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Unveiling the Process of Collaborative Learning Through the Use of Digital Whiteboard Historical Action Logs

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Abstract: The Covid-19 pandemic has forced many educational institutions to transit from face-to-face to online delivery of lessons. Precluded from meeting face-to-face in a classroom due to pandemic curbs, a digital whiteboard affords both teacher and learners to be collaborating and completing a task from home instead. In this paper, we first used a survey to assess learner's acceptance and use of digital whiteboard. We next web-scraped and visualized historical action logs recorded by the digital whiteboarding tool to uncover the process of problem-solving between and within the teams. This is significant as social-loafing and free-riding are typically difficult to detect and prevent in collaborative learning. In addition, instructors traditionally evaluate only the product but not the process of collaborative learning as most collaborative work of learners occur outside scheduled teaching hours. From the results of the survey, we can conclude that the digital whiteboard is accepted by the learners. It also encourages collaboration and leads to higher learning motivation of learners. From the visualizations of the historical action logs, we were able to discover differing interaction and collaboration practices among the teams as well as the contributions of team members within each team (e.g. some teams exhibiting uneven effort distribution). We believe that our findings are significant as to the best of our knowledge, this is the first study that uses historical action logs from digital whiteboard to gain insights into the process and evidence of collaborative learning through visualization techniques.

Keywords: digital whiteboard, collaborative learning, visualization, historical action logs

1. Introduction

Collaboration is an essential skill for the 21st century workforce. The affordance of modern technology has enabled businesses to build global teams possibly located in different geographical regions and time zones. It is thus imperative that modern and future workers learn to collaborate in distributed and diverse settings for the attainment of common business goals. In the modern classroom, collaborative learning, an educational approach which involves learners working together in small teams towards a common goal, is posited to lead to enhanced learning outcomes as compared to didactic instruction. In contrast to didactic instruction where learners receive knowledge passively from the teacher, collaborative learning is an active learning approach where learners participate actively with each other and co-construct their knowledge in the process. Collaborative learning (Smith & MacGregor, 1992), conditioned on enhanced interactivity, individual accountability and teamwork is underpinned by the theories of constructivism (Piaget, 1952) and the sociocultural theory of learning (Vygotsky, 1980). It is also recognized that adoption of collaborative learning fosters social interaction (Tinto, 1997), develops high order thinking skills (Webb, 1982), embraces diversity (Loes et al., 2018) and leads to higher motivational levels of learning (Astin, 1977).

Traditionally, before the proliferation of technological tools into classrooms, teachers rely on blackboard, whiteboard or even pen and paper for groups of learners to work on collaborative tasks. The use of whiteboards or blackboards, however, constrain a single team of learner to be working on the board at any one time. A team of learners huddling at the board in turn occluded other teams from observing what the team is doing. In addition, the short-lived nature of the content on the board poses further obstacles to learning (Price et al., 2008). The advent of interactive whiteboard (IWB) eases the collaboration effort (Armstrong et al., 2005) by allowing other teams to be viewing and even

contributing by annotating using their tablets or laptops while the main team is working on the main interactive whiteboard.

In recent years, development of digital whiteboards eliminated the need to invest in a physical interactive whiteboard hardware. A digital whiteboard offers almost equivalent features as a physical interactive whiteboard with a pure software offering. The Covid-19 pandemic has forced many educational institutions to transit from face-to-face to online delivery of lessons. Precluded from meeting face-to-face in a classroom due to pandemic curbs, a digital whiteboard affords both teacher and learners to be collaborating and completing a task from home instead.

Some of the challenges associated with collaborative learning relates to that of individual effort attribution. Social loafing (reduction of personal effort when working in a group) (Harkins & Jackson, 1985) and free-riding (individual bearing minimum work but sharing benefits of the group) (Albanese & Van Fleet, 1985) are some undesirable side-effects of collaborative learning but yet they are difficult to detect and prevent. Assessing only the outcome or final artifact but not the process is another issue which resulted in groups taking the safe and tested instead of some unorthodox and innovative means of solving the allocated tasks. Most digital whiteboards record the historical traces of participants' interactions within the board and these traces are key to uncovering the process that learners took in resolving the problem and for distilling evidence of social-loafing and free-riding. This will be part of our investigation in this study.

