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Supporting the Assessment of Collaborative Design Activities in Multi-tabletop Classrooms

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***Abstract*—The present study describes a proposed multi-tabletop system for supporting collaborative database design activities in the classroom. Additionally, two experiments were conducted to evaluate students' and teachers' perceptions of the proposed system potential on aspects of group work assessment such as: ease of grading individuals as well as groups; equality of students' participation; and, capability to accurately reflect individual contributions. Ten educators and 22 students from a Computer Science program participated in the experiments. The findings of this work show that the use of the proposed system impacted positively on the educators' perception about the ease of grading individuals and groups. In addition, distinguishing users in collaborative group work is key for decreasing social-loafing. The results suggest that the proposed system does have potential to support a better group work assessment.**

I. Introduction

Traditionally, software design teaching has been one of the strongest focus of Computer Science (CS) undergraduate education [1]. Around the world, most CS programs have based their software design education on a group project-based approach [2][3][4]. This focus on group work allows CS programs to offer students real life-like experiences, as well as to meet professional accreditation requirements and employers' demands [5][6]. Nonetheless, the management of group work in the classroom imposes a number of challenges that can impact negatively on educators' and students' enthusiasm and motivation. Most of these difficulties are related to the assessment of the work done: fear of free-riding of individual members and doubts on the ability to assess individual contributions [7][8][9]. Additionally, educators face the challenge of supporting each group effectively, given time constraints, their skills for class control and their ability to manage each group's learning pace [10].

Previous research on multi-touch tabletops has shown that this novel technology has a strong potential to support group work in the classroom [10][11][12][13][14][15], while providing educators a mean for class management and control task [16][17][18][12]. Although some of this work has extended the application of these technologies to multi-tabletop classroom environments, few research has explored the usage of tabletops for real and concrete purposes, within realistic environments [10][13][14]. In order to better understand the strengths and limitations of tabletop-mediated classrooms, usage observations should follow the recommendations of Suchman [19], Nebe et al. [20] and Xambo et al. [21], and be conducted within the classroom, with the participation of students and educators on tasks directly related to their interest.

Additionally, specific studies on in-class group work supported by tabletops have mostly focused on: helping educators gain awareness of group activities to decide when to intervene [16]; analyzing and visualizing data captured from the usage of tabletops to reveal aspects such as the process and the quality of group work, interactions, contributions and leadership [22][15][23]; and, investigating the impact of design choices on educators' pedagogy [18]. In spite of the relevance of assuring students a fair assessment of their work to improve their attitude towards group work, little attention has been paid to study the influence of this technology on students' and educators' perceptions of group work assessment during in-class activities.

This research explored the potential of a proposed multi-tabletop system (MTS) in software design classrooms, in contrast to a paper-based design approach. To be more specific, this study investigated the MTS' potential for the assessment of design group-based activities throughout a CS Database course. The aim of this work was to answer questions about the differential impact of students' and educators' perceptions of assessment-related variables when using the MTS versus the paper-based approach. The variables were: educators' perception of ease of grading at an invidual and group level; educators' perception of the equality of participation of their students; students' perception of the equality of participation amongst group members; students' perception of the capability of tools to accurately reflect individual contributions. This work's findings show that the use of MTS impacted positively on the educators' perception of the ease of grading individuals and groups. Additionally, distinguishing users in collaborative group work is key for achieveing a better group assessment. The results suggest that the proposed MTS has potential to help assure students they will be rewarded for their efforts.

This paper is structured as follows: first, a related work section is presented, the design guidelines and implementation specifications of the proposed MTS are explained. Then the research context, experiments and corresponding results are described. Finally, a discussion section along with reflections

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about further research is proposed.

II. Related work

Group work assessment is a critical but hard task. Several studies have proposed frameworks for group work assessment that considers individual contributions [24] [25] [2][4]. For example [26], presented an on-line Team Contribution System that attempted to provide an accountable assessment for both individuals and groups. This solution, however, heavily depended on students self-reporting, which could be cumbersome and inaccurate.

