing various aspects of the problems associated with teaching teamwork. In an effort to share successes and challenges within the college, we have organized informal, but regularly scheduled meetings, where faculty can discuss ways to improve student learning with respect to teamwork. To further broaden the discussion, members of our Industrial Advisory Board are periodically invited to our meetings in order to provide industry perspectives on teamwork.

Individual faculty members have developed many tools and techniques for teaching teamwork, but like our students, we tend not to share our ideas with one another or to ask others for help. These sessions have provided a way to improve collaboration among faculty. We are improving

teamwork among faculty in an effort to improve team collaboration among our students. These meetings have been going on for only about a year but have already produced results in terms of raising the faculty consciousness regarding the importance of developing teamwork skills among our students and in transferring useful tools and techniques among the faculty. In particular, the specific approach outlined in this paper of using web-based tools to aid in teaching student collaboration has recently been adopted by other faculty in the college, and we will soon be able to evaluate their experiences.

CONCLUSIONS

We have utilized the process and techniques described here in conducting student team projects in both undergraduate and graduate classes. These techniques are particularly useful in running team projects in regular lecture discussion classes that attempt to reinforce the course material with teamwork based experiential learning. Our experience is that the process and methods described here result in greater levels of student participation in teamwork projects while providing faculty with an insight into the team progress, and the degree collaboration among the team members. Using agile methods and encouraging self-organizing teams permit faculty to assign fairly complex project tasks without getting overwhelmed by tasks associated with managing the teams.

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