Modeling Diffusion of Tabletop for Collaborative Learning Using Interactive Science Lab Simulations

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Abstract. Within the context of Roger's Diffusion of Innovation theory we propose a pedagogical framework for attributes that can significantly affect student adoption of collaborative learning environment like multi-user, multi-touch tabletop. We investigated the learning outcomes of secondary school students in India collaboratively using OLabs on a tabletop (EG1 = 30) vs. individually using at desktops (EG2 = 92). We analyzed the nature of communication, touch and non-touch gesture actions, position around the tabletop, focus group interviews, and pre and post test scores. Using Bass model the study also accounts for the inter influence of related group of potential adopter teachers who are likely to exert positive influence on students. The results revealed that learning outcomes on tabletop are strongly associated with innovation attributes like Relative Advantage, Compatibility, Ease of Use, Perceived Enjoyment, Perceived usefulness and Teachers support. Overall students expressed much more positive attitude to adopt tabletop technology for learning vs. desktop. We find that the mean group performance gain is significant with collaboration using tabletop and significantly greater than the group using desktops. We also find that the group interactions with the tabletop area significant factor that contributes to the group's average performance gain. However, the total time spent in while using the tabletop is surprisingly not a significant factor in the performance gain. Our findings contribute to the design of new pedagogical models for science learning that maximizes the collaborative learning potential of tabletops.

Keywords: Laboratory, Diffusion, Innovation, Simulation, Collaboration, tabletop, experiments.

1 Introduction

The diffusion of innovative learning technologies like interactive multi touch tabletop, tablets etc. and associated pedagogies in school education continues to garner tremendous research interest. Rogers (2003) observed that innovations like Tabletop have five attributes that influence the rate of their adoption -Relative Advantage, Compatibility, Complexity, Trialability, and Observability. As the elements of the theory are discussed, the challenges to tabletop adoption will be

R. Natarajan (Ed.): ICDCIT 2014, LNCS 8337, pp. 333–340, 2014.

considered. Educational activities like science lab experimentation may benefit significantly from interactive tabletop technology because it combines the face-to-face interaction style of traditional small group work. More often students doing science lab experiments collaborate because of the need to share the equipment hence the tabletop provides an ideal virtual learning environment for our study. The purpose of our study is to investigate student perceptions of tabletop as a collaborative learning tool for performing science lab experiments. Additionally we also explored whether collaborative learning environment of tabletop differs from individual learning afforded by desktops. An interactive simulation application called OLabs (Prema Nedungadi, Raghu Raman, 2011) was modified so that it allowed multiple students to collaboratively perform the experiment on the tabletop.In the recent years Tabletops have found their ways into educational learning environments. SynergyNet (Hatch et al. 2009) is a classroom environment where several multi touch tables are connected into a large network that allows for sharing of multimedia objects. Then there are tabletop applications that focus on learning numbers and sorting (Khandelwal and Mazalek, 2007) and concept mapping (Son Do-Lenh et al., 2009). Quadratic (Rick, 2010) is another educational Tabletop application which allows learners to explore algebraic expressions on a tabletop. Bryce and Robertson (1985) observed that in majority of the schools the assessment of science lab work is non-hands in nature with much more focus on the report writing skills. What is needed is continuous formative assessment of lab work to assess procedural, manipulative, reporting and observational skills.

2 Case Study: Factors Affecting Diffusion of Tabletop Technologies for Collaborative Learning

Bass (1969) proposed a mathematical model as a nonlinear differential equation for diffusion of an innovation in a group of size M. According to Karmeshu and Pathria (1980), in such a scenario adoption of innovation is due to two influences viz. external influence (mass media) which is a linear mechanism and internal influence (word-of-mouth) which is a non-linear mechanism. The differential equation giving the diffusion is,

$$\frac{dN(t)}{dt} = \big(p + qN(t)\big)\big(M - N(t)\big) \tag{1}$$

Where, N(t) is the cumulative number of adopter-students who have already adopted by time t, M is total number of adopter-students who will eventually use the innovation, p is the coefficient of external influence and q is the coefficient of internal influence. This equation yields the S-shaped diffusion curve. It is assumed that the carrying capacity M of the adopter-students remains constant. Now we extend the Bass model to account for the influence of teachers on students (Table 1, Differential equations for Diffusion) by defining the following terms -m total number of adopters who will eventually adopt the innovation; μ relative importance students give to teachers for their support ($0 \leq \mu \leq 1$); α proportion of teachers in the total population of potential adopters ($0 \leq \alpha \leq 1$).