Conversely, multi-touch tabletops have the ability to capture students interactions during in-class group activities. Previous work on this technology has shown that the captured data can be transformed into visualizations of the collaboration process [17][23] [27]. Collaid [17], a tabletop learning environment that captures collaborative multimodal data, offers visualizations that provide real-time feedback and recognizes frequent interaction patterns.

Moreover, there is a growing interest in researching the integration of the captured data with the learning process. Based on a critical analysis of previous work, [28] generated a set of guidelines for the design of multi-tabletop learning systems for the classroom. Other research presented a group of visualizations to help educators decide when to intervene [16]. SynergyNet [18] [29] is a MTS that explores the quality of school children's collaboration and its impact on educators' pedagogy. Similarly, [12] described the classroom deployment of Tinkerlamp, a system designed for logistic apprentices that allows educators' orchrestration. MTClassroom and MTDashboard are part of a MTS presented by [14], that captures interactions enabling educators to design, monitor and assess collaborative activities. The research of [14] was later extended to design a multi-touch classroom ecology to support practical work of university subjects [15].

However, most of this work has focused on general learning activities such as concept mapping. Few research [12] has explored tabletop applications for realistic usage scenarios, meaningful for both students and educators, such as software design. Existing studies of tabletops' potential for software design have mostly concentrated on exploring interactions and gestures for diagramming or sketching on tabletops. [30] [31][32].

III. Proposed solution

A. Design guidelines

The solution presented in this work is based on the following single-tabletop design guidelines:

1) Support simultaneous user actions: As suggested by [33] in their critical analysis of group-work on tabletops, people working in groups often interact with artifacts on tabletops simultaneously.

2) Allow users to freely move and regulate their workspace: Xambó [21] warned against the harmful effects on creativity and free collaborative activities that tabletops with territorial constraints can cause. Additionally, when designing tabletop applications for students that are used to work with paper and pen, [20] recommends transferring some of the affordances of these artifacts, such as free movement, to tabletop design.

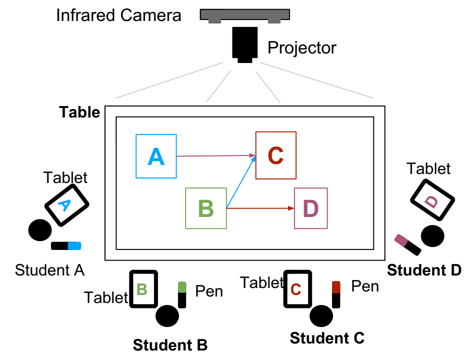

Fig. 1. Physical scheme of the student side of the proposed MTS.

3) Tangible interaction with pen-based input: In line with [20] [21] [34] and following the well-established guidelines of [33], the proposed solution allows for integration of digital and physical objects, such as a pen, to support already existing paper-based design practices.

4) Interconnection with devices: Although [17] suggested designing for non-intrusive interactions with tabletops, the proposed MTS uses tablets as text-input devices to facilitate the transitions between the work related to tabletops and external work [33].

5) Distinguishing users' work: Successful collaborative work in the classroom requires group members and educators to be aware of individual contributions [28] [17].

Additionally, the design of the proposed MTS is grounded in the following design guidelines for multi-tabletop learning environments:

6) Progress monitoring of students at the invididual and group level: To enable educators' awareness, the design of the proposed MTS is based on the work of [18][16] [14]. These studies presented a variety of visualizations to monitor learners' contributions and progress.

7) Storing the design process as well as the outcome of each group for further assessment: To increase the educators' awareness of the group work process that leads to the final database design, the proposed MTS follows Kharrufa's et al. [28] design recommendations of recording students' interactions and storing the final database design.

B. Implementation

The proposed MTS is a combination of hardware and software, including a web-based application. Students interact with the system through tabletops, pens and tablets. Figure 1 shows an upper view of the physical scheme of the student side of the system. On the other hand, educators only need a device with a browser to access the system. The educator's view of the system allows monitoring student progress in collaborative tasks.

