Collaborative Learning Skills in Multi-touch Tables for UML Software Design

Mohammed Basheri
Faculty of Computing and IT
King Abdulaziz University
Jeddah, Saudi Arabia

Malcolm Munro
School of Engineering and Computing Sciences
Durham University
Durham, United Kingdom

Liz Burd
School of Engineering and Computing Sciences
Durham University
Durham, United Kingdom

Nilufar Baghaei
Department of Computing
Unitec Institute of Technology
Auckland, New Zealand

***Abstract*— The use of Multi-touch interfaces for collaborative learning has received significant attention. Their ability to synchronously accommodate multiple users is an advantage in co-located collaborative design tasks. This paper explores the Multi-touch interface's potential in collaborative Unified Modeling Language diagramming by comparing it to a PC-based tool, looking at the Collaborative Learning Skills and amount of physical interactions in both conditions. The results show that even though participants talked more in the PC-based condition, the use of the Multi-touch table increased the amount of physical interactions, and encouraged the "Creative Conflict" skills amongst the team members.**

Keywords—Collaborative Design; Multi-touch Table; PC-based; Collaborative Learning Skills

I. Introduction

The use of Multi-touch interfaces for collaborative learning has received significant attention. They can accommodate more than one user at a time. This is particularly useful for learning through large, shared display systems like tabletops [2]. Another interesting aspect of the Multi-touch environment is that it provides new opportunities for interaction between humans and computers. This area has been investigated by researchers from different educational backgrounds who have found Multi-touch environments to be useful as interaction through touch is both intuitive and natural [3, 4].

Many studies have shown the benefits of using Multi-touch environments to enhance collaborative work. Using such systems encourages students to collaborate and create an environment wherein they can discuss their findings and integrate their ideas seamlessly with no technological hindrances. In addition, such systems can enhance students' interaction skills and promote teamwork. For instance, [5] built a system called Futura which is a game based learning system for learning about sustainable development. In this study, players use Multi-touch surfaces to build healthy environment by supporting population growth in an urban environment. Multi-touch surfaces have also been used for collaborative information gathering. A tool called WebSurface was used to facilitate users' browsing of the Web collaboratively in order to collect information from different websites. With the use of Multi-touch surfaces users were able to seek information, browse multiple pages simultaneously, and easily gather the information they found [6]. Multi-touch surfaces also have the potential to allow co-located collaboration activities, thus permitting small groups to work together collaboratively [7] and offering equal opportunities for such group work [8].

To the best of our knowledge, there has been little research to determine the potential of using Multi-touch tables to enhance co-located collaboration in software design using Unified Modeling Language (UML). Object-oriented analysis and design can be a very complex task, as it requires knowledge of requirements analysis, design and UML. The problem statement is often vague and incomplete and students need a lot of experience to be successful in analysis. UML is a complex modelling language and students have many problems to become skilled at it. Furthermore, UML modelling like other design tasks is not a well-defined process. There is no single best solution for a problem, and often there are several alternative solutions for the same requirements. The level of collaboration in Futura [5] and WebSurface [6] is limited and restricted to simple actions performed by users, such as putting words in the right context, arranging items over tables, and simple click and drag actions. However, UML design involves advanced design issues that raise new collaboration needs, such as linking nodes and annotation. In this paper the potential of using Multi-touch technology for software design using UML is explored by comparing it with PC-based collaborative software design and examining the collaboration learning skills and physical interactions in both conditions.

II. Related Work

A great deal of interesting work has recently been done on Multi-touch tables, much of it investigating the role of Multi-touch in enhancing collaborative activities. Morris et al. [9] investigated the success of using Multi-touch tabletops to improve cooperation during group functions and tasks. They reported that Multi-touch tabletops improved team member awareness considerably, indicating that Multi-touch tabletops improve information sharing between group members. Harris et al. [10] compared the differences between single and Multi-touch tabletops in group task performance and found that Multi-touch tabletops improved task performance, whereas single-touch tabletops did not. In another research study [11] the effectiveness of Multi-touch tabletops was examined, by comparing multi-mouse and Multi-touch tabletops. Multi-mice were seen to be utilized more than Multi-touch tabletops for the following reasons: (1) users were better able to interact with any part of the display using multi-mice than using Multi-touch; (2) users were more familiar with multi-mouse tabletops; (3) variability in the usage of Multi-touch tables. On the other hand it was noted that users of Multi-touch displayed fewer grammatical errors than those of multi-mouse. A study by [12] shows that Multi-touch tabletops increase the awareness and common ground of group members working collaboratively to achieve a specific outcome, as well as increasing the effectiveness of group tasks and obligations [13]. From the aforementioned research studies, it can be concluded that Multi-touch tabletops enhance group interaction and therefore enhance the realization of group goals.