2. Related Studies

Glover et al. (2005) evaluated the use of interactive whiteboards (IWBs) undertaken in five elementary schools in England. The responses were collected using questionnaires, observations, and interviews of 35 teachers. The results indicated that students' motivation was enhanced, and the students were more willing to interact and participate. This coincides with another study (Aflalo et al., 2018) where the authors surveyed and observed the students instead of teachers using questionnaires and observations. From the results, the authors concluded high student enthusiasm and satisfaction with correspondingly high active learning and participation rates from the students with the use of IWB. The authors of both studies acknowledged that more research is however required for conclusive results on the benefits of IWBs especially in encouraging and discovering evidence of learners' interactions in classrooms.

Campbell et al. (2019) leveraged a digital whiteboard for promoting graduate social work students to engage and collaborate with their peers on a fully online course delivery mode. A logic model digital worksheet assignment was designed to be completed by the learners on a collaborative basis. The learners then reviewed what their peers had added and answered questions on their experiences with the use of digital whiteboard as a tool for information exchange and learning. The authors employed a cross-sectional design using traditional open-ended survey questions and online focus group to elicit their learners' responses. From the analysis, the authors concluded that their learners engaged more with each other and had a greater motivation to learn with the use of digital whiteboard.

Assessment plays an integral role in driving students' learning appropriately (Knight, 2012). Notwithstanding the pedagogical benefits of collaborative learning, adequate assessment of individual inputs in group work to the final output is difficult as much of the work occurs outside formal teaching sessions. The study by Johnston * and Miles (2004) investigated the use of self and peer assessment to minimize free-riding effects and better evaluate individual contributions to the final artifact. The use of online collaboration tool such as digital whiteboard may triumph over a face-to-face collaborative setting in this aspect as the medium provides a written record of the interactions between learners (Macdonald, 2003). These interaction logs can be analyzed to gain a deeper understanding of the collaboration and interactions of learners for identifying free-riders. The analysis of these logs may offer further insight into the process of problem solving by the learners, allowing for the attribution of marks to the process on top of the final product.

Extending from the aforementioned work, this study thus addresses the following research questions:

RQ 1. What are students' perceptions of the digital whiteboard in terms of acceptance, collaboration and learning motivation??

RQ 2. What are the patterns of collaboration that can be derived from trace data in digital whiteboards?

3. Methodology

A total of 28 year-one university students (by convenience sampling) from the faculty of computer science and information systems undertaking the course of data management participated in this research. The author and another fellow instructor co-teach the class of 34 students (6 students opted out of participating in this research). The data management course spans a total duration of fifteen weeks and covers the fundamentals of relational database which includes data modelling, data design (Entity-Relationship diagram) and database implementation.

The digital whiteboarding software – Miro (http://www.miro.com) was introduced to the students in week 2 of the course. In each lesson, the students were first introduced to the concepts to be covered in the class. Other than instructor elaboration on some demonstration exercises, in-class exercises were dispersed throughout the entire lesson. An active learning approach was undertaken where students worked on the in-class exercises on the digital whiteboard collaboratively in pairs or in groups of three. Due to social distancing measures in our institution, arising from the Covid-19 pandemic, part of the class may be attending the lesson face to face while the others are attending remotely.

The digital whiteboarding software, Miro facilitates discussions and interactions among groups with a mix of remote and in class students. Miro offers collaboration features such as chat and zoom integration and more importantly synchronous interaction features where participants can see each other's annotations and drawings on a real time basis. In a typical lesson, instructors went around the groups and facilitated by asking guiding questions.

The students were also tasked with a group assignment to be submitted by week 8 (which involves designing an ER diagram for a provided scenario) and most students disclosed that they worked in a mix of synchronous and asynchronous fashion for group discussion. The students were allowed to form their own teams with the restriction that teams must comprise of 2 to 3 members.

The students were briefed on the aims and details of the research and only those who provided informed consent filled in an anonymous questionnaire, adapted from (Türel, 2011), on the use and benefits of digital whiteboard. A five-point Likert scale (Likert, 1932) was used for measuring the intensity of responses for the questionnaire.

Students who used Miro for their assignments were also requested on an optional basis to share their digital whiteboard canvas anonymously with the instructors for analysis of the historical interaction events logged by Miro. A total of 7 groups shared their Miro canvas with the instructors. This research is approved by the university's Institutional Review Board (IRB).

The board history feature in Miro stores a list of historical actions performed by the logged in user. The logged information includes the user who performed the action, the date and time of the action and details on the specific action performed e.g. add, edit and delete and the object acted on e.g. text, line, shape, sticky note e.t.c. Miro offers a Representational State Transfer (Fielding & Taylor, 2002) Application Programming Interface (REST API) interface for developers to extend on the current capabilities of Miro but unfortunately does not provide for the retrieval of board histories through REST API. Thus, we developed our own Python program to web scrap (Mitchell, 2018) the board histories of the seven groups' canvases. The scrapped logs are stored as comma delimited files. We then developed dashboards to pre-process and visualize the logs.

