1. ABSTRACT

This paper examines the potential use of the Tablet PC-based Flash Cards Application (“application”) in a collaborative learning environment. The application provides the flexibility of handwritten input and the ability to share flash card decks. The application was deployed in an eighth grade geometry classroom at a girls’ school in Pittsburgh. Nine students participated in the study and each student was asked to individually create decks of flash cards reviewing the material that they had already learned (“review case”) as well as create separate decks previewing upcoming material (“preview case”). We randomly selected groups of students of different sizes, pooled their flash card decks, and measured the percentages of topics represented on the cards. The teacher's decks were used as the control. We found, in the preview case, that the decks of fewer students covered a higher percentage of material than in the review case. We also surveyed eight students to determine their criteria for selecting material when they created the cards. Half of the students created flash cards for material with which they were confident that would answer correctly, half created cards for material that they thought they should review more, and 3 out of 8 did both. The findings of this study gave us a better insight into the use of Tablet Flash Cards in a collaborative K-12 educational setting and also for higher education.

2. PROBLEM STATEMENT AND CONTEXT

2.1. Development of the Application

In recent years, several web based flash card programs and different intelligent testing algorithms were studied in the context of language training [2]. Microsoft also created a basic ink flash card program in its experience pack. However, it does not appear that these programs are developed using sound pedagogical principles to maximize the utility. So, we developed a new flash card application at Carnegie Mellon University (CMU) to increase the usability, provide more efficient and enjoyable ways to increase memory retention rate, and create more opportunities for ink flash card research. We iteratively created the application by following user-centric design methodologies and conducting usability studies in Human Computer Interaction (HCI) in order to make this application intuitive and useful in an educational context.
These methods include contextual inquiry, heuristic evaluation, and think-aloud testing on the prototypes and initial versions of the application. We also observed that students usually have two different types of sessions when studying with flash cards: card creation session and reviewing session. To suit their needs in both sessions, we created two modes in this application: the authoring mode [Figure 1] and the game mode [Figure 2]. In the authoring mode, they can easily draw on the cards which are especially useful in math educational settings. They can also easily draw figures or insert images on the cards. In the game mode, an algorithm reorders the card decks according to the individual student’s performance on each card by keeping track of the scores in order to present the next “best” card for review (this feature is called “smart testing”). The current version of the application also enables the users to review the cards sequentially as well. These features were added to the original application after studying the use cases in a classroom environment. During pilot studies, we found that the learning materials are often built upon previously learned materials and hence sequential presentation of material was important for new material or for the material that a student has not yet mastered. Application also allows images to be imported to individual cards and to entire card deck. This feature is especially useful in adding diagrams and grids for drawing graphs. These card decks can be saved as electronic files for exchange or further enhancement.

2.2. Application in Context of a Larger Study

In an effort to extend the application as an online collaborative educational tool, we wanted to first explore the benefits of the use of this application in a collaborative environment. More specifically, we wanted to first verify whether sharing decks with others would be more beneficial than using them alone. While observing the students’ use of this application, it was apparent that each student’s perception of her study material played a major role in forming the questions and the answers on the cards. Therefore, each student emphasized on different points as they selected the portion of the material. Hence we wanted to understand students’ criteria in selecting the material, the amount of the material each student covers individually, and the optimal number of group size for effective collaboration to increase the full coverage of the material.

2.3. Relevant Research

Our study was first motivated by Bonnie John’s study of “The evaluator effect in usability studies: problem detection and severity judgments” [3]. In this study, she focused on finding usability problems in software applications. She measured how the usability problem detection rate increased as the number of evaluators increased. Following a similar idea, we framed our study to measure the number of students needed to cover all or most of the study material in a Tablet Flash Card setting.

2.4. Research Question

Our research question in this study was to understand how the amount of the coverage of the study material varies as the number of students increase. Since the students create cards individually, it is apparent that the criteria that each student uses to select the topics and to form questions about chosen topics can vary widely. We asked individual students to create card decks for the materials that they had already learned in the class and for the upcoming material that they had not yet learned. Then we analyzed the student decks compared to controlled deck files from their teacher. We also conducted online surveys with the participants to see how their
selection criteria varied depending on whether they have already studied the materials or not. We also attempted to understand how sharing the decks would help in both cases as well as finding out the optimal number of students needed to cover the most amount of the material.