Much research has been conducted with the aim of improving collaboration among users in software design using UML. This includes studies such as COLLECT-UML [14], CoLeMo [15], CAMEL [16], and AUTO-COLLEAGUE [17]. AUTO-COLLEAGUE does not support collaborative drawing for UML diagrams, as COLLECT-UML and CoLeMo do; it does, however, offer a chat system as its main collaboration tool. These systems are not designed to support a face-to-face collaboration style, but rather for distributed collaborative work. Very little research other than the Software Design Board [18], which is a shared whiteboard application, supports collaborative software design.

III. Comparative Study

Using Multi-touch table for collaborative UML diagramming has not been widely researched. To the best of our knowledge, there is no Multi-touch table based editor for UML diagramming available. We have developed a Multi-touch collaborative UML editor named "MT-CollabUML" [19] to encourage face-to-face collaborative software design. In order to keep a same variable in both Multi-touch table and PC-based conditions, MT-CollabUML tool was used in both settings.

IV. Participants

For the purposes of the research sixteen master program students who were studying "Software Engineering for the Internet" were selected. The participants were all familiar with collaboratively designing software using UML and had completed the course. The participants formed eight groups, each consisted of two people.

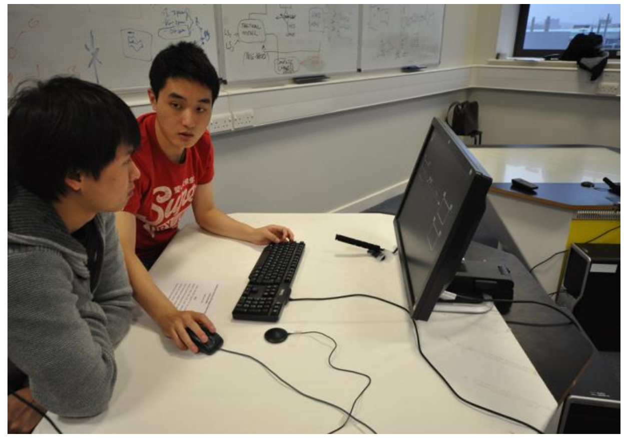

Fig.1. PC-based condition

V. Experiment Design

A within-subject experiment was conducted to compare how the participants used PC with how they used Multi-touch table in terms of collaborative design.

Similarities and differences were studied in terms of qualitative behavior in the eight groups of two students, who worked on creating UML-State diagrams. The goal was to identify differences in the level of collaborative design process across experimental conditions. To ensure the validity of our investigation, we decided to compare the use of MT-CollabUML tool in both PC-based and Multi-touch table conditions. In both conditions, we provided two similar design tasks with the same level of difficulty and complexity.

Two separate tasks were implemented, each of which involved the creation of UML-State diagrams through a process of planning, discussion, decision making, drawing and reflection. In order to ensure that the tasks were of the same complexity and required the same level of skills, the course tutor was consulted.

Counterbalanced measures design was conducted in this experiment to help keep the variability low. For every pair of groups, we gave one group a UML design task and asked them to complete it using the MT-CollabUML tool in PC-based "Fig.1" The other group was asked to complete the same task using the MT-CollabUML tool on Multi-touch table based "Fig. 2". Then the groups switched and were asked to complete the second task using PC and Multi-touch conditions.

Before the experiment began, all the students underwent basic training in the use of the MT-CollabUML tool in the Multi-touch table and PC-based. The experiment took place in Durham University's SynergyNet lab "Fig. 3", and a within-subject study design was used for both the PC-based and the Multi-touch surface. The groups were given as much time as they needed to complete the tasks. All collaborative UML diagramming activities were video recorded for analysis. For the Multi-touch and the PC-based conditions, two cameras were focused on the tables from two directions to ensure all group members captured. Qualitative analysis was followed to analyze the collaborative design process. Timeline (in minutes) for all design activities along with discussion timeline per subject was generated using Microsoft Visio. Design activities included adding or deleting node, adding or correcting text, linking or unlinking node and moving node.

Furthermore, the quantitative analysis was considered by calculating the physical interactions (design activities) per minute for each subject in Multi-touch and PC-based conditions following Harris el al. work [20].