From the raw logs, we compiled a count of the actions for each user by the type of actions i.e. edit, add and delete and the average duration between each action. Durations that are more than five minutes are considered as pauses. We regard learners who were working on the same Miro canvas as being in the same team. This is a reasonable assumption as learners were instructed to share and work on their assignment only within their own team. The questionnaire response is summarized in Table 1.

Table 1. *Summary of questionnaire responses on the use of digital whiteboard*

Question	**SA/A (%)**	**Neutral (%)**	**SD/D (%)**	**Category**
I feel comfortable with the use of digital whiteboard tool.	89.29	7.14	3.57	Acceptance
I look forward to my professor's use of digital whiteboard in class.	85.71	14.29	0	Acceptance
Digital whiteboard should be used for more classes.	82.14	14.29	3.57	Acceptance
Digital whiteboard offers more convenience when engaging in collaborative discussions with my course mates.	89.29	7.14	3.57	Collaboration
Digital whiteboard allows me to collaborate better with my course mates.	89.29	10.71	0	Collaboration
Digital whiteboard is useful in pandemic situation as it allows us to collaborate online on exercises and assignments	78.57	17.86	3.57	Collaboration
I can learn more when my professor uses a digital whiteboard.	96.43	0	3.57	Learning Motivation
The use of digital whiteboard increases my interest in class	82.14	14.29	3.57	Learning Motivation
Digital whiteboard allows me to learn more effectively.	60.71	35.71	3.57	Learning Motivation

The Cronbach's alpha (Cronbach, 1951) values in Table 2 are above 0.8 for all three categories of Acceptance, Collaboration and Learning Motivation, thus indicating high internal consistency among the questions within each category.

Table 2. *Summary of questionnaire responses on the use of digital whiteboard*

Category	**Mean**	**Standard Deviation**	**Cronbach's alpha**
Acceptance	4.153	0.767	0.897
Collaboration	4.31	0.618	0.849
Learning Motivation	3.99	0.757	0.935

The high averages of 4.0 and above for all three categories indicate the students' high acceptance of digital whiteboard, high perceived ease of collaboration and learning motivation (RQ1) with the use of digital whiteboard.

From the processed historical action logs, we constructed the visualizations listed below to address RQ4.

- Total duration in days (from the date of their first action to the date of their last action on the canvas) that each team spent on the assignment.
- Number of actions by day across teams.
- Number of actions and average duration between actions across users by teams.

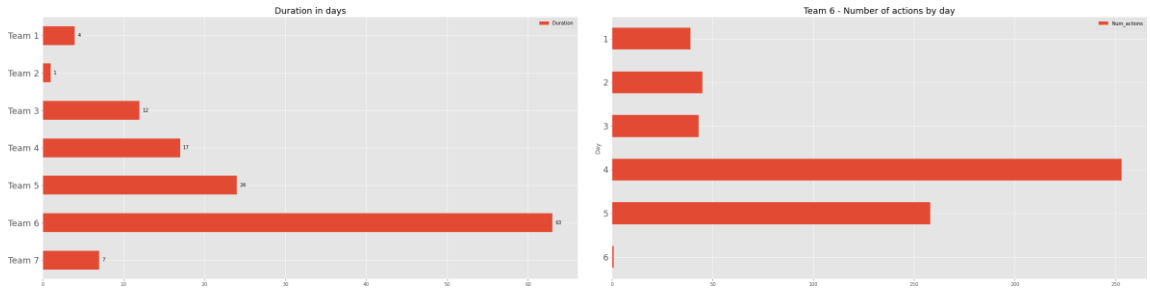

Figure 1. Left: Number of days spent on assignment, Right: Number of actions by day (team 6)

From Figure 1(left), we can see that team 2 worked on their Miro canvas for only a single day which is much shorter than the other teams. On the other hand, team 6 worked on the assignment for a longer duration as compared to the rest (almost triple that of the team 5). From the processed logs, we uncovered that team 6 started on the assignment earlier than the rest of the teams and worked on it till the due date. In Figure 1 (right), we drill into Team 6 for a breakdown of the number of actions by day. We sequence the day for the dates which the team worked on the canvas and summed up the number of actions performed by day. Thus, we can summarize from Figure 1 (right) that team 6 worked on the canvas consistently for at least five days. When we looked at similar graphs for other teams (not shown due to constraint of space), most of the other teams were working on the canvas for only two days.

