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Development of Computer Game Based Instruction: The Periodic Table Game

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ABSTRACT

A collaboration between the Materials Research Science and Engineering Center (MRSEC) and the Integrated Science (IS) program run by the Center for Communication and Educational Technology (CCET) at The University of Alabama has been developing a computer game based approach to teaching Periodic Table concepts and facts to middle school students. The game is broken into seven different sections. There are three information centers, which are each paired with a game, and there is a "Dream Room" which provides an incentive for students to master the subject matter of the game. The three information centers focus on learning the elements, their positions in the periodic table, and trends in physical and chemical properties. The games then test the students' knowledge of the concepts and facts in the information centers. The game is currently in a late beta version and can be accessed over the web at http://www.mint.ua.edu/periodictable.
Preliminary results from a large evaluation exercise shows that classes that use the computer games improved significantly more on tests of subject matter than a control group.

INTRODUCTION

The idea of using computers to play games predates the development of the personal computer: one of the authors fondly remembers playing computer games on a DEC PDP-8. The idea of using computer games as educational tools can be traced back at least as far as work by Malone [1,2] and Malone and Lepper [3] in the 1980s. There currently exist various commercial educational computer games to teach students from pre-kindergarten onwards. In the mid 1990s Research Experiences for Teachers (RET participants working with The Materials Research Science and Engineering Center (MRSEC) at The University of Alabama explored using computer simulations to let students explore how simple machines, such as levers and inclined planes functioned. The success of this project lead to a more ambitious goal of developing the use of computer games to help middle school students master the content, organization and use of the periodic table.

PROGRAM DESIGN AND IMPLEMENTATION

The earlier simulations were programmed in MacroMedia Director, for the new suite of games,

the decision was made to program in Flash, as this was believed to be more flexible. Drawing on expertise and resources in the Center for Communication and Educational Technology (CCET) at The University of Alabama a suite of three games, three accompanying information centers and a "Dream Room" were designed. The Dream Room was envisaged as part of the reward system of the program. By reading their way through the information centers and successfully answering questions, and playing the games, the students would accumulate "carbon cash", which can be spent to furnish their own Dream Room with furniture of a variety of different

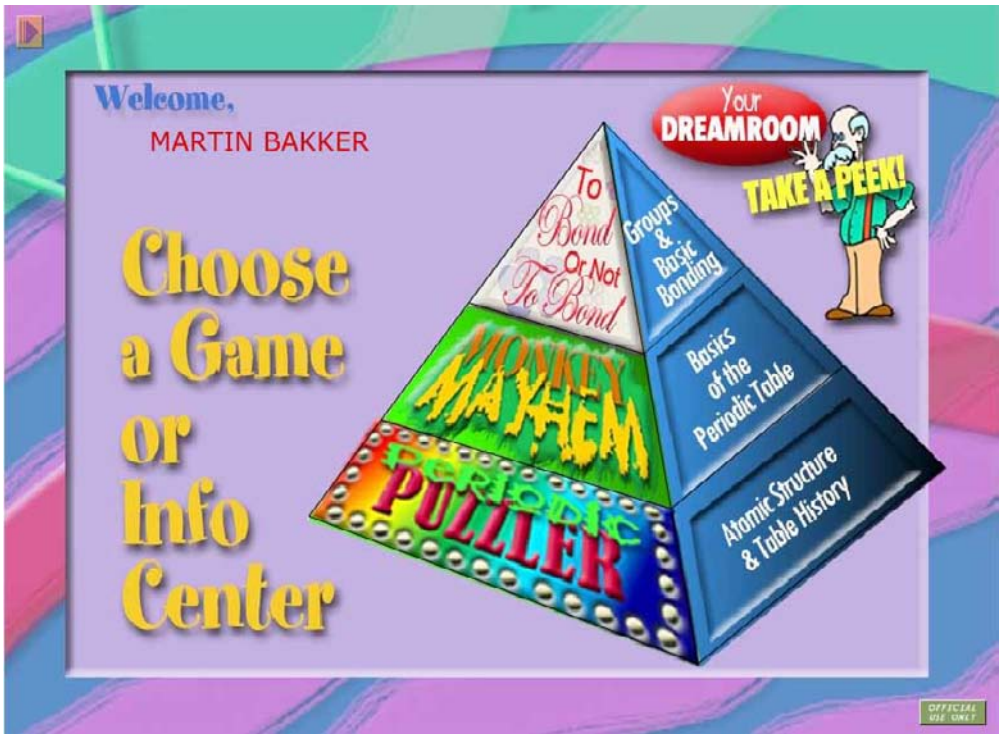


Figure 1. Central Menu of Periodic Table Game Suite.