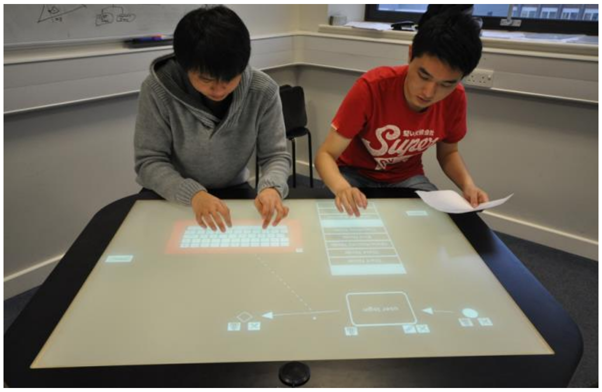

Fig.2. Multi-touch table condition

Fig.3. SynergyNet lab

Group member's learning experience and success are influenced by the quality of communication in team discussion [21]. Collaborative learning Skills includes Active Learning, Creative Conflict and Conversation [21, 22]. According to Soller [23] using Collaborative learning Skills promotes effective collaboration learning. Therefore, the verbal communication among each pair in both conditions were recorded and analyzed to find out if there were differences between conditions in term of type of verbal contribution. Baghaei [1] and Soller [23]'s verbal communication categories were used in this study. Communication Categories includes ten types; *"Request, Inform, Maintain, Acknowledge, Motivate, Argue, Introduce & Plan, Disagree, Task and Off-Task"*. TABLE I describes the communication categories used in the Multi-touch table and PC-based conditions.

VI. Study Findings & Discussion

The aim of this study was to explore the benefits of using a Multi-touch table as a tool to encourage students' collaboration and to enhance the quality of communication amongst team members. We looked at the amount of talking, the amount of physical interaction, collaboration logs and the use of communication categories in both conditions.

TABLE I. Description of Communication Category [1]

Communication Category	Description
Introduce & Plan	Introduce yourself to your team-mates and plan the session in advance before start collaborating.
Inform	Direct or advance the conversation by providing information.
Request	Ask for help in solving the problem, or in understanding a team-mates comment.
Maintain	Support group cohesion and peer involvement.
Acknowledge	Agreement upon team-mate's comment
Argue	Reason about suggestions made by team-mates.
Motivate	Provide positive feedback.
Disagree	Disagree with the comments or suggestions made by team members.
Task	Shift the current focus of the group to a new subtask.
Off-Task	Off-Task discussion.

The results showed that participants talked more in the PC based condition (M= 5.61, SD=2.18) than they did in the Multi-touch table based (M=4.29, SD=1.71). The difference between the conditions was statistically significant (p=0.004). The qualitative analysis for the collaboration logs (design process) explained the reason behind this difference: the PC-based condition did not support parallelism design activities on the face-to-face collaboration, and it only allowed for sequential-participative design to be carried out. Therefore, subjects had to stop designing activities to engage in discussion to decide the next step. However, the Multi-touch table condition supported the parallel-participative design, in which subjects were able to carry out multiple designing activities and discussion at the same time. Also, the PC-based condition increased single-subject domination, in which one subject performed most of the designing activities. A study by Paul Marshall et al. [24] showed that dominant subjects talk more, and the results supported Marshall's findings, showed that the subject who interacted more physically (dominated more) talked the most.

A. Use of Communication Categories

TABLE II shows that "*Inform*" sub-skill used in PC-based condition (35.72%) more than in the Multi-touch based condition (31.53%). In PC and Multi-touch settings subjects tend to "*Request*" help, used "*Acknowledge*", "*Motivate*", "*Maintain*", "*Disagree*" as well as discussed about the next step "*Task* " almost at the same level. However, the subjects discussed about what are they going to do "*Introduce & Plan*" in the Multi-touch condition (2.13%) more than in the PC-based condition (1.49%). Furthermore, Multi-touch setting encouraged "*Argue*" more (21.31%) than the PC setting (19.60%). However, subjects used "*Off-Task*" discussion in the Multi-touch (3.64%) more than in the PC (1.79%). Both conditions promoted the effective collaborative learning. The Multi-touch condition encouraged the "Creative Conflict" skills more than the PC-based condition as shown in TABLE II. The PC-based condition encouraged "Active Learning" skills more than the Multi-touch condition. It can be seen that the subjects in both conditions engaged in "Conversation" skills almost at the same level.