Fig. 2. Students working with the tabletop interface

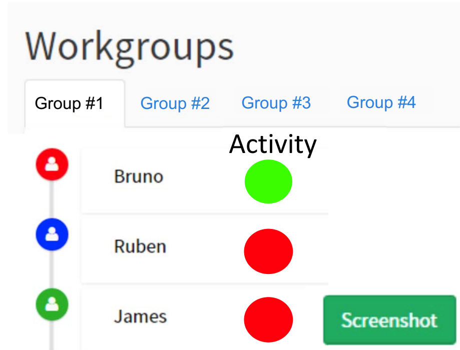

Fig. 3. Colored alert indicators of levels of activity shown by members of a group.

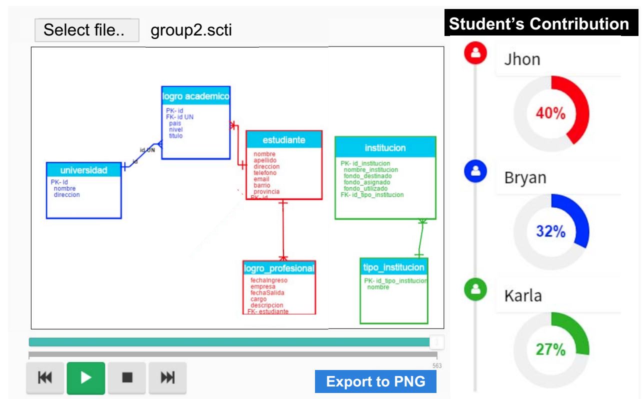

Fig. 4. Educator interface with the playback option and overall individual contributions.

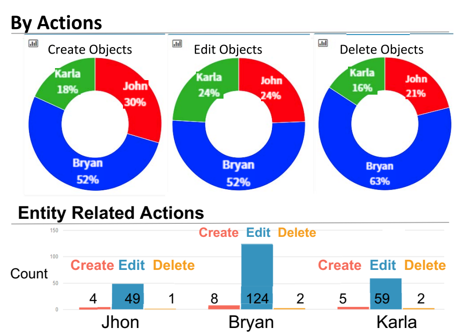

Fig. 5. Proportions of student participation per type of activity (above) and proportions of actions related to objects in the scheme per student (below).

1) Hardware: The solution is composed of a portable projector camera system that works with an Optitrack Motion Tracking V.120 Duo System and a mini projector (aaxa Technologies P300 Pico projector). Other hardware components of the system are: a computer with CoreI5 2.9 GHz processor - 4GB RAM - 500GB HDD, a Samsung Galaxy Tab 3, and a pen with three infrared markers. The projector and camera hang above the table. The image on which the students work is projected on a flat horizontal surface. Students interact with the projected image using a pen with infrared markers. Besides, each student interacts with a tablet to input text related to the task.

2) Software: On the student's side of the system, the application is composed of a web application, a collaborative control client and a tracking server. The web application enables student to log in and edit text using a tablet. This application was developed in Python using Django Framework. The collaborative control client is responsible for two tasks: recognition of strokes and drawing on the table. This client was implemented on the open source framework Multitouch for Java (MT4J) [35]. Each stroke students make is processed by the library PaleoSketch [36]. The strokes are traced using a pen with three infrared markers. The tracking server keeps track of pens' positions, which are provided by the Optitrack's library Camera SDK. When students draw on the table, a touch event is generated through the TUIO (Tangible user interface) protocol, and then sent to the collaborative client. Figures or texts entered by students are differently colored to identify each member of the group. Every action on the tabletop and its related information is stored in a JSON file. When students finish their task they are able to download their final scheme file. Figure 2 depicts students working with the proposed MTS in activities related with database modeling.

On the educator's side of the system, the web-based application enables them to better assess in-class group work through visualizations of students' activities. On one hand, the system alerts the educator on the level of individual activity; changing from green to yellow or yellow to red when no actions are detected after five minutes (See Figure3). On the other hand, the system enables educators to review the most important aspects of the collaborative design activity such as: the final design; how and how much each individual contributes to that design (through colored indicators in the scheme and statistics per individual); and, the design process within itself (through a playback functionality, see figure 4). In this way, educators are granted insights to qualitative data that depicts the actual collaborative process of design.

