Learning Affordances of Collaborative Educational Multimedia Design by Children

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Abstract: We present and discuss the results of a project in which seven teams of elementary school students were involved in designing and implementing interactive multimedia resources in science for younger children. We found that students improved significantly in their science understanding and programming skills. We discuss the benefits and problems of integrating science content with multimedia design and discuss why the quality of dynamic and interactive components in students' multimedia production proved to be a better indicator of students' learning than the quantity of multimedia produced.

In recent years there has been a surge of interest in the use of multimedia in educational computer applications. Developers have added sound, graphics, photographs, and video to applications that were previously dominated by text. Various research efforts investigate ways in which multimedia features such as video [e.g., Cappo & Darling, 1996; Rubin, Bresnahan & Ducas, 1996], graphics [Rieber, 1994], or combinations of features [e.g., Jackson et al., in press] can contribute to students' learning. One underlying premise of most research is that providing students with multiple representational formats in a content domain helps to build their understanding and addresses the diversity found in students' learning and thinking approaches.

While these multimedia features potentially add value to applications, less attention has been given to approaches that provide learners with the opportunity to design and program their own multimedia software applications. To take a closer look at the potential of multimedia design for learning, we examined the cases of seven design teams that were involved in creating interactive multimedia resources about astronomy. We examine various program functions and the multimedia content of the final software products. Furthermore, we investigate how the team products themselves reflect the contributions of their individual authors. The purpose of these analyses was to illuminate some of the knowledge that young students have about multimedia design—as expressed in their products and in their interface design—and in which ways designing multimedia afforded learning opportunities for them.

Theoretical Background

Learning through designing multimedia applications is part of a larger effort to provide children with rich learning experiences [e.g., Brown, 1992]. It proposes software design as a new model of integrating programming with other learning that goes beyond learning programming for its own sake [Harel & Papert, 1991]. Software design requires students to consider interface design issues, deal with content aspects, and create, debug, and maintain their programs. In designing their own applications, students reformulate their knowledge by creating and implementing external representations in their software.

Multimedia features of software can facilitate this process, as they allow students to use and combine various representational formats in one medium.

While knowledge reformulation is an important feature of learning through software design, personal expression of one's ideas is another. With the increasing proliferation of commercial education and entertainment software, students have become accustomed to a software production level that makes extensive use of multimedia features. While students might have a wealth of experience in using multimedia applications, they have little knowledge about making multimedia software. Creating multimedia applications is a complicated and collaborative enterprise. In research and commercial contexts, groups of professional designers, programmers and content specialists work together for several months (Lammers, 1986]. Several studies have used this approach to study the thinking and learning of young software designers [Blumenfeld et al., 1991]. One series of projects focused on children designing instructional software for mathematics (e.g., Harel, 1991; Kafai & Harel, 1991] and instructional games in science and mathematics [e.g., Kafai, 1995; Kafai & Yarnall, 1996]. While these studies made special use of programming as a vehicle to foster children's learning of content, other studies used platforms such as hypermedia and authoring environments [e.g., Lehrer, 1991; Carver, 1991; Spoehr, 1995]. In this particular study, we decided to focus on the nature of the applications created by the students. We used the final computational artifacts as a starting point for investigating what kind of learning opportunities in science and programming was afforded by the design of an interactive multimedia resource and how this was related to individual students' contribution to the multimedia product.

Research Context and Participants

The project took place in an urban elementary school that functions as the laboratory school site for UCLA. The participating classroom was equipped with seven computers, one of each was set up as a workstation for the seven table clusters. An integrated class of 26 fifth and sixth grade students participated in this project (10 girls and 16 boys of mixed ethnic background) ranging between 10 and 12 years of age. Students were grouped in seven teams. One week before the start of the project, students were given an introduction to the main features of the Microworlds™ Logo programming environment. The assignment was to build an interactive multimedia resource about astronomy for younger students. Students worked 3-4 hours per week on the project for a period of 3 months, spending 46 hours in total of which 23 hours were dedicated to programming. Science instruction and programming time were combined. For this paper, we concentrate on the final software products which were analyzed in regard to the nature of their functions and the contributions of individual team members. The main data comes from a classroom activity conducted toward the end of the project in which each team met and determined which individuals should take credit for which parts of the final product (e.g., text, graphics, and animations).

Results

All seven teams finished a multimedia information resource at the end of the project. Our project observations documented that the completion process was not an easy one. For one, students had considerable problems in the beginning sharing work and computer resources, as each team consisted of 3-4 students each, but only one computer was available to all the team members. Furthermore, many students were learning Logo programming as they were designing their multimedia resource. While this provided an authentic context for students' learning, it also limited students' expression in the beginning to simple page designs. Later on, students started including animations of the life cycle of stars or the planet movements for lunar and solar eclipses. As for its science inquiries, each team posed several questions such as "Is there life on Mars?" or "What do we know about Black Holes?" which they intended to follow up in their science research. As the project progressed, these questions changed in focus and range. Some students reformulated their questions, while others added new ones which usually were more specific such as "What is the Big Bang?" In terms of the effectiveness of the overall intervention, we found that the design project was successful as a vehicle for both science learning and Logo programming development. To assess students' improvement in their knowledge of science content, we administered pre- and post-tests in astronomy. Our preliminary analysis showed significant differences for the pre- and post-tests in students' understanding of astronomy (Pre-Test: 31.5, Post-Test: 37.2, df 25, t: 5.65, $p<0.05$). Students' understanding of Logo also improved (Pre-Test: 13.3, Post-Test: 18.6, df 24, t: 4.38, $p<0.05$). In addition, in terms of programming skills, many students started out at ground zero, knowing no Logo at all.