Table 1. Extended Bass model with influence factors

	Adopter-teachers	Adopter-students
External influence	p_1	p_2
Internal influence	q_1	q_2
Total number of Adopters who will eventually adopt the innovation	F	S
Cumulative number of Adopters who have already adopted by time t	f	s

Based on Table 1, we formulate diffusion differential equations for

Adopter-teacher f(t)

$$\frac{df}{dt} = f(t) = (p_1 + q_1 f)(F - f) \quad (2)$$

Adopter-students with teacher influence s(t)

$$\frac{ds}{dt} = s(t) = (p_2 + q_2 s + \mu f)(S - s) \quad (3)$$

Combined teacher-student population m(t)

$$\frac{dm}{dt} = m(t) = \alpha f(t) + (1 - \alpha) s(t) \quad (4)$$

2.1 Research Model and Hypothesis

The tabletop's rate of adoption was investigated by assessing two groups of characteristics, which were the independent variables - innovation characteristics and environment characteristics. The most obvious advantage of tabletop is its large size, multi-user, multi-touch features that provides a rich immersive dynamic experience to the learners. We hypothesize that Tabletop's Relative advantage positively affects student's intention to adopt tabletop for learning (H1). Tabletop technology is compatible in its functionality with the preceding technology devices like desktop. We hypothesize that Tabletop's Compatibility positively affects student's intention to adopt tabletop for learning (H2). An important question is to what extent tabletop and related applications on them are perceived by users as complicated to use. We hypothesize that Tabletop's Ease of Use positively affects student's intention to adopt tabletop for learning (H3). Trialability is limited in the case of tabletop due to its initial high cost but users can still try the technology at electronic shops. We hypothesize that Tabletop's Trialability positively affects student's intention to adopt tabletop for learning (H4). We hypothesize that Tabletop's Observability positively affects student's intention to adopt tabletop for learning (H5). Upon adoption, individuals are more likely to use the tabletop that offer enjoyment more extensively than those which do not. We hypothesize that Tabletop's Perceived Enjoyment positively affects student's intention to adopt tabletop for learning (H6). We hypothesize that Tabletop's Perceived Usefulness positively affects student's intention to adopt tabletop for learning (H7). More often teachers and students are motivated to consider technology decisions that are sanctioned by the school management since those will have adequate support resources. We hypothesize that School Support for Tabletop positively affects student's intention to adopt tabletop for learning (H8). Teachers play a pivotal role in implementing innovations; their perception of the innovation will strongly influence their students thinking. We hypothesize that Teacher Support for Tabletop positively affects student's intention to adopt tabletop for learning (H9).

3 Research Methodology

3.1 Experimental Design

The study was conducted during a five day Science camp attended by over180 students. To ensure uniformity in performance levels and similar abilities selection of students was based on a minimum score of 90% in science in their grade 10 exams. None of the students had previous exposure to tabletop or OLabs but were exposed to using interactive educational content on desktops. A group of (EG1=30) students were randomly selected and divided into groups of 3 to participate in the collaborative tabletop study. To ensure diversity each group had members of both sexes and students in the group were from different schools to avoid any biases due to previous familiarity. Another group of (EG2=92) students were randomly selected for individual participation for the desktop study. The larger number of students in EG2 was solely due to the availability of large number of desktops. Both quantitative and qualitative measures were used to analyze the results. Pre and post lab assessment each consisted of 20 items, 5 each in the areas of procedural skills, conceptual skills, knowledge of equipment and reporting skills. Likert scaled questionnaire with 35 items was designed to evaluate student feedback. Qualitative measures consisted of analyzing the Video recordings for interaction among the students and a face to face interview with the students. All students were individually administered the pre and post-lab assessment. Next students filled out an online survey to capture their feedback.