To elucidate the contributions of individual members for the group assignment within each team, we constructed scatter plots of the number of actions by mean duration between actions by the individual members of the various teams (with the exception of team 2). We eliminated the records with has more than 50 actions as we noted that the initial copying and pasting of shapes and text from the template generated a huge number of actions. We are only interested in the edits and addition done by the students after this initial phase of copying and pasting. The duration between actions (in minutes) helps to distinguish between actions that does not require thinking e.g. moving of shapes from actions that require some time to contemplate (e.g. deciding on the relationship cardinality) which we will call "long actions".

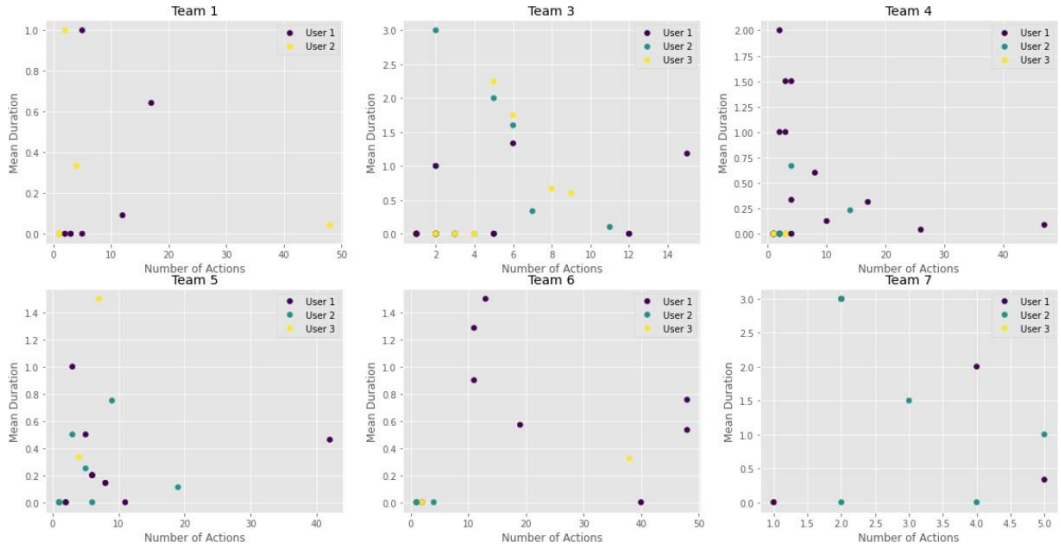

Figure 2. Number of actions and average duration between actions across users by teams

We can surmise from Figure 2 that across the teams, most of the members contribute to the assignment with non-zero number of actions with the exception of "User 3" in team 4 and "User 3" in team 7 (with close to zero actions). This offers us a quick way to identify potential free-riders which we may have to confirm further (e.g. by interviewing the teams or peer review). Focusing on the "long actions", we discover that the teams do have a mix of "long" and "short" actions with teams 4, 5 and 6 having more "long actions" as compared to the rest. When we further evaluated the ER diagrams of teams 4, 5 and 6, they are found to be more complete which correlates with more deep-thinking actions. We can also identify different team dynamics across the teams e.g. the contributions of members for some of the teams are evenly distributed but are uneven for other teams. To illustrate, both "User 1" in team 4 and team 6 dominates with proportionately more actions as compared to the other members. We postulate that the team dynamics factor could be further investigated on whether it influences the performance of the team.

4. Conclusion

From the results of the survey, we can conclude that the digital whiteboard is not only well-accepted by the learners but also perceived as fostering collaboration and leading to higher motivation. These address research question 1 which we set out in Section 2. In addition, we contend that assessment is difficult in collaborative work as much of the collaborative work occurs outside formal teaching hours. Typically, a major proportion of the assessment will be on the final produced output or artifact which leads to issues such as free-riding and difficulty attributing marks to individual contributions. We proposed to visualize the process of collaboration from the action logs recorded by the digital whiteboard Miro.

With these visualizations, we were able to discover differing interaction and collaboration practices among the teams as well as the contributions of individual team members within each team (e.g. some teams exhibiting uneven effort distribution).

In summary, we believe that our findings are significant as to the best of our knowledge, this is the first study which uses historical action logs from digital whiteboard to gain insights into the process and evidence of collaborative learning through visualization techniques. This work is just the tip of the iceberg in the use of digital whiteboard for collaborative learning. We acknowledge that the small sample size and use of only a single digital whiteboarding software may limit the generalizability of the study results. We intend to extend this work to cover diverse collaborative learning scenarios e.g. collaborative writing and with different digital whiteboard software.

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