Evaluation of Educational Multimedia Software: Team Contributions

Each interactive multimedia resource consisted of a set of interrelated screen pages that were linked together with the help of buttons or clickable objects that could be activated through a mouseclick. Some of the screens had combined media elements such as text and graphics while others worked only in one medium, text or graphics. The number of created screen pages differed considerably for each multimedia design team; yet this was not a good measure of production value because screens differed in their functionality. We defined three categories of screens: content screens, quiz/feedback screens, and information/ navigational screens. Table 1 provides an overview of the distribution of the different screen functions.

Content screens represent some piece of knowledge about the field of astronomy. They can take the form of text, pasted pictures, drawings, or any combination of those three design elements. The larger category of content screens was also broken down further to specify content animation screens. Content animation screens (CA) contain animations or simulations that exemplified dynamic aspects of the solar system such as the lunar eclipse, the life cycle of a star or effects of gravity. Only in one instance was the player given the possibility to set the parameters for a game-like animation (team3).

Many groups in the project decided to include *Quiz/feedback screens* to complement their multimedia resource. Quizzes usually asked questions about the content displayed elsewhere in the product but occasionally introduced new material. Most quiz screens contained one or two multiple-choice questions with buttons linking the user to feedback on his or her response. Feedback screens consisted primarily of simple pages exclaiming "right!" or "wrong!" in a very large font. Only in a few instances were users provided with additional information, as in the question "Can Martians Dance: Yes or No?" The answer page in either case replied "There is no right or wrong answer to this question, because we don't know if there are Martians on other planets" (team 6).

Another type of screen common to most group products was *Information/ navigational screens* that provided information about the designers themselves or displayed the title of the software and subtitles of topic areas, such as, "This is the Planets Section!" Other screens contained buttons or turtles which linked to different topic areas and provided information to the user on how to navigate the software, such as a table of contents. The graphical arrangements on these pages differed considerably. While in a few instances students took advantage of a graphical representation of the solar system as an entrance to different planets, many others just placed a variety of buttons on the page.

To summarize the design efforts by the teams, we see that students made extensive use of multimedia. A pervasive feature of all software applications is that students tried hard to emulate commercial software models. A comprehensive analysis of all seven final versions of the educational multimedia resource showed that all of them used "Point&Click" as their main mode of advancing through the program. They provided menu options, had navigational features such as title screens, introductions, content overviews and final screen and credit messages. In the instructional component, students (with the exception of one team) provided limited positive and negative feedback and sometimes explanations. But students' software did not provide the player with a "Quit" option, a feature that either many designers did not have time to implement or did not consider important. Furthermore, "Help" options were absent as well. Being beginning interface designers, the students were able only in a limited way to foresee their users' needs.

Evaluation of Educational Multimedia Software: Individual Contributions

While all students contributed to the final versions of their software, the levels of individual effort among the students in any group needed further examination. We decided to use the final artifacts themselves to not only document effort and equity, but also to examine the ways in which individual contributions to each group's final product have different affordances for product appearance, individual credit-taking, and learning benefits. To create a score commensurate with students' experience, we created a "design differentiated score" by looking at the types of screens created by individuals in the context of their total contribution. For that purpose, we used the three types of screens defined above, content screens, quiz/feedback screens, and information/navigational screens. Student differentiated scores for each type of screen were created using the same values as the raw scores. To create design differentiated screen type scores for each student we added up all their points for each category of screen. Thus, a student with a raw score of 8 screens might have 4 content, 3 quiz/feedback, and 1 information/ navigational screens.

Table 1: Distribution of Screen Page Functions

	CON	AN	IN	QU
Team 1	17	2	4	6
Team 2	15	3	3	11
Team 3	9	2	3	-
Team 4	12	1	6	13
Team 5	14	2	2	12
Team 6	23	1	6	18
Team 7	11	0	2	31

KEY: CON=content screens; AN=Animations; IN=Info/Navigation; QU=Quiz/Feedback

Table 2: Distribution of "Design Differentiated Scores"

Team 1	10	1	.75	2
	2.5	-	.25	-
	2.5	-	2.25	4
	2	1	.75	-
Team 2	1.25	1.5	1	5.5
	6.75	.5	-	1.5
	4.25	1	-	0
	2.75	0	2	4
Team 3	3	-	2	-
	1	1.5	1	-
	5	.5-	-	-
Team 4	3	1	6	-
	4	-	-	-
	3	-	-	-
	2	-	-	13
Team 5	3.33	1	.25	-
	3	1	.25	2
	4.83	-	1.25	10
	2.83	-	.25	-
Team 6	4.5	1	2.5	0
	13.5	-	1	10
	2.5	-	1.5	8
	2.5	-	1	0
Team 7	2	-	1.5	5
	8	-	.5	14
	2	-	-	12

