Learning to Collaboratively Design Software Systems

Debbie Richards[1], Andreas U Kuswara[2]
[1] *Computing Department, Macquarie University, Sydney, Australia*
richards@ics.mq.edu.au
[2] *Department of Education, Macquarie University, Sydney, Australia*
andreas-utomo.kuswara@students.mq.edu.au

Abstract

In a study conducted in 2004 we found that our students recognized the need to collaborate but that, due to inadequate communication skills, limited time and lack of experience and training in group work, the extent to which they collaborated was far less than they believed to be ideal. Since the advent of Web 2.0 we were interested to see if these increasingly tech-savvy digital natives were choosing to both collaborate more and to use technology to do so. In particular, we consider how 29 groups in a second year software analysis and design unit utilized a collaboration and project management tool known as TRAC. We suggest that different patterns of usage were observed due to different perceived affordances of the technology driven by students' interests and needs. We characterize the affordances and conclude that while we are seeing an increase in collaboration mediated by technology, more intended intervention is needed to assist students to discover a wider range of affordances.

Keywords: Collaborative Learning, System Design, Web 2.0, Affordances.

1. Introduction

Competence in designing software systems is not achieved by hearing but by doing. Furthermore, in today's complex and highly integrated software systems, design cannot be achieved by an individual and thus "doing" design involves collaboration. From a learning perspective, collaboration involves working with peers and teachers.

In the following sections we firstly review the results of a survey conducted in 2004 with our second and third year computing students [4], which considered the role of collaboration in their learning experiences. Not surprisingly, students concluded that group work was the key way in which collaborative learning should be achieved. Taking this a step further in Section 3, using an evidence-based approach, we look at the patterns of collaboration by groups of second year students in 2008 involved in their first group-based activity. Conclusions are given in Section 4.

978-1-4244-3535-7/09/$25.00 ©2009 IEEE

2. Collaboration in 2004

In 2004 we conducted a 30 item online survey with our second and third year undergraduates to better understand their learning experiences and needs. From the 103 responses received, we found that students had various perceptions of the role of collaborative learning. While group work did not feature as a typical response to how lectures, tutorials or practicals (laboratory sessions) could be improved, it was included within the 74 responses to the open-ended question "describe the ideal way for you to learn computing" (Table 1).

Table 1: Describe the ideal way for you to learn computing

Practical application/frequent problem solving practice	20
Group work/working with friends	10
Online lectures	6
Standard tutorials and practicals	6
Learn concepts individually then practice in groups	5
Supportive and quick responding academic staff	4
Online collaboration	4

Using a seven-point likert scale with answer options ranging from very poor (1) – poor – moderately poor – neutral – moderately good – good – very good (7), responses to a question concerning the importance of being able to work in a group for programming related roles achieved the highest rating (average 5.22) of all questions in the survey. Students also strongly believed (average 5.10) that they needed to be taught to work effectively with others. Further, when asked how they rated their own ability to work with other people the average response was 4.31. Conversely, when asked to rate other's ability to work with them the average was only 3.79. The difference in scores between their perceptions of their own ability compared to the ability of others is highly significant (paired t-test, $t = 4.83$, $df = 102$, $p<0.001$). This difference occurs because people tend to believe that they are working harder/better than the others. It is important that students learn to appreciate different ways of working and also to appreciate that just because they cannot see work being done, it does not mean that it isn't. When asked to rate their confidence in working with others the average response was 4.08. An almost identical response of 4.09 was given to the question "How would you rate your enjoyment of working with others?" When asked to rate their general communication skills the average response was 4.41. From correlation analysis it was found that

there was a positive linear correlation between the student's confidence in their ability to work in a group and their communication abilities, confirming the perceived importance of good communication skills for working successfully in a team. Further there was a positive linear correlation between communication abilities and enjoyment of group work. Given that so many of our students do not have English as a first language (English was the first language for 48/103 of the participants with 42 students having lived eight or less years in an English speaking country and 35 had lived five or less years in an English speaking country), and thus probably have poor communication skills, we must seek to both improve these skills, perhaps as part of a generic skills program, and also make all team members aware that the person still must be accepted, assisted and allowed to contribute. In addition to language barriers, we found lack of time to be a major inhibitor of increased group work, as our students were already feeling overloaded.