Additionally, the educator's view presents the proportions of each student's participation in specific database modeling-related tasks (See the upper section of Figure 5). Details of individual contributions per type of activity are available. The bottom section of Figure 5 portrays this information resource.

IV. Methodology

A. Research context

Students perceptions of the equality of members' participation as well as of the capability of tools to accurately reflect individual contributions, were measured when students worked with and without the proposed MTS. Additionally, educators' perceptions of the ease of grading individuals and groups, and of the equality of students' participation during group work, were measured. The measurements took place in the Ecuadorian setting of an engineering-oriented university, Escuela Superior Politecnica del Litoral (ESPOL). Twenty-two undergraduate students, enrolled in a Database System course of a CS program, were invited to participate in this study, as well as 10 educators from the same program (4 females and 6 males). Educators were highly experienced in modeling and designing, with more than 10 years of teaching experience; their average age was 42. The experiments took place during the second academic semester of year 2014. The study included two experiments; educators participated in Experiment 1, and students in Experiment 2. Both experiments aimed to measure the perception of the participants through questionnaires. In the next subsections details of both experiments are presented.

B. Experiment 1

Ten educators from the CS program participated in a pre-test post-test experiment. Educators were tested using a questionnaire that included items related to the following variables of group work assessment: ease of grading individuals and groups; and, equality of individuals' participation. The first variable was measured using a Likert scale, being (1) very difficult and (5) very easy. Likewise, a Likert scale was used to measure equality of individual participation, being (1) completely unequal and (5) completely equal. The pre-test aimed to measure educators' perceptions of these variables considering any collaborative design-based activity. The post-test focused on educators' perceptions of these variables considering the potential of the proposed MTS. Educators were invited to participate in a demo session of the proposed system. Before the session started, educators were asked to answer the pre-test questionnaire. During the session, educators could observe students using the proposed MTS to collaboratively design a normalized-logical database model. The demo session also included a hands-on experience of the educator's view of the system. At the end of the session, educators were asked to answer the post-test questionnaire.

C. Experiment 2

Twenty-two students from a Database Systems course were appointed to participate in a pre-test post-test with control condition experiment. Equal number of students were randomly selected into the experimental and control conditions. Before the experiment started, students were asked to answer a pre-test questionnaire, which included two items. The first item was related to the perception of equality of students' participation while working collaboratively in design-based activities. This was measured with a Likert scale, being (1), completely unequal and (5), completely equal. Similarly, a Likert scale was used to measure the capability of a given tool to accurately reflect individual contributions, being 1, very inaccurate and being 5, very accurate.

TABLE I. Descriptive Statistics and Hypothesis Tests of Educators' Perceptions

Variables	Median Pre-test	Median Post-test	Z	p-value	Effect size r
Easiness to grade individuals	2	5	-2.859	0.004	0.900
Easiness to grade groups	4	5	-2.333	0.020	0.737
Equality of participation	2	4	-2.372	0.018	0.750

In both conditions, students integrated groups of 4 to 5 members. Educators assigned each group a task that required the design of a normalized-logical database model. The students in the control group used large paper sheets, color markers (each color identifying a member of the group), and stickers to do the activity; while students in the experimental condition used the proposed MTS. Students had 60 minutes to finish this task. At the end of the experiment, students filled in the post-test questionnaire.

V. Results

A. Experiment 1

What is the differential impact when students use the proposed MTS on educators' perception about ease of grading individuals and groups? Table I, summarizes the descriptive results of the variables measured on educators and the results of testing the differences between the pre-test and post-test of these same variables. As it can be seen, after the demo session educators perceived it is easier to grade individuals and groups with the proposed MTS. The other question that this experiment aimed to answer was: What is the differential impact when students use the proposed MTS on educators' perception about the equality of students' participation? Educators' perception of equality of participation with the proposed MTS is higher than their perception before the demo session. The hypotheses tests, using Wilcoxon signed-rank test, resulted in significant differences for these three variables. The effect sizes for all the tests were large ($r>0.5$). At the end of the demo session, educators mentioned their willingness to use such tools in their classrooms.