4 Results Analysis and Discussion

4.1 Quantitative Analysis

Students had no difficulty in using the tabletop though none of them had prior exposure to working on a tabletop (based on the post-test questionnaire feedback). In terms of demographics both EG1, EG2 had about 50% split between males and females. The reliability of the nine factors had values ranging from 0.78 to 0.89 which according to Nunnally (1978) are acceptable. The discriminant validity for the factors confirms that the AVE (Average Variance Extracted) for each factor on the diagonal is higher than the correlations between the given factor and all other factors. The convergent validity was also good as AVE for each of the 9 factors were larger than 0.5Regression analysis was performed using all the 9 independent variables on the dependent variable intention to adopt tabletop. There is strong support for Hypothesis H1, H2, H3, H6, H7 and H9. The regression model was statistically significant ($p < .0001$) and accounting for 76% of the variation in intention to adopt ($R^2 = .76$). Since student's perception of teacher support emerged as a significant factor for adoption of Tabletop for collaborative learning, we looked at the shape of the resulting diffusion curve using intergroup influence adoption diffusion equations. It is intuitive to assume that the proportion of teachers is much less than that of the students. To illustrate different types of diffusion patterns we plot the m(t) (Equation 4) along with its two parts αf(t) and (1 – α) (s(t) for different set of parameter values of p's, q's, αand μ (Table 2).

Table 2. Set of parameters for different diffusion patterns with varying levels of teachers support

Case	Teacher parameters	Student parameters	Level of Teacher support (μ)	Proportion of Teachers (α)
1	$p_1 = 0.02; q_1 = 0.4$	$p_2 = 0.005; q_2 = 0.2$	0.3 (high)	0.2
2	$p_1 = 0.02; q_1 = 0.4$	$p_2 = 0.005; q_2 = 0.2$	0.005 (very low)	0.2
3	$p_1 = 0.02; q_1 = 0.4$	$p_2 = 0.005; q_2 = 0.2$	0.05 (low)	0.2

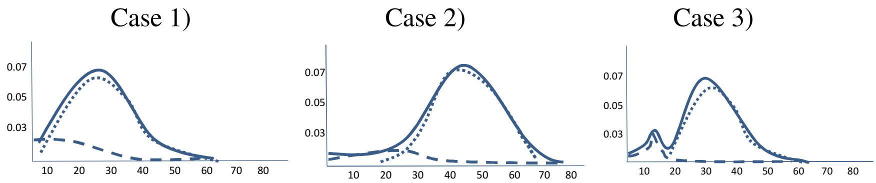

Fig. 1. Diffusion patterns based on students' perception of varying levels of teacher support

In Figure 1, Case 1) deals with the situation of high teacher support for students and results in a bell shaped diffusion curve. Case 2) deals with the situation of very low teacher support which results in delayed start of adoption by students but still results in a bell shaped diffusion curve. Case 3) where there is low teacher support, it results in a bimodal diffusion curve as teachers have reached their peak adoption levels before the students start adopting. It is easy to observe that low values of teachers support results in delay of diffusion among students.

4.2 Tabletop vs. Desktop

Students in EG1 expressed much more positive attitude to adopt tabletop technology with a mean score of 4.16 while the EG2 was slightly more than the middle of the range of scores (3.24).From the t-test, it is evident that the two experimental groups differed statistically significant in their intention to adopt tabletop and desktop for learning ($p < 0.001$, $p < 0.001$, respectively). Students in the EG1 perceived higher value for the tabletop based learning ($t = 5.73$, $p < 0.001$).

4.3 Video Analysis of EG1

To evaluate how the OLabs application on tabletop impacted collaboration among students we examined several measures like the number of touches on the tabletop (physical participation) and the number of times members in a group spoke while performing the experiment (verbal participation). Both individual and total touches and talk within a group where tracked. Successful completion of the experiment is another indicator of the group collaboration. It was observed that the students in a group focused mostly on the task and less on the interface. Frequent discussions were around "entering the values for the various configuration values" followed by touching the "the experiment procedure" tab and "theory tab". Though tabletop supported multiple concurrent touches we observed that they often choose to take turns interacting with the system and only sometimes worked concurrently.