TABLE II. COLLABORATIVE LEARNING SKILLS IN MULTI-TOUCH AND PC-BASED CONDITIONS

Collaborative Learning Skills	**Sub-Skills**	**Multi-touch**		**PC-based**	
Creative Conflict	Argue	21.31%	23.18 %	19.60%	21.00 %
	Disagree	1.87%		1.39%	
Active Learning	Motivate	1.51%	41.39 %	2.09%	45.97 %
	Inform	31.53%		35.72%	
	Request	6.22%		6.67%	
	Introduce & Plan	2.13%		1.49%	
Conversation	Acknowledge	25.04%	31.79 %	24.48 %	31.24 %
	Maintain	1.15%		1.49%	
	Task	5.60%		5.27%	

Collaborative problem-solving has some benefits such as encouraging students to verbalise their thinking; encouraging students to work together, ask questions, explain and justify their opinions; increasing students' responsibility for their own learning; and encouraging them to elaborate and reflect upon their knowledge [23, 25, 26]. Verbal communication is one of the most important components of any collaboration [27]. In this study, Collaborative Learning Conversation Skills Taxonomy has been applied. Collaborative Learning Conversation Skills Taxonomy is the understanding and knowledge of how to communicate effectively, aimed at enhancing the learning process in a group discussion [23]. Most of the previous studies applied the Collaborative Learning Conversation Skills Taxonomy to structured non-verbal communication in distributed collaboration settings [1, 28, 29]. This taxonomy has been applied in this present study in order to explore which skills might be adopted by subjects in face-to-face collaboration in both experiment conditions without forcing them to use a structured communication. The result shows that there is some difference between the Multi-touch table condition and PC-based conditions in terms of the collaborative learning communication skills that were adopted. TABLE II shows that in the Multi-touch table condition, subjects tended to use the 'Creative Conflict' skills more than when they were in the PC-based condition. Using 'Creative Conflict' skills, which are 'Argue' and 'Disagree', can be useful in producing creative interactions; it leads to productive discussion when it is directed at ideas rather than people [30]. In both conditions, subjects used the 'Conversation' skills almost an equal amount of the time. However, in the PC-based condition, 'Active Learning' skills were used the most, particularly using the 'Inform' skill, which was highest in the PC-based condition. The reason for the frequent use of 'Inform' skills in the PC-based condition is related to single-subject domination, in which the dominant subject used 'Inform'. For example, Subject 2 in Group 1 was the dominant subject in the PC-based condition, and was using leading phrases such as: 'I think it is better to have a circle here and an end button here', and: 'Actually, I think you do not have to make capital letter, write specify amount'. The total number of 'Inform' phrases used by this subject was 58, while in the Multi-touch table condition it was 44.

B. Collaboration Log

The mouse in the PC-based condition played an important role in the use of the MT-CollabUML tool, where it is used for adding, deleting, linking, unlinking, and moving nodes. Therefore, the subject who controls the mouse dominates the physical design activities in the PC-based condition as shown in TABLE III. The collaboration log shows that Subject 2 "Fig. 5" was controlling the mouse in the PC-based condition all the time and he/she was dominating the design activities as well. In contrast, because of using hand gestures instead of the mouse in the Multi-touch condition, the single subject domination decreased as shown in "Fig.4". The Multi-touch table encourages parallel-participative design and equity of physical interaction. These findings are supported by our previous study showing that Multi-touch table increases the equity of participation [31].

TABLE III. DOMINATING IN BOTH CONDITIONS

	Subjects	Control Mouse (PC-based)	Dominating in PC-based	Dominating in Multi-touch
Group 1 PC→Multi-touch	1			✓
	2	✓	✓	✓
Group 2 Multi-touch →PC	3	✓	✓	✓
	4			✓
Group 3 PC→Multi-touch	5	✓	✓	✓
	6			✓
Group 4 Multi-touch →PC	7			
	8	✓	✓	✓
Group 6 Multi-touch →PC	9	✓	✓	✓
	10		✓	✓
Group 7 PC→Multi-touch	11	✓		✓
	12	✓	✓	✓
Group 8 Multi-touch →PC	13	✓	✓	✓
	14			✓
Group 9 PC→Multi-touch	15	✓	✓	✓
	16			✓
Total		10/16	9/16	15/16

The analysis of the collaboration log also shows that the Multi-touch table enabled pairs to engage in more physical design activities than the PC-based condition as shown in TABLE IV and TABLE V. For example, Subject 1 in the PC setting "Fig. 5" was able to interact physically only in some design activities such as "Adding Text" or "Correcting Text". On the other hand, when the same subject (Subject 1) worked in the Multi-touch condition "Fig. 4", it was an opportunity to be engaged in all design activities such as "Adding Node", "Moving Node", "Linking Node", and "Deleting Node".