To determine how much collaborative learning is currently going on we asked what percentage of time was spent learning computing by themselves. The response was an average 72.3 % of their time. This means that 28% is spent working with others. However a subsequent question which asked how much time they would like to spend working with others, the response was an average of 44%, with the mode response of 50%. This was a highly significant difference between the observed and desired amount of time spent working with others (paired t-test, $t = 7.78$, $df = 99$, $p < 0.001$). The 16% absolute difference becomes a more substantial figure when it is considered as a proportion; on average students wish to spend an extra 60% more time working with others.

Table 2: What things do you like about learning computing in isolation? What are the disadvantages of working with others? (comment/frequency)

Less distractions	28
Can focus on concept formation/difficult problems	14
Can choose own pace	13
More time efficient	12
Can choose own area to focus upon	9
Not held up by less motivated/lower ability peers	9
Flexibility of time chosen to work	7
Satisfaction of personal achievement	7
Fairer (since credited for work performed)	5
Less conflict	5

Interestingly 37 respondents thought working alone was more effective for them to learn computing. 64 did not agree that working alone was better for learning computing. Substantial responses were provided by 82 out of the 103 students to why working alone was better (Table 2). So while students indicated they were keen to do more group work than they currently did, they did not see that group work was the only or most appropriate means for learning computing. Many of the categories come under the theme of self management and satisfaction. The views expressed are encouraging as employers do not just want team players they also want independent and self motivated workers that can be relied on to do their own part. This must be borne in mind in redevelopment of learning activities to ensure that students are also encouraged to manage both themselves and others. Table 3 summarises the perceived benefits of working together.

Table 3: What things don't you like about learning computing in isolation? What are the advantages of working with others? (comment/frequency)

Can get help/alleviate frustration of being stuck	27
Can improve techniques/understanding	16
Saves time	13
Seeing things from multiple perspectives	12
Finding solutions/errors that couldn't have otherwise	12
More fun/less boring	7

Table 4: What are the secrets to working effectively with others? (comment/frequency)

Communication	36
Listening	10
Contributing	10
Respect/Patience/Consideration	9
Understanding others/empathy	7
Strong work ethic amongst team members	6
Forming friendships	4

Table 4 reveals the secrets to working effectively with others?" While the key idea offered involved good communication, an even better source of "secrets" would be to ask those that have worked in groups (which was not a data item we collected). The purpose of getting the answers to such a question is then to design activities that allow the students to discover those secrets for themselves in perhaps less time and in less risky situations such as the workplace.

Seventy-two respondents believed that lecturers should provide more formal opportunities for working with others in the activities they set. 28 respondents disagreed. By far the most popular response to what sorts of tasks should be provided by the lecturer was "group assignments/projects" (38). It is important to note that several students who suggested this as a task also made mention of the caveat that the work in group assignments needs to be fairly delegated and marked. The next most frequent response types to this question were "tutorial group work" (7), "short team problem-solving tasks" (4), "group industry style projects" (3) and "group work in practical" (2). Other suggestions were "group work in workshops", "group class presentations" and "group work for creative tasks".

For tasks that specifically involved collaboration, 39 preferred to meet with their group online from anywhere and 63 preferred to meet with their group in person on campus. For tasks that specifically involved collaboration: 41 preferred for the unit convener to nominate specific times and places for groups to meet on-campus and 60 preferred to allow groups to schedule their meetings themselves.

It is interesting that more students indicated that they preferred to meet face-to-face on campus rather than

online. This is confirmed in the virtual laboratory study [4] where only 25% of the online groups chose to participate from home. Further, this finding is consistent with the findings of several studies conducted at Carnegie Mellon University [1, 9] using computer supported collaborative learning (CSCL). These studies involved a range of engineering design projects over a period of at least five years and the use of various hardware and groupware tools to assist collaboration. While the tools were used for archiving and monitoring of progress by the lecturer, most if not all of the work and thinking was done offline and groups still chose to meet face to face. Perhaps distributed technology has not delivered as promised due to the nature of tacit knowledge transfer which has been found to require face to face contact. Various studies (Lee 1994 in [12]) have shown that technology such as email and fax only transfer data, information or occasionally explicit knowledge.

3. Four Years On – Web 2.0

Since the advent of Web 2.0 in 2005, characterised by the increasing pervasiveness of social software (e.g blogs, wikis, chat rooms, communities of practice, etc) and other technologies (e.g. MSN, text messaging, etc), we were interested to see if students were still reluctant to collaborate in general. Specifically we wanted to see if they were ready to embrace the use of technology to collaboratively learn and collaborative design. This time rather than use a survey instrument as in 2004 which clearly revealed a mismatch between reported desire and action when it came to collaboration, we used a more evidence-based methodology involving analysis of the ways in which a second year group of undergraduates enrolled in "Requirements, Analysis and Systems Design" (RASD) collaborated for a group-based assignment involving the review and revision of a requirements document, creation of the analysis models and design models including the system architecture, design of screens, report and complex algorithms.