styles. Figure 1 shows the control center menu. On the left hand side of the pyramid are links that take students to the three games, at the bottom is "Periodic Puzzler" which is a "Hangman" style game designed to help students learn the abbreviations of common elements of the periodic table. Paired with this is an information center that gives the students information about the structure of atoms and the history of the periodic table. This information center is reached by clicking on the link at the bottom right hand side of the pyramid. The middle link on the left hand side of the pyramid is for the game "Monkey Mayhem" in which the students are given a blank periodic table and then asked to place elements in their correct places. The students get three clues, consisting of the atomic numbers, abbreviations, row or group. Success is rewarded by an animated graphic in which a monkey falls off a vine with accompanying "Uh-Oooh…" sound effects. This game is paired with an information center, accessed by clicking on a link in the middle of the right hand side of the pyramid. This information center gives the basics of the layout of the periodic table. Again, various questions designed to check for student comprehension are included in the text sequence. The top most game is "To Bond or Not to Bond" which is accessed by the top link on the left of the pyramid. This game has the format of "The Dating Game" with the eligible bachelor/bachelorette being an element on the periodic table which is presented with three other elements and has to decide with which element he/she

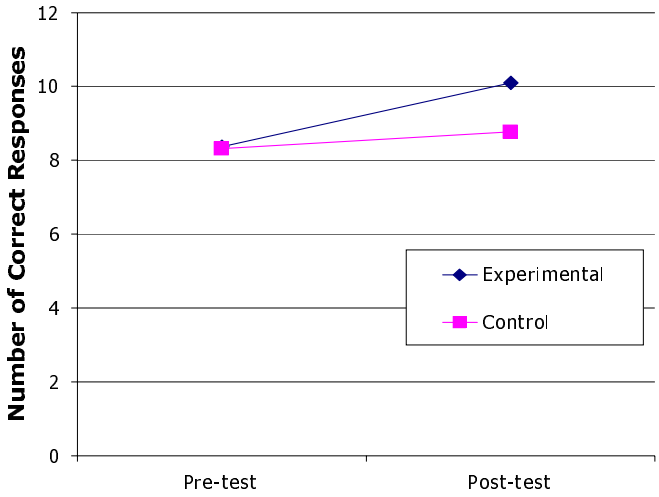
can bond. The students are allowed to ask various questions designed to determine which the appropriate element would be. In order to be able to play this game, the students must first earn a "matchmakers license", which requires them to correctly answer a set of questions on which elements will form (ionic) bonds. This game is matched with an information center on Groups and Basic Bonding, which discusses the chemical similarities of elements in a group, and how elements form ionic bonds.

The program was developed and written over a period of seven years, with a series of RET teachers helping develop the story board during the summers. The graphics were developed year round by a graphic designed on the staff of CCET. The programming was predominantly carried out during the academic year by a series of students employed by CCET and the MRSEC. Based on advice from our teachers, the game was designed to run completely from CD-ROM. This was because many computer administrators at schools are reluctant to allow installation of programs or to allow programs to store information on computer hard-drives. To enable students to save their information between sessions using the game, at the end of the game the computer gives the student a code that tells the program where the student finished and how much Carbon Cash he or she had accumulated. This can then be input at the beginning of the next session. The games can also be played over the Internet at http://www.mint.ua.edu/periodictable.

By 2004, although the Dream Room had not been implemented, the games and information centers were sufficiently complete that it became feasible to carry out an evaluation of the effectiveness of the program for teaching students about the periodic table. We had already carried out various informal evaluations in a variety of circumstances that indicated that the game was popular with teachers and students over a range of ages from 4th grade to high school. However, we had not run any sufficiently large-scale assessment to provide an appropriate, statistically valid, determination of effectiveness. The informal evaluation also suggested that many students were well motivated by the desire to maximize their numerical score, and that addition of the Dream Room might not be necessary for all students.