B. Experiment 2

This experiment aimed to answer two research questions: What is the differential impact when using the proposed MTS on students' perception about equality of students' participation?; and, What is the differential impact when using the proposed MTS on students' perception about the capability of tools to accurately reflect individual contributions in a group? These two questions were answered by means of between-group tests and intra-group tests.

1) Equality of participation, between-group tests: Students from the experimental and control conditions reported no differences in the pre-test ($U= 35$, $z= -1.74$, $p>0.05$). As for the mean rank for the experimental condition, it was 11.45; in the control condition this value was 9.33. This indicates that students in the experimental condition have a slightly higher positive perception than those in the control condition. However, the Mann-Whitney U test used to test differences between both conditions resulted in U=39, z =-0.93, p=0.355 in the post-test. This implies there are no statistical differences on students' perception about the equality of participation.

2) Capability of tools to accurately reflect individual contributions in a group, between-group tests: Students from both conditions did not differ in the pre-test (U= 58, z= -0.19, p>0.05). The descriptive mean rank suggests that students in the experimental condition perceive that the MTS accurately reflected their individual contributions (mean rank experimental condition=13.27, mean rank control condition=7.11). Moreover, the results of the Mann Whitney U test used to test differences among both conditions, corroborated the initial suggestion; when compared to the students in the control condition, students in the experimental condition perceived that the proposed MTS reflected more accurately their contribution (U=19, z= -2.73, p=0.006 two-sided).

3) Equality of participation, intra-group tests: As it was expected, students under the control condition did not show any difference between the pre-test and post-test (z=-0.63, p=0.527); however, students in the experimental condition perceived that the MTS favored equality of participation among the members of a group (z=-2.54, p=0.011).

4) Capability of tools to accurately reflect individual contributions in a group, intra-group tests: Again, students in the control condition did not perceived any difference before and after they engaged in the task (z=-1.19, p=0.234). This was not the case of students from the experimental group, they perceived that the proposed MTS reflected more accurately their contributions in the group (z=-2.97, p=0.003).

VI. Discussion and Further Work

The potential of a MTS for group work assessment from the educators' and students' perspective was explored in this study. The evident positive educators' perceptions of the measured variables are aligned with the results reported in [14], which to the knowledge of the authors, is one of the few studies that reports quantitative results in this specific area. The study confirmed that, indicators of group work and individual participation would be valuable for teachers to conduct post-hoc analyses. However, the findings of the present study have to be taken with a critical view; the educators that participated did not experiment with multi-tabletop classrooms during a complete semester, nor their experience with these technologies was linked to their own courses. Thus, further experiments where educators use the proposed MTS in their own courses should be considered.

Another limitation of the study is that it did not focus on the semantics of the database design process, nor it analyzed the quality of student's interactions. Further research on assessment supported by MTS should concentrate on these aspects.

The students' perception was also measured in this study. When asked about the equality of students' participation when working in groups, they did not find differences between the paper-based and the MTS supported approach. These findings suggest that the usage of colors to distinguish individuals' contributions in the paper-based approach already decreased free-riding. The fact that inviduals are able to distinguish each others contributions during colocated work triggers social comparison, which is known to decrease social-loafing [37]. Thus, distinguishing users' work is key for supporting equality of participation and consequently for achieving a better group work assessment. Nonetheless, the present study focused on a very general aspect of equality of participation. Further studies should conduct more in-depth explorations.

Regarding the ability of the MTS to accurately reflect individual contributions, students indicated that the proposed MTS truly reflected their actual participation. This coincided with the point of view of the educators. These results could not be contrasted to similar studies; research on multi-tabletop learning environments has focused mainly on qualitative observations of its potential for classroom orchestration [12][10] [13][15] rather than for group work assessment. Nevertheless, the findings of the present study indicate that the use of MTS in educational environments has potential to help assure students a fair reward for their individual efforts.