Students were given 8 weeks (including the mid-semester break) to produce the specified designs. Groups of 5 were formed in week 4. This was the first unit these students had experienced involving working with more than one other student on an assessment task. Just over half of the teams chose to self-form (groups 1-18). The lecturer formed the remaining 11 groups.

To ensure all students met the learning goals, students were required to participate in all types of tasks. For example, rather than one individual do all the UML sequence diagrams, each student needed to contribute at least one of the sequence diagrams to the final solution. Class and Use Case diagrams were to be result of collaborative discussion. The first task (out of 16) in the assignment required a half-page team statement which outlined team members and their roles, planned methods of communication, conflict and change management strategies. The second task required students to use subversion for version and change control and also to use a tool known as TRAC, which is an enhanced wiki and issue tracking system for software development projects (http://trac.edgewall.org/). Failure to use subversion resulted in the loss of marks. Use of TRAC attracted bonus marks. The next subsection considers the patterns of usage of TRAC by the 29 Groups. The following subsection considers briefly other collaboration technologies used.

3.1. Using TRAC

There are a few common usage patterns observable for TRAC by the RASD cohort. As shown in figure 1, 28 of the 29 groups chose to use TRAC, 20 used versioning and 26 used ticketing. In contrast, in 2007 only around half of the groups decided to use TRAC and get bonus marks. We also note that in 2007 very little use was made of the features of TRAC beyond uploading files. In 2008, 20 groups out of the 28 (71%) utilized TRAC for more than document versioning (which was mandatory in the assignment specification). These groups utilized the wiki components as well as the ticketing system as communication tools. However, most of the usage was one-way communication (involving posting announcements, minutes of meetings, news and other resources) that most commonly was done by one and the same group member (90%). Only two groups out of 20 used the system as a multi-way communication tool by giving comments to other posts and using the wiki as a discussion board (e.g. Figure 2).

Despite being given the same instruction and opportunity, it appears that each team perceived the TRAC system to have different affordances and utilized those affordances according to their needs. Affordances is the term that Gibson [8] used to describe the possibilities of action between a person and an aspect of the environment, and it can be used to describe features of software which may support learning [3]. It is then the characteristic of affordances to be subjective. Different interest or needs would drive the discovery of different affordances. The evaluation of affordance in this study is guided by Activity Theory [6, 7]. We have characterized a number of specific affordances under three main types: Subject-Rules-Community (Exchange); Subject-Tools-Community (Production-Consumption); Subject-Division of Labor-Community (Consumption-Distribution). Note that a group may exhibit behavior, which indicates more than one affordance for TRAC.

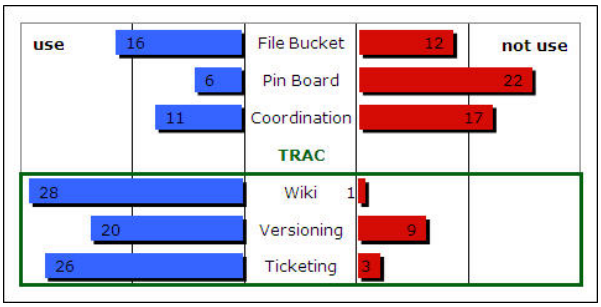

Figure 1: TRAC wiki utilization

Subject-Rules-Community (Exchange) affordances:

Communication affordance enables the members of a group to exchange comments that do not necessarily contribute directly to the production of a shared object (i.e. the design documents), but more to support the community itself. For example, comments may be added which inform other members what they are doing socially to indicate their (un)availability or even just to share some of their lives with the others beyond contact needed to achieve the project tasks.

Subject-Tools-Community (Production-Consumption) affordances:

The combined production-consumption affordances enables each individual to produce a publishable work online and share it with other members of the community (e.g. through online publication or attachment of files), which in turn would then individually consume that object and produce another (e.g. their own part of the work). There are basically two types of such affordances, which we call File Bucket and Pin board.

File bucket. As shown in Figure 1, the file bucket use was the most commonly used (16/28 - 57%) of the production-consumption affordances, where the community utilized the tools as a place to upload and store files then share them amongst the members of the community. Some groups structured and customized the wiki pages in the system to allow the files and resources to be categorized and structured; while others placed all files on a single page containing a list of the shared resources whiteboard.