2.5. Deployment and Participants

The participants of this study were students from the Ellis School, an urban private girl’s school in Pittsburgh. Since 2004, Carnegie Mellon University has been helping eighth grade geometry students in Ellis school to use Tablet PC application programs for note taking, reading electronic books and classroom student-teacher interactions. The students and the teachers use electronic ink to write mathematical equations, draw diagrams, and highlight materials in the electronic books. The school has a one to one laptop program and especially the students in eighth grade Geometry class uses Tablet PC’s for all school related activities. For this particular study, all of the participants were from the eighth grade Geometry class. There were total of nine students in this class and these students were among some of the best students in eighth grade class.

3. SOLUTION EMPLOYED

As classroom activities and as homework, the students in eighth grade Geometry class have been using the application to create flash cards since 2008. In spring 2009, each student was asked to individually create a deck of flash cards covering the material that they had learned in the previous two weeks. Later, they created another deck previewing upcoming material. The decks were used to review and preview material for their geometry course. No specifics were given to the students as to which topics within the assigned materials shall be included in the card decks. We wanted to observe how each student decides which topics to include in the decks. The students freely created the questions and answers from the material. An example of a student created card is shown in Figure 1. To make it easy for the research team to access the decks, the students uploaded their deck files on a Google group a useful online collaboration tool.

![Figure 1: Card Authoring Mode](image1)

![Figure 2: Card Game Mode](image2)

The teacher created control cards for each of the topics within the assigned materials. The topics range from finding angle measures to finding arc length of a circle. Among the nine students, only five decks per each material were analyzable due to problems from the participant: some did not create the card decks, and some faced technical difficulties in uploading or emailing the deck files. A total of twelve decks were collected and analyzed including two decks from the teacher. On average, each deck had about seven cards for the review case and five cards for the preview case. For both preview and review cases, we randomly chose groupings of 1, 2,
3, 4, and 5 decks in a group to measure whether more students collectively cover a wider range of materials, and if so what would be the optimal number of students needed to cover most of the material. Figures 3 and 4 display the relationship between the group sizes (x-axis) versus percentage of topic coverage (y-axis). The averages were taken in order to measure the percentages of the material covered for different grouping sizes. A follow-up survey was used to determine the inclusion and exclusion criteria that they used when creating the decks as well as to find out how the participants felt about collaboration in learning. The survey questions and topic list references are available in additional resource section.

4. EVALUATION

4.1. Results on Coverage of Material

There were ten topics for the learned material and only three topics for the new material. A topic is defined as an important conceptual fact that student should master. The list of topics and their difficulty levels were generated by analyzing the teacher’s decks that were created based on teachers perception of what students should know. Then each of the students’ cards was analyzed to see which of the topics the card covered. The results from the deck analysis are given below showing the group size (x-axis) versus percentage of topics covered (y-axis) by the group.

![Figure 3: Review Material Case](image1)

![Figure 4: Preview Material Case](image2)

For the review material case, even when the decks from all five analyzable decks were combined, the combined deck only covered 80% of the materials from the control deck. For the preview material case, 100% of the material was covered by groups of four students or more. Thus, for the review case, we would need more than five students to cover most of the materials, whereas for the preview case four students are sufficient to cover all of the material.