Relevant research questions in this regard were

1. Does collaborative learning on a tabletop using interactive simulations like OLabs result in performance gain?
2. Are there significant differences in performance gains with collaboration using tabletop vs. individual learning of the same OLabs experiment with a desktop?
3. What are the collaboration metrics that contribute to the performance gain?

4.4 Performance Gain between Pre and Post Tests

A paired t-test was performed to see if the collaborative labs were effective in terms of increasing the average group scores between mean pre and posttests. For EG1, the mean percentage performance gain (M= 25.00%, SD=15.31, N=30) was significantly greater than zero ($p < .001$) providing evidence that the tabletop is effective in increasing the average group performance score. A 95% confidence interval about mean performance gain was (19.28%, 30.72%). For EG2, the mean percentage performance gain (Mean=19.78, SD=12.75, N=92) was also significantly greater than zero ($p < .001$). A 95% confidence interval about mean performance gain was (17.14%, 22.42%). In both cases the mean percentage is positive and the confidence interval does not contain zero and we infer that the mean difference is nonzero and positive. We conclude that collaborative learning of OLabs (EG1) with tabletop and individual learning of OLabs with desktops (EG2) were both effective in improving the performance of students. An independent-sample t-test scores assuming unequal variance shows a significant difference in performance gain ($p < .05$) and hence we conclude that performance gain was greater in EG1 than in EG2.

4.5 Regression Model for Collaborative Learning Using Tabletops

We analyzed the effect of both the number of touches performed by each student within a group and the total number of touches by the group on the performance gain. The number of individual touches by a student did not significantly contribute to the performance gain but the total number of touches (Total Touch) by the group was significant. The average total time spent by the group was also a significant factor in the performance gain ($p < .05$). This may be explained by the fact simulations in OLabs are highly interactive, the total number of touches would mean more interaction with the labs such as using additional variables, repeating the experiment etc. Though the group's total number of touch interactions was significant factor in both the group and the individual performance improvement, the individual touch interactions by a student was not a significant factor. This may be because the entire activity was done collaboratively with no part of the learning activity performed individually. Hence any student's interaction with the tabletop could contribute to learning for the other group members. From the audio recordings of each group session we found that groups spent an average 12.3% of the total session time talking among each other though the individual group talk time widely varied from 3.3% to 26.5% of the total session time. While analyzing the effect of amount of total talk time by each group to the average performance gain, we found that there was no significant effect on performance gain ($p > .05$) from the total talk time. Generally, we expect only the discussions about the subject to directly contribute to learning and hence to gain in performance. This may be a reason that the group's total talk time was not a significant factor in the regression analysis as it included both actual discussions that contributed to learning and also other items such as agreement, questions about using the tabletop etc. that may not contribute to learning.

5 Conclusions

Our study has provided a deeper investigation of multi touch tabletop for collaborative learning guided by the framework of Roger’s theory of perceived attributes. Our empirical results show that DOI theory operationalized in this study was successful in predicting adoption of tabletop for learning. The results indicated that attributes like Relative advantage, Compatibility, Ease of Use, Perceived Enjoyment, Perceived Usefulness, Teacher support were positively related to acceptance of innovation while Trialability, Observability, and School support were not. Application developers for tabletop and tabletop designers seeking to increase the rate of adoption of tabletop by students will be better served adopting strategies that address the attributes of the tabletop found to be significant in this study. Our findings show that the collaboration using tabletop had a positive learning outcome with performance gain significantly larger than in the desktop. The significant factors are the groups' total touch interaction with the tabletop, the total time spent by a group and the interaction between total touch and time. Student interactions as observed in the video and feedback after the testing sessions validated that tabletop is both appropriate and motivating for students to learn.

Acknowledgements. This project derives direction and ideas from the Chancellor of Amrita University, Sri Mata Amritanandamayi Devi and is funded by Amrita University. The authors would like to acknowledge the contributions of faculty and staff at Amrita University whose feedback and guidance was invaluable.

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