TABLE IV. DESIGN ACTIVITIES IN PC-BASED CONDITION

Subjects	Add Nodes	Link Node	Add Text	Delete Node	Unlink Node	Correct Text	Move Node
1			√			√	
2	√	√			√	√	√
3	√	√	√			√	√
4	√		√	√		√	√
5	√	√	√	√		√	√
6	√	√				√	√
7			√			√	
8	√	√		√			√
9	√	√	√		√	√	√
10	√	√					√
11	√	√	√		√	√	√
12	√	√		√	√	√	√
13	√	√	√				√
14	√	√	√		√	√	√
15	√	√	√	√	√	√	√
16	√	√		√	√		√
Total	14/16	13/16	10/16	6/16	7/16	12/16	14/16

TABLE V. DESIGN ACTIVITIES IN MULTI-TOUCH CONDITION

Subjects	Add Nodes	Link Node	Add Text	Delete Node	Unlink Node	Correct Text	Move Node
1	√	√	√	√	√	√	√
2	√	√	√	√	√	√	√
3	√	√	√	√	√	√	√
4	√	√	√		√		√
5	√	√	√		√	√	√
6	√	√	√	√		√	√
7	√	√	√				√
8	√	√	√	√	√	√	√
9	√	√	√				√
10	√	√	√		√		√
11	√	√	√	√		√	√
12	√	√	√			√	√
13	√	√	√	√	√		√
14	√	√	√	√		√	√
15	√	√	√		√	√	√
16	√	√	√	√	√		√
Total	16/16	16/16	16/16	9/16	10/16	10/16	16/16