The Pin board. There was a 21% adoption of the pin board affordance, which was mainly used to publish drafts or previews of the assessment deliverables and share those publications with other members of the group, such as shown in Figure 2. Each group then built their own discussions or other form of information exchange around this published document. It is observed that, groups who adopted this affordance became more active in the adoption of the exchange affordances.

Subject-Division of Labor-Community (Consumption-Distribution) affordances:

The combined consumption-distribution affordance enables the group to break down the workload into smaller (i.e. individualized) and more manageable workload chunks for which each group member would then be responsible. The process of breaking down the workload was tied closely to the way each part of the work is consumed within the group. Surprisingly only 39% of the groups utilized this affordance, ranging from a simple list of tasks that were managed manually, to adoption of the built-in task ticketing system to dispatch and track work assignments. Although many tickets may have been raised, it appears that students still heavily relied on other collaboration strategies (e.g. face to face and email) to perform coordination functions.

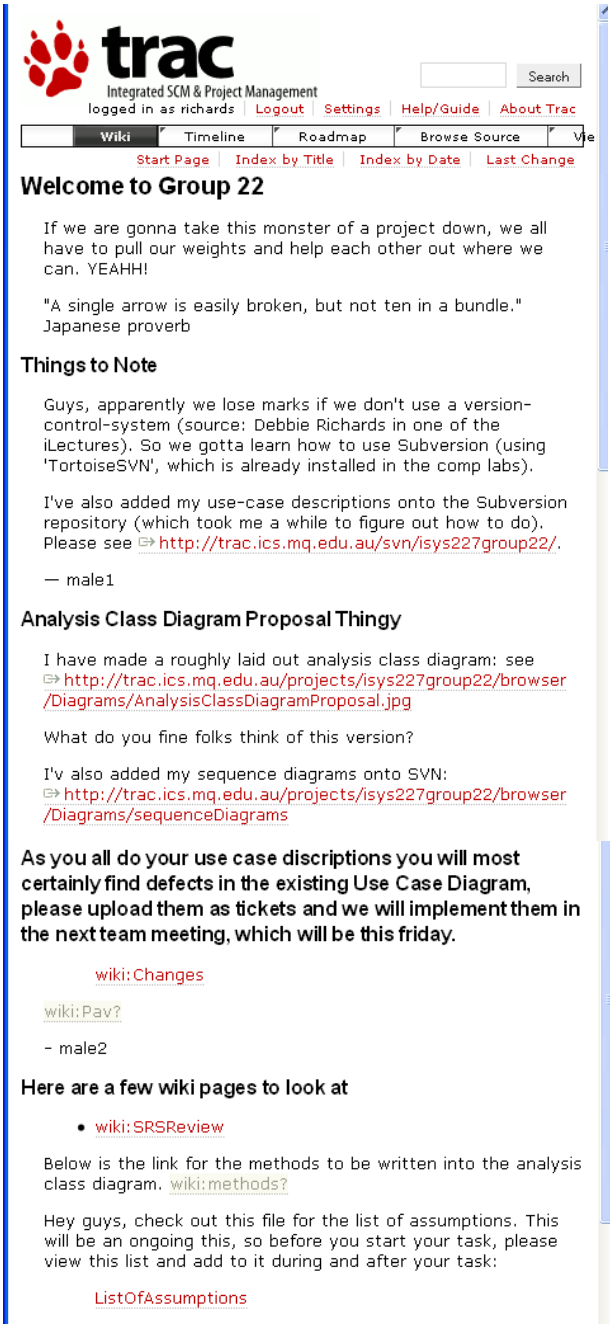

Figure 2: Sample Wiki from Group 22

3.2. Other Systems

The study also revealed that students tended to use a set of tools rather than just one tool to support their collaboration. There is a particular affordance that students look for in each tool and they seem to prefer using a mix of tools rather than just one.

Figure 3 shows that while the traditional email system still prevails as the preferred primary collaboration tool (82%), other systems such as mobile (cell) phones, web based wiki and online chats have become more widely used with 58%, 53% and 41% usage, respectively. Only a few numbers of groups (12%) that utilized other discussion forum.