The overall positive results of this work open doors for future research about the use of MTS for group work assessment in realistic learning environments. Besides, recordings of the students' collaborative design process could be used as input for research on user studies, multimodal learning analytics, and more.

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References

[1] ACM/IEEE-CS Joint Task Force on Computing Curricula, "Computer science curricula 2013," ACM Press and IEEE Computer Society Press, Tech. Rep., December 2013. [Online]. Available: http://dx.doi.org/10.1145/2534860

[2] J. K. L. Poon, "Students' perceptions of peer evaluation in project work," in *Proceedings of the Thirteenth Australasian Computing Education Conference - Volume 114*, ser. ACE '11. Darlinghurst, Australia, Australia: Australian Computer Society, Inc., 2011, pp. 87–94. [Online]. Available: http://dl.acm.org/citation.cfm?id=2459936.2459947

[3] M. Wiggberg and M. Daniels, "A method for analyzing learning outcomes in project courses," in *Proceedings of the Thirteenth Australasian Computing Education Conference - Volume 114*, ser. ACE '11. Darlinghurst, Australia, Australia: Australian Computer Society, Inc., 2011, pp. 73–78. [Online]. Available: http://dl.acm.org/citation.cfm?id=2459936.2459945

[4] A. Basholli, F. Baxhaku, D. Dranidis, and T. Hatziapostolou, "Fair assessment in software engineering capstone projects," in *Proceedings of the 6th Balkan Conference in Informatics*, ser. BCI '13. New York, NY, USA: ACM, 2013, pp. 244–250. [Online]. Available: http://doi.acm.org/10.1145/2490257.2490268

[5] ABET. Criteria for accrediting computing programs, 2015-2016. [Accessed: 2015-03-26]. [Online]. Available: http://abet.org/cac-criteria-2015-2016/

[6] NACE. The skills and qualities employers want in their class of 2013 recruits. [Accessed: 2015-03-26]. [Online]. Available: http://www.naceweb.org/s10242012/skills-abilities-qualities-new-hires/

[7] D. Hall and S. Buzwell, "The problem of free-riding in group projects: Looking beyond social loafing as reason for non-contribution," *Active Learning in Higher Education*, vol. 14, no. 1, pp. 37–49, 2013. [Online]. Available: http://alh.sagepub.com/content/14/1/37.abstract

[8] K. Jones, "Discouraging social loafing during team-based assessments," *Teaching Innovation Projects*, vol. 3, no. 1, p. 13, 2013.

[9] R. Swaray, “An evaluation of a group project designed to reduce free-riding and promote active learning,” *Assessment & Evaluation in Higher Education*, vol. 37, no. 3, pp. 285–292, 2012. [Online]. Available: http://dx.doi.org/10.1080/02602938.2010.531246

[10] R. Martinez Maldonado, Y. Dimitriadis, J. Kay, K. Yacef, and M.-T. Edbauer, “Orchestrating a multi-tabletop classroom: From activity design to enactment and reflection,” in *Proceedings of the 2012 ACM International Conference on Interactive Tabletops and Surfaces*, ser. ITS ’12. New York, NY, USA: ACM, 2012, pp. 119–128. [Online]. Available: http://doi.acm.org/10.1145/2396636.2396655

[11] E. Mercier, S. Higgins, E. Burd, and A. Joyce-Gibbons, “Multi-touch technology to support multiple levels of collaborative learning in the classroom,” in *Proc. ICLS*, vol. 12, 2012.

[12] S. Do-Lenh, “Supporting reflection and classroom orchestration with tangible tabletops,” *École Polytechnique Federale De Laussane*, 2012.