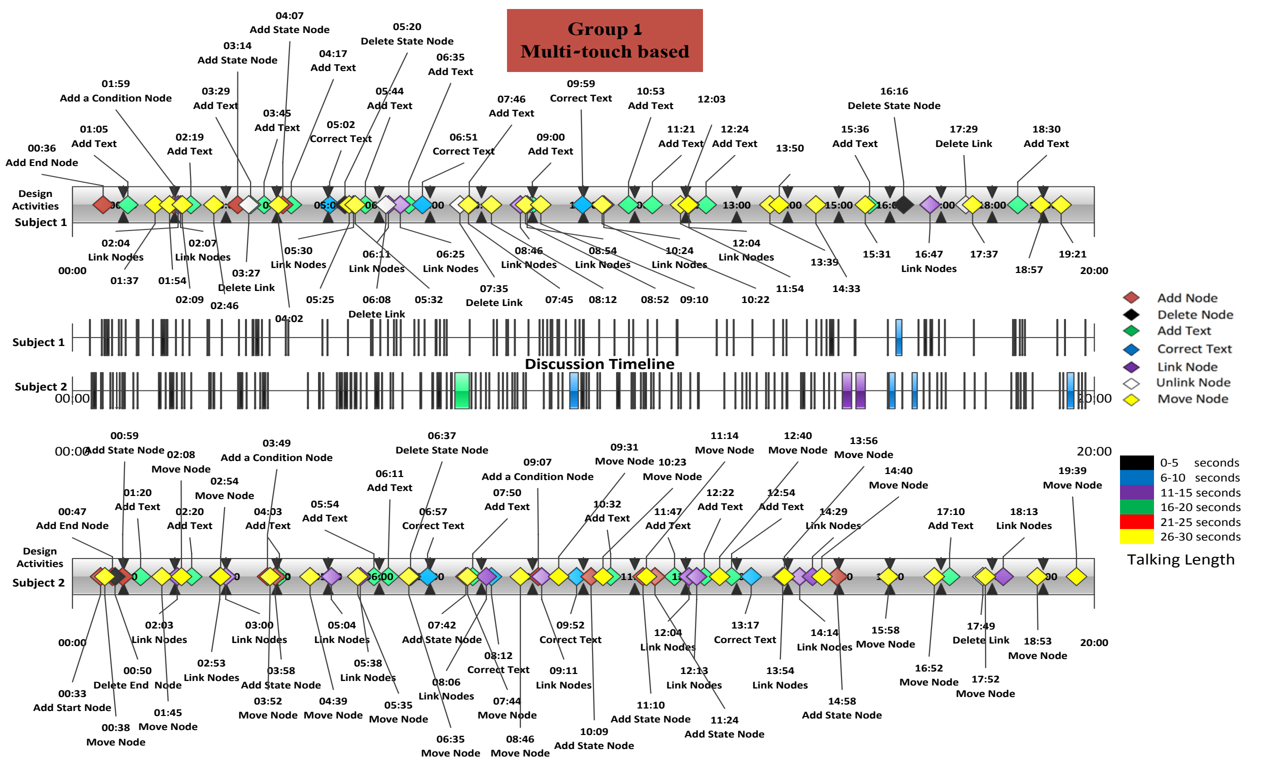

Fig.4. Collaboration log for Multi-touch table collaborative design

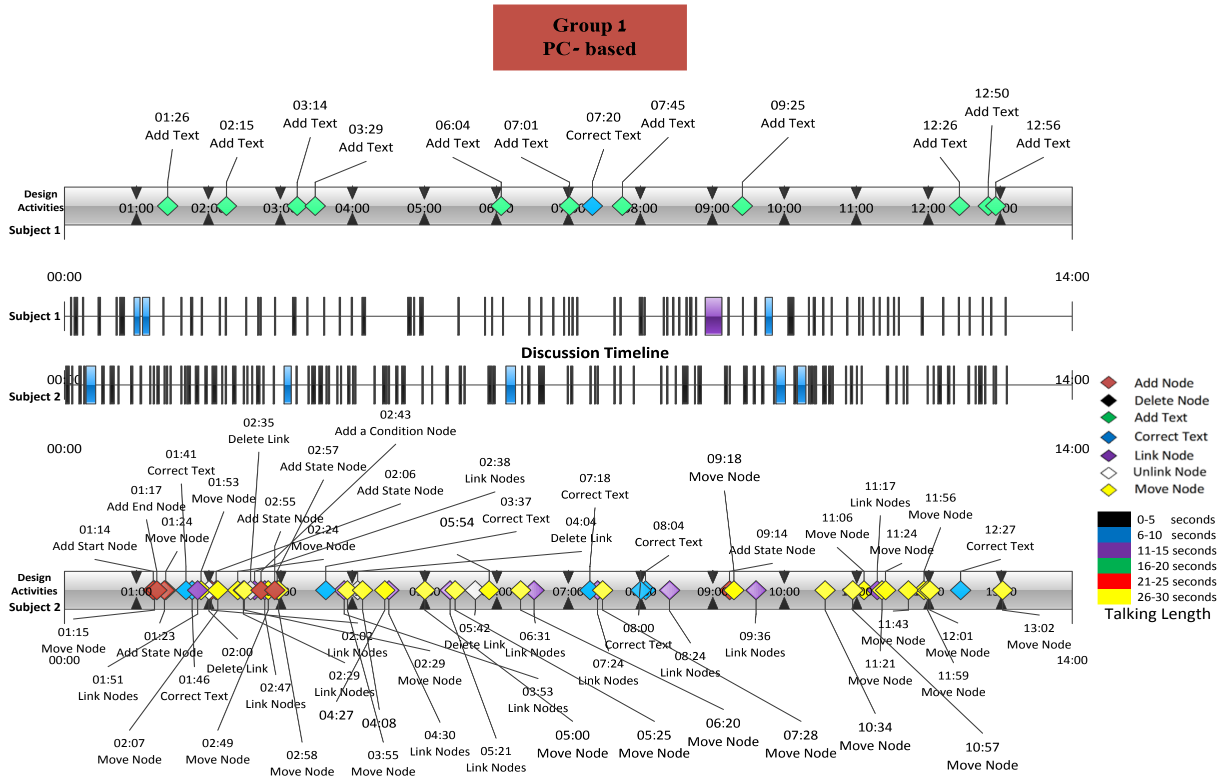

Fig.5. Collaboration log for PC-based collaborative design

VII. Conclusion

In this paper, the differences in collaborative software design amongst groups of students working in PC-based vs. Multi-touch conditions were investigated. We hypothesized that the Multi-touch table would increase the effectiveness of the collaborative process by enhancing collaboration learning skills and increasing physical interactions amongst team members.

The results indicate the benefit of using the Multi-touch MT-CollabUML tool as opposed to the PC-based version in enhancing collaborative software design. The Multi-touch environment increases the amount of physical interactions and subjects' engagements in the design activities. MT-CollabUML tool in the Multi-touch setting encouraged subjects to be engaged in a discursive conversation using "Creative Conflict" skills. More research needs be done in this area to fully explore the advantages and disadvantages of using Multi-touch tables in professional software design.

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