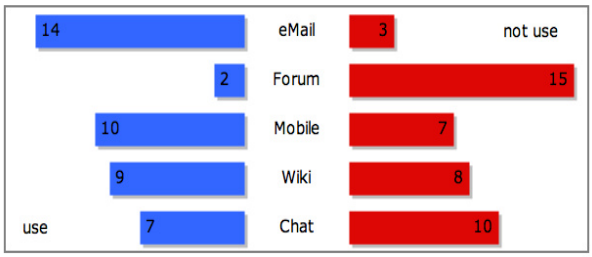

Figure 3: Preference of use

4. Discussion and Conclusions

Getting students to interact and collaborate is an important skill that they will need as future team members in their ICT careers. It appears, however, that students are reluctant to collaborate in the typical defensive climate that exists in the computer science classroom [2]. The use of technology to assist collaboration has been employed by many others. For example, the internet has been used to encourage peer learning (e.g. [5], [10]), multimedia to convey specific computing ideas such as algorithm design and efficiency [11] and the use of Macromedia products to provide a virtual classroom (e.g [14]) with the goal of increasing participation and improving understanding.

In 2004 the most frequent response by a factor of at least 2 to the question regarding why working in isolation is better was due to the increased distraction. Wikipedia defines distraction as "diversion of attention of an individual or group from the chosen object of attention onto the source of distraction". We interpret distraction in the context of group work to encompass increased interruptions, communication overheads involving more travel time, more time-constrained and effort-intensive decision making due to conflict resolution, increased number of unproductive activities not directly related to the task.

We were interested to see if our Web 2.0 enabled students (who are increasingly choosing to distract themselves by being constantly connected socially via technologies such as text messaging and who are spending many hours online) still consider group work to be too distracting. Observing usage patterns in TRAC and their approach to handling group communication (described in their team statements) sought to determine if they were more inclined and enabled to collaborate than in the past. To determine whether the high level of collaboration we observed this semester was influenced by their attitude to group work as a distraction we conducted a lightweight email-based and optional survey asking the three questions shown in Figure 4. Nineteen responses were received and recorded after each option in Figure 4. Selected comments to each question are shown in Figure 5.

```
Pick the option that matches your view:
1. "Working in groups is a distraction
from getting the work done."
    Strongly agree (4)
    Agree (1)
    neither agree nor disagree (3)
    disagree (7)
    strongly disagree (4)
2. "Using technology like MSN, TRAC,
email, etc, helps to minimise the
distractions involved in group work"
    Strongly agree (8)
    Agree (8)
    neither agree nor disagree (2)
    disagree (1)
    strongly disagree (0)
3. What technology did you use that
assisted you to learn collaboratively?
```

Figure 4: Lightweight survey with RASD students

In answer to question 3, email was the most common and most used form of communication, then TRAC, then SMS, then phone, then MSN. The learning management system discussion board was also mentioned by one student. The one person (male) who responded differently to the others had these comments:

Q1 - Strongly agree - Motivating other group members should not be another students concern or responsibility.

Q2 - Strongly disagree - If the whole group utilised the tool it would have been invaluable but in my experience (assignment 2), it was ignored by most group members.

Q3 - E-mail was the most useful tool, my group responded to e-mail (most of the time) but never responded to or acknowledged information placed on TRAC. (male)

While the number of responses is small, the message is clear. Groupwork was not found to be distracting and technology could minimize distraction. The 2008 students are demonstrating that the use of technology has afforded them to be more collaborative than their predecessors with less social overhead than would usually be associated with physical groupwork. However, at the same time the introduction of a tool that is not immediately recognized or familiar to them added an extra learning curve. Educators need to take this into consideration by providing the opportunity to become familiar with the tool or try to adopt the same tools that students have used socially.

Q1 Maybe for a 100 level subject, but as far as with the 200 level group work, i think everybody that is still enrolled in the course is there to do well or at least pass, so group work is not a 'social' occasion as it once was. (male)

I don't think it has very much impact because groups can work just as efficiently with it, if not sometimes better? In cases where they live far apart and travelling is an issue. (male)

Q2 The use of TRAC and email did in fact keep me from being lazy and leaving my work till the last minute.. i can put that down to the use of a bonus mark for the use of TRAC. (male)

Q3 TRAC was helpful in keeping TRAC of everything :) and email was a big help. MSN would have been good if the other members were actually on when needed to be. (female)

The technology of TRAC which enabled us to work in more professional manner. We divided our task and updated it on Track which helped us to finish the work on time and also the work could also be timed. (male)

Text messages helped with organisation, TRAC helped us complete the actual project (male)