[13] A. Kharrufa, M. Balaam, P. Heslop, D. Leat, P. Dolan, and P. Olivier, “Tables in the wild: Lessons learned from a large-scale multi-tabletop deployment,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI ’13. New York, NY, USA: ACM, 2013, pp. 1021–1030. [Online]. Available: http://doi.acm.org/10.1145/2470654.2466130

[14] R. Martinez-Maldonado, Y. Dimitriadis, J. Kay, K. Yacef, and M. Edbauer, “Mtclassroom and mtdashboard: supporting analysis of teacher attention in an orchestrated multi-tabletop classroom,” *Proc. CSCL2013*, pp. 119–128, 2013.

[15] R. Martinez-Maldonado, A. Clayphan, C. Ackad, and J. Kay, “Multi-touch technology in a higher-education classroom: Lessons in-the-wild,” in *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: The Future of Design*, ser. OzCHI ’14. New York, NY, USA: ACM, 2014, pp. 220–229. [Online]. Available: http://doi.acm.org/10.1145/2686612.2686647

[16] R. Martnez Maldonado, J. Kay, K. Yacef, and B. Schwendimann, “An interactive teachers dashboard for monitoring groups in a multi-tabletop learning environment,” in *Intelligent Tutoring Systems*. Springer, 2012, pp. 482–492.

[17] R. Martínez, A. Collins, J. Kay, and K. Yacef, “Who did what? who said that?: Collaid: An environment for capturing traces of collaborative learning at the tabletop,” in *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces*, ser. ITS ’11. New York, NY, USA: ACM, 2011, pp. 172–181. [Online]. Available: http://doi.acm.org/10.1145/2076354.2076387

[18] I. AlAgha, A. Hatch, L. Ma, and L. Burd, “Towards a teacher-centric approach for multi-touch surfaces in classrooms,” in *ACM International Conference on Interactive Tabletops and Surfaces*, ser. ITS ’10. New York, NY, USA: ACM, 2010, pp. 187–196. [Online]. Available: http://doi.acm.org/10.1145/1936652.1936688

[19] L. A. Suchman, *Plans and Situated Actions: The Problem of Human-machine Communication*. New York, NY, USA: Cambridge University Press, 1987.

[20] K. Nebe, T. Müller, and F. Klompmaker, “An investigation on requirements for co-located group-work using multitouch-, pen-based- and tangible-interaction,” in *Human-Computer Interaction. Interaction Techniques and Environments*. Springer, 2011, pp. 90–99.

[21] A. Xambó, E. Hornecker, P. Marshall, S. Jordà, C. Dobbyn, and R. Laney, “Let’s jam the reactable: Peer learning during musical improvisation with a tabletop tangible interface,” *ACM Trans. Comput.-Hum. Interact.*, vol. 20, no. 6, pp. 36:1–36:34, Dec. 2013. [Online]. Available: http://doi.acm.org/10.1145/2530541

[22] R. Martinez, J. Kay, and K. Yacef, *Visualisations for longitudinal participation, contribution and progress of a collaborative task at the tabletop*. School of Information Technologies, University of Sydney, 2011.

[23] A. Al-Qaraghuli, H. B. Zaman, A. Ahmad, and J. Raoof, “Interaction patterns for assessment of learners in tabletop based collaborative learning environment,” in *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, ser. OzCHI ’13. New York, NY, USA: ACM, 2013, pp. 447–450. [Online]. Available: http://doi.acm.org/10.1145/2541016.2541062

[24] D. Richards, “Designing project-based courses with a focus on group formation and assessment,” *Trans. Comput. Educ.*, vol. 9, no. 1, pp. 2:1–2:40, Mar. 2009. [Online]. Available: http://doi.acm.org/10.1145/1513593.1513595

[25] V. Farrell, G. Ravalli, G. Farrell, P. Kindler, and D. Hall, “Capstone project: Fair, just and accountable assessment,” in *Proceedings of the 17th ACM Annual Conference on Innovation and Technology in Computer Science Education*, ser. ITiCSE ’12. New York, NY, USA: ACM, 2012, pp. 168–173. [Online]. Available: http://doi.acm.org/10.1145/2325296.2325339