4.2. Survey Results on Selection Criteria

Out of eight respondents, half preferred to study alone while the other half preferred to study in a small group of size two or three. All of the respondents felt comfortable sharing their deck files with their peers. Seven students used the application for science classes, three students used it for language courses, three students used it for social science classes, one student used it for music and art related courses, and one used it for other math courses. It was interesting to observe that three students noted that they like collaborative learning, because they feel “safer” or more “comfortable” that everyone’s would be on the same page with them. Furthermore, five students thought that in a collaborative learning environment they feel that others can correct them in case they were wrong. Half of the students also liked the fact that they get to learn more about different ideas and opinions from others. Some negative perceptions about collaborations were also noted by students. Seven students indicated that the biggest problem in collaboration in learning was that there are “free riders” who do not do their part in a group. The next biggest
complaints (five students each) were that when collaborating with others, the organization of the work is inefficient and that there are conflicts of opinions and ideas. Furthermore, it was interesting that for both the review of the learned material and the preview of the new material, half of the students created some of the cards for the topics that they did not know well enough so that they can review it more in the game mode; and half of the students created some of the cards for the materials they knew they would answer them correctly. Two students indicated that they created the cards for the materials they thought the teacher will ask them on the exams later, and two students responded that they created the cards without much thought.

4.3. **Limitations of this Study**

Creating flash cards were not part of the student grade and hence the incentive to participate was low. If grades were to be an influencing factor, that may have changed students’ behavior in creating the cards and interacting with the application.

A larger study is needed to be able to more accurately understand the different behaviors in creating the cards for the learned material and for the new material. The experiment must be repeated for a large group size in order to verify the optimal group size to measure the benefits in collaborative learning. Since this study was conducted at a girls’ school, it will be interesting to repeat a similar study in boys’ schools and coeducational schools to learn if gender plays a role in collaborative educational settings.

4.4. **Impact on the Students and the Teacher**

The students were eager to use new technologies in their classroom. They were excited to use an application that clearly demonstrates the benefits of Tablet PC’s. They started using the application in other classes and at home on their own. Many indicated that the application is useful for language, science, music, and art courses as well. The teacher also appreciated that this application was an effective way to encourage students not only to study on their own but also to share their knowledge with each other. Students were excited to use tools such as Google groups for collaboration.

5. **FUTURE WORK**

Our study focused on finding the ideal deck size in authoring mode. A study to measure the optimal number of repetitions of the cards in the game mode would also be a good follow up study. We can also study how we should choose the cards to merge with other decks. As shown from this study, sharing all the cards from everyone may not increase topic coverage drastically after four decks are merged. An interesting experiment would be to select cards based on a few criteria such as the students’ grades and students’ topic coverage in previous cards to see if we can have less number of users’ deck to create better topic coverage.

As vast majority of the students were concerned about the “free riders” problem that in traditional group settings some members of the group do not contribute. Hence it would be interesting to test different methods of collaboration in order to minimize the free riders problem. We were able to avoid this problem in the current study by encouraging students to share the cards only after they have created the cards individually first, instead of encouraging the collaboration in the creation of the cards. We can effectively share the cards by merging the decks of three to four students randomly and perhaps be able to cover most of the topics. This way, we can also satisfy both types of people: people who prefer to study alone and people who
prefer to study in small groups. Further research can be done to find the optimal number of cards, not just the number of students to achieve the best topic coverage.

By making the participation of this study voluntary and performance not counted towards their grades, we were able to introduce the application to the students as a fun way to help them study more effectively. The game mode also seems to have largely contributed in making their interaction with the application and learning experience more enjoyable. To this end, it would be interesting to study how grades and teachers’ recommendation (or their enforcement) affect students’ interaction with educational software and the likelihood of using it voluntarily outside of classroom environment.

Though it may take years of research, measuring the memory retention rate or the learning outcome of the material studied using the application would also be interesting. Especially because using electronic pen input as the new input modality decreases the cognitive overload in entering math equations and figures using keyboards or mouse [1], it may help students to focus more on study material itself rather than entering math on a computer. In addition, we should also investigate whether students learn better or remember for a longer period of time for the material in which that they had created the cards compared to the material that their peers have created and they merely used in the game mode. Even if the students remember better when they actually create the cards than when they just study their peers’ cards, it may still benefit them to study the cards that their peers created since their peers may include some material that they had missed. Further studies with larger sample sizes must be conducted to verify these hypotheses.

6. ADDITIONAL RESOURCES

The survey questions, topics, images, videos and software downloads are available from http://www.cs.cmu.edu/~ab/TabletFlashCards/

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8. REFERENCES