TRAC and the svn repository, but none of them work out without organisation/planning (female)

Not really MSN between all member, too hard to organise, but for like 2-4 teammates, it's good. (male)

Other unsolicited comments received include:

Its good having group projects, it is harder to organise but it promotes communication (male)

All in all, a pretty rewarding assignment, i think the group work was needed, not so much as to cover the content, but to allow an insight into what it would be like actually designing or collaborating ideas for a real life system. that is dealing with other ideas and working as a team and learning to be very diplomatic very quickly...(male)

Figure 5: Comments from RASD students

TRAC is a collaboration tool to assist in the design and development of software. Kay et al. [13] has developed a plugin which allowed the extent and type of collaboration to be visualized in spider diagrams and concluded that the TRAC system supported more than basic project management processes, and also sustained the big five elements of teamwork [15]: team leadership; mutual performance monitoring; backup behaviour; adaptability; and team orientation. Our observations and analyses of the usage of TRAC further confirm this conclusion. By characterizing the patterns of usage according to a number of perceived affordances, we hope to understand better why TRAC was utilized in different and limited ways.

In 2009 using a third year team-based project unit which runs over the whole year, we intend in the first semester to again monitor the types of usage of TRAC. In the second semester we will begin with an intervention, which seeks to train students to be aware of a greater range of potential affordances and to reevaluate patterns of usage to see if training can increase the level and type of collaboration via Web 2.0 technologies such as TRAC.

Acknowledgement

Thanks to Matt Bower who set up the 2004 survey and performed the data analysis and reporting.

References

[1] Amon, C.A., Finger, S., Siewiorek, D. And Smailagic, A. (1996) Integration of Design Education, Research and Practice at Carnegie Mellon University: A Multi-disciplinary Course in Wearable Computer Design, *Journal of Engineering Education*, 1996, 279 - 285.

[2] Barker, L. J., Garvin-Doxas, K., & Jackson, M. J. (2002). Defensive climate in the computer science classroom. *SIGCSE Technical Bulletin*, 34(1), 94-99.

[3] Bower, M. (2008). Affordance analysis - matching learning tasks with learning technologies. *Educational Media International*, 45(1), 3 - 15.

[4] Bower, M. and Richards, D. (2005) A Comparison of Online Media in Computer Science Education Proc. SIGCSE 2005 Tech. Symp. on Comp. Sci. Education, St. Louis, Missouri USA February 23-27, 2005.

[5] Chiang, A, Fung, I. And Kemp, R. (2004) Developing an intelligent learning tool for knowledge acquisition and problem-based discussion, *Proc. PKAW'04*, August 9-13, 2004, Auckland, New Zealand, 127-142.

[6] Engeström, Y. (1987). *Learning by expanding: An activity theoretical approach to developmental research*. Orienta-Konsultit Oy, Helsinki.

[7] Engeström, Y. (2000). Activity theory and the social construction of knowledge: A story of four umpires. *Organisation*, 7(2), 301-310.

[8] Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

[9] Finger, S. And Amon, C. (1997) Designing and Prototyping Interactive Fluid Dynamics Exhibits for the Carnegie Science Center: An Undergraduate Team Project Experience, *ASEE / IEEE Frontiers in Education Conference*, 1: pp. 366 - 370.

[10] Gehringer, E. F. (2001). Electronic Peer Review And Peer Grading In Computer-Science Courses. *ACM Sigcse 32nd Technical Symposium On Computer Science Education*, Charlotte, Nc, Acm Press.

[11] Hübscher-Younger, T. & Narayanan, N. H. (2003). Constructive and Collaborative Learning of Algorithms. *Computer Science Education*, ACM Press, pp. 6-10.

[12] Johannessen, J., Olaisen, J., Olsen, B., (2001) Mismanagement of tacit knowledge: The importance of tacit knowledge, the danger of information technology and what to do about it. International *Journal of Information Management* Vol 21 :3-20

[13] Kay, J. Maisonneuve, N., Yacef, K., Reimann, P. (2006). The Big Five and Visualisations of Team Work Activity. *Intelligent Tutoring Systems 2006*: 197-206.

[14] Kurtz, B., Parks, D., Nicholson, E. (2002) Effective Internet Education: A Progress Report, *SIGCSE Bulletin*, Vol. 33, No. 1, February 2002, pp. 312-316

[15] Salas, E., Sims, D.E., Burke, C.S. (2005). Is there a big five in teamwork? *Small Group Research*, 36(5):.555-99.