[26] V. Farrell, G. Farrell, P. Kindler, G. Ravalli, and D. Hall, “Capstone project online assessment tool without the paper work,” in *Proceedings of the 18th ACM Conference on Innovation and Technology in Computer Science Education*, ser. ITiCSE ’13. New York, NY, USA: ACM, 2013, pp. 201–206. [Online]. Available: http://doi.acm.org/10.1145/2462476.2462484

[27] A. Tang, M. Pahud, S. Carpendale, and B. Buxton, “Vistaco: Visualizing tabletop collaboration,” in *ACM International Conference on Interactive Tabletops and Surfaces*, ser. ITS ’10. New York, NY, USA: ACM, 2010, pp. 29–38. [Online]. Available: http://doi.acm.org/10.1145/1936652.1936659

[28] A. Kharrufa, R. Martinez-Maldonado, J. Kay, and P. Olivier, “Extending tabletop application design to the classroom,” in *Proceedings of the 2013 ACM International Conference on Interactive Tabletops and Surfaces*, ser. ITS ’13. New York, NY, USA: ACM, 2013, pp. 115–124. [Online]. Available: http://doi.acm.org/10.1145/2512349.2512816

[29] E. M. Mercier and S. E. Higgins, “Collaborative learning with multi-touch technology: Developing adaptive expertise,” *Learning and Instruction*, vol. 25, pp. 13–23, 2013.

[30] M. Frisch, J. Heydekorn, and R. Dachselt, “Diagram editing on interactive displays using multi-touch and pen gestures,” in *Proceedings of the 6th International Conference on Diagrammatic Representation and Inference*, ser. Diagrams’10. Berlin, Heidelberg: Springer-Verlag, 2010, pp. 182–196. [Online]. Available: http://dl.acm.org/citation.cfm?id=1884734.1884759

[31] R. Chen, P.-J. R. Chen, R. Feng, Y. E. Liu, A. Wu, and A. Mazalek, “Scisketch: A tabletop collaborative sketching system,” in *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*, ser. TEI ’14. New York, NY, USA: ACM, 2013, pp. 247–250. [Online]. Available: http://doi.acm.org/10.1145/2540930.2540973

[32] Y. Rangoni, V. Maquil, E. Tobias, and E. Ras, “Implementing widgets using sifteo cubes for visual modelling on tangible user interfaces,” in *Proceedings of the 2014 ACM SIGCHI Symposium on Engineering Interactive Computing Systems*, ser. EICS ’14. New York, NY, USA: ACM, 2014, pp. 205–210. [Online]. Available: http://doi.acm.org/10.1145/2607023.2610271

[33] S. D. Scott, K. D. Grant, and R. L. Mandryk, “System guidelines for co-located, collaborative work on a tabletop display,” in *Proceedings of the Eighth Conference on European Conference on Computer Supported Cooperative Work*, ser. ECSCW’03. Norwell, MA, USA: Kluwer Academic Publishers, 2003, pp. 159–178. [Online]. Available: http://dl.acm.org/citation.cfm?id=1241889.1241898

[34] A. Clayphan, R. Martinez-Maldonado, C. Ackad, and J. Kay, “An approach for designing and evaluating a plug-in vision-based tabletop touch identification system,” in *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, ser. OzCHI ’13. New York, NY, USA: ACM, 2013, pp. 373–382. [Online]. Available: http://doi.acm.org/10.1145/2541016.2541019

[35] Mt4j - an open framework to create visually rich 2d/3d multi-touch applications in java. [Accessed:2014-03-15]. [Online]. Available: https://code.google.com/p/mt4j/

[36] B. Paulson and T. Hammond, “Paleosketch: accurate primitive sketch recognition and beautification,” in *Proceedings of the 13th international conference on Intelligent user interfaces*. ACM, 2008, pp. 1–10.

[37] S. Buisine, G. Besacier, A. Aoussat, and F. Vernier, “How do interactive tabletop systems influence collaboration?” *Computers in Human Behavior*, vol. 28, no. 1, pp. 49 – 59, 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0747563211001658