PROGRAM ASSESSMENT

In the summer of 2004 we began the process of designing the study and obtaining permission from the Institutional Review Board at The University of Alabama. Consent to the study was obtained in the summer of 2005. Early in Fall, 2005, requests to participate went out to principals and teachers at schools that had expressed interest in participating. These were drawn predominantly from schools participating in the Integrated Science Program run by CCET. The letters requested participation from teachers who taught multiple classes, so that one class could be used as a control group, which would not use the game. From 35 solicitations, a total of 23 teachers (or groups of teachers) were recruited. To each participating teacher (or group of teachers) we sent out sets of parental and student permission forms, sets of pairs of pre and post-surveys to be given out to each participating class before and after the periodic table section was taught, plus thirty CD-ROM class sets of the games. To maximize the return rate we also included prepaid, addressed envelopes for each set of surveys that the teachers would administer. It was not until the middle of the Spring 2006 that we began to receive the returned surveys. This was a consequence of the teaching plan in the participating schools, which results in the Periodic Table being taught in spring. At the time of writing we have received a total of four complete sets of surveys (pre and post treatment surveys) drawn from 6th, 7th and 8th grades.



Figures 2. Total number of correct responses for experimental and control groups.

Figure 2 summarizes the key result which is that performance averaged over the four classes is significantly higher for the classes using the game than for those classes not using the game. There did not appear to be any significant correlation with grade level.

We also included some questions designed to determine if using the games might change attitudes towards science, and if the impact of using the games might be affected by whether or not they liked computer games. For the question "*I think I am good at science"* **.** We found that the experimental group was more positive than the control group, with the post-test group being marginally more positive than pre-test. For the question *"Science is more fun for boys than girls"*. We found that those groups using the games were more likely to rate science as more fun for boys. This suggests that boys may be more comfortable using computers, or that use of computers was perceived as something that boys were better at. Interestingly, there was no observed correlation between how students felt about playing computer games ("*I like to play computer games"*) and the impact of using the computer games on student performance. There was also no observed effect on *"Science helps me solve every day problems"* and *"I think science is boring"*. It is possible that the planned inclusion in the programs of materials science examples will change the former response. The lack of impact on the latter question is perhaps disappointing, but may reflect the ability of the students to differentiate between playing a game and learning the contents of the game. It is possible that as the number of responses increases (since at present we only have 4 out of the 23 class sets returned) some of the questions that currently do not show significant correlations, may later show such correlations.

We believe that there are also lessons to be learned in the management of the development effort. The resources committed to the project were only sufficient to pay for student programmers who generally worked largely during the regular semester. The teachers responsible for the content of the games visited during the summer, and then returned to their schools which were all hundreds of miles from Tuscaloosa where the programming was being carried out. This resulted in relatively slow feedback cycles. To minimize this effect, development proceeded on a number of the modules in parallel, with the result that late in the development effort, all three games, two information centers and the dream room were being worked on simultaneously. Further, there was a rather high turnover in student programmers so

that a total of six programmers took part over the duration of the project. This significantly slowed down development, as each programmer in turn needed to become familiar with the whole suite of programs and with the overall concept. Turnover of teachers produced a similar result in the development of content for the games. The parallel development of the various games also made it difficult to carry out much in the way of formative evaluation, e.g. by using local school students to test the performance of the games, so that what was learned about one game could be used to shape others still in development.

Given the positive results determined from our preliminary analysis, we believe that the use of computer games as a teaching tool has merit. For more efficient development of future games we believe that a number of changes should be made in the program. It is clear that unless development is to be carried out by full time staff, it is important that each individual module should be designed to be completed within the involvement time of a single student, i.e. no longer than a year. This would therefore entail, either enlisting teachers in the local area who can be involved during a substantial portion of the school year to develop content, or choosing student program-mers with sufficient science background that six weeks of teacher time (during the summer) is sufficient to specify the content. The effort involved in the current evaluation exercise is not commensurate with the size of game that could be developed in one year. However, the age gap between the student programmers (late teens-early twenties) and middle school student (11-13 years) is sufficient that regular feedback is a must. This can best be achieved by collaborating with local schools, perhaps through the school science clubs. Another avenue for feedback that we have not yet explored is web access. The URL for the online version has only recently been publicized, and as yet contains only very rudimentary provision for feedback. It may be possible to implement a more sophisticated version that would allow student use patterns to be studied to gauge the success of various components of current and future games.

CONCLUSIONS

Preliminary assessment of a suite of computer games developed to teach middle school students the content and concepts of the periodic table has shown that students that use the games score better on tests of content than those who have not. There are also indications that the use of such games may change student attitudes towards science.

ACKNOWLEDGEMENTS

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