KEY: CON=content screens; AN=Animations; IN=Info/Navigation; QU=Quiz/Feedback

	CON	AN	IN	QU

After examining the differentiated scores (see table 2), it appeared that they explained much of the deviation from expectations that showed up in the objective scores. Looking at screen types seemed to be a much more viable measure of participation than total screens. Students who created the most content screens and content animations were the same as those who displayed the most leadership, spent the most time at the computer, and showed the most developing astronomy knowledge. In the group products where the student with the most total screens was not the same as the most dominant and knowledgable student, we saw that the one with the highest raw score created mostly quiz/feedback and information/navigational screens. This finding is interesting not only because it lends support for measuring individual performance and contribution by some deeper means than merely counting the number of pages created, but it also provides a window into which types of screens are valuable for what purposes. In the following section, we discuss how the different screen types afforded different modes of thinking and learning benefits, and served different personal goals.

Discussion

Working on different multimedia functions served different goals for the designers, in both science content and multimedia learning. While informational/ navigational screens presenting tables of contents, title pages, or personal information about the designers may not necessarily contain science content, they have definite value in terms of technological fluency. Making tables of contents, main title pages, and topic area title pages requires taking the perspective of the user and considering what he or she would find most helpful in navigating the software. Navigational screens are not by nature devoid of content, as illustrated by the comparison of the solar system model title page and buttons title page shown earlier, but many of the information/navigation pages designed by students in this study had little or no content. The process of making such pages is relatively easy, since no animations are required, no astronomy research is required, and little programming is necessary other than linking buttons.

Quiz/feedback pages afford several benefits from a software design perspective. For one thing, the type of drill-and-practice quiz designed by most groups is a "quick and dirty" way to add interactivity to the software. In fact, when asked by researchers why they were making a quiz, the students often responded that it was because the users would want more interactive features. Making a quiz takes relatively little time, when all that is required is a series of questions with buttons leading to pages that say "right" or "wrong." Another benefit is thus that students who felt that their contribution was too small were able to increase the number of pages they created by adding a quiz on some topic at the last minute. From a science learning perspective, making quizzes does not allow the designer to experience the maximum benefits of the software creation process. Most quizzes in this project were a disjointed set of questions with little or no relation to one another, followed by feedback pages which gave no explanations of the correct answer. The process of designing a quiz such as the ones we saw may not help the designer develop systemic understanding in science, since a quiz only requires that he or she know the right answers to a series of unconnected science facts.

Content/animation screens are the most difficult to create, but they also afford the most learning benefits, both in terms of technological fluency and systemic understanding. Even the most basic kind of content page, one with only text and/or pictures, requires deeper levels of thinking about astronomy than the disjointed kind of knowledge represented by a quiz. Because students had to think about their users, 3rd and 4th graders, they had to write all the text sections in their own words and explain astronomy phenomena in language that younger students would understand. This consideration discouraged practices such as cutting and pasting of text from the Internet or copying word-for-word from books. Opportunities for even deeper thinking about users, programming, and the subject matter are afforded by more elaborate content pages, which use animation to depict some astronomy phenomenon. Creating animations requires the designers to learn Logo beyond relying on the basic point-and-click controls of the Microworlds system, because they have to direct the turtle in complex patterns and series. Most importantly, animations afford remarkable growth in systemic understanding. They require the designer to comprehend something well enough to create a model of the whole phenomena, as opposed to merely possessing a descriptive understanding of "what happens."

From the preceding analysis and discussion it is clear that instructional multimedia development is a challenging enterprise for young software designers (as it is also, incidentally, for most professionals). One could argue that the concurrent learning requirements might have hindered more than helped students. On the other hand, while schools traditionally introduce these subjects sequentially, we see a special synergy in learning them together at the same time. For one, it is difficult to imagine a course about multimedia design without students being engaged in designing media about something. Design has to be situated within a particular context or domain, so that designers as well as users can judge the value of their implementations. Furthermore, situated multimedia design provides an opportunity for the learners/ designers to approach subject matter from a different vantage point than their own. Instructional design, as implemented in this project, affords particular learning possibilities not only for the designated user of the instructional material but also for the instructional designer. We found that interactive and dynamic aspects of screen designs provided a good indicator for learning that integrated the programming and science. The development of instructional animations facilitated students' better understanding of systematic aspects of science while it led them at the same time into more sophisticated programming and vice versa.

Designing multimedia software presented students with complex issues, some of which became evident in the previous discussions. Students needed to coordinate multiple demands in designing and implementing their work. Based on our observations and analyses, we found that elementary students' experiences and associated conceptions do not adequately prepare them for managing long-term, less well-defined design projects, which require more flexibility and iterative planning strategies. Furthermore, we found that students need more support in their collaborative work if the design situation is to be an effective learning context for each individual team member. It is obvious that the transition from a multimedia consumer to a multimedia producer is not an easy one. Yet the potential benefits make it a worthwhile learning experience.

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