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ABSTRACT

This paper investigates the effect of engaging students in designing interactive multimedia programs. The design process has been shown to heighten motivation and to develop skills in project management, research, organization and representation, presentation, and reflection. At the same time, previous studies have also revealed that it is necessary for teachers to implement and sustain learner-as-designer environments by thoroughly explaining design knowledge and design issues. The semester-long study lasting approximately 18 weeks described in this report implemented such an environment with a four-phase model in which students: (1) received explicit instruction about the design process; (2) took part in a simulated production environment; (3) interacted directly with clients of the programs; and (4) interacted directly with multimedia experts, some of whom were guest speakers and some of whom coached the students throughout the semester. The treatment class consisted of 24 high school students from grades 10 through 12 of whom 71% were minority students and 16% were considered learning disabled. Students were divided into four teams, three of which opted to assemble multimedia presentations on separate topics for the local children's museum, and one of which decided to develop a CD-ROM yearbook. Students were asked to complete questionnaires, to list and prioritize design tasks, and to submit to observations and interviews. Their comments, along with statistical data, shed light on the value of various collaborative activities and about their growing sense of technical compete\` and self-efficacy. (Contains 18 references and 7 tables.) (BEW)

The Effect of A "Learner as Multimedia Designer" Environment on At-Risk High School Students' Motivation and Learning of Design Knowledge

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RUNNING HEAD: Learners As Multimedia Designers

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RESEARCH FRAMEWORK

A distinction has been made between learning *from* computing and learning *with* computing (Jonassen, 1994). According to Jonassen, learning *from* computing refers to situations in which computers are tutors. Computers "direct the activities of the learner toward the acquisition of pre-specified knowledge or skills" (p. 4). Learning *with* computing, on the other hand, emphasizes the use of computers as cognitive tools to extend human minds and help learners to construct their own knowledge. In this paper, we will examine one way of learning *with* interactive multimedia/hypermedia technology: Engaging students in designing multimedia programs.

In a learner-as-designer environment, learners, instead of merely receiving information from computers, become an intellectual partner with the technology and engage in a constructive learning process (Salomon, Perkins, & Globerson, 1989). The emphasis is on using multimedia tools to assist in processing information meaningfully and in integrating new knowledge with prior knowledge. As designers, learners are given the opportunity to be creative and pursue actively their own intended goals. According to Seymour Papert, "better learning will not come from finding better ways for the teacher to instruct but from giving the learner better opportunities to construct" (1990, p. 3). Because of its nonlinear and associative characteristics as well as its use of various media, interactive multimedia is considered to be capable of assisting information presentation, representation, and construction (Nelson, & Palumbo, 1993) and capable of facilitating this learner-as-designer process (Jonassen, 1994; Lehrer, 1993).

Designing interactive multimedia programs is, however, a complicated and challenging task. This designer role calls for many critical thinking skills. Sixteen major thinking skills have been identified that form five categories: (1) project management skills, (2) research skills, (3) organization and representation skills, (4) presentation skills, and (5) reflection skills (Carver, Lehrer, Connell, & Erickson, 1992). Each of these skills has its own place in the entire development process, and is needed for producing a successful program. The development process, from the inception of an idea to the finished product, involves not only exercising the aforementioned thinking skills but also learning various multimedia tools, working with team members, working against a deadline and, more importantly, making a strong commitment. As the practice in the real world suggests, multimedia development relies heavily on various talents in a team (McDaniel & Liu, 1996). Whether a team member is a programmer, a graphic artist, a designer, or a manager, collaboration among team members is crucial. Although each member will have his/her distinctive role, the success of a multimedia program depends on constant communication and understanding between team members and their working together to reach the goal. Such collaboration and group interaction provides a concrete and meaningful context for enhancing cognitive development through social negotiation (Lehrer, Erickson, & Connell, 1994).

Several research studies on examining learners as multimedia designers show some encouraging results. Lehrer, Erickson, and Connell (1994) reported a study in which ninth-graders created hypermedia presentations on America history for other students to use. Their study showed that the designing process helped students to inter- lize various design skills. Students reported increases in mental effort and involvement, interest, planning, collaboration, and individualization (Lehrer, Erickson, & Connell). Spoehr (1993) found that designing in hypermedia could help students develop more complex knowledge representations and assist the development of their thinking skills.

Literature on motivation and classroom learning has shown that motivation plays an important role in influencing learning and achievement (Ames, 1990; Dweck, 1986). Beichner (1994) described a study in which junior high schools students used a multimedia editing program to produce information screens for zoo visitors. The result showed that students were highly motivated and often spent extra time working on the project. The study by Lehrer et al (1994) found that students' time on-task increased significantly over the course of successive design projects, and the design process helped them to make the transition from receivers of knowledge to authors of knowledge.

RATIONALE OF THE STUDY AND RESEARCH QUESTIONS

Designing a multimedia program integrates a variety of activities, incorporates a wide range of thinking skills, and "taps a diverse set of skills" (Carver et al, 1992, p. 388). The comprehensive nature and extensiveness make it a unique learning opportunity, an opportunity that can lead to the development of highly valued mental skills important for learning. The instructional benefits of such a learning-with-technology approach are obvious. However, research also indicates that implementing a learner-as-designer environment is not an easy task. Indeed, any instructional situation involving such a process requires some extent of "adventurous teaching" (Sheingold, 1991). One important issue for designing such an environment is the extent to which the design knowledge, design discussions and design skills are made explicit to the learners. In the study by Carver et al., it was found that explicit discussions of design skills organized by the teachers were far from sufficient and, therefore, students lacked an understanding of the overall design process. Their data revealed that students, though acquiring individual skills, continued to need help from adults in putting together a project. They concluded that "the challenge to be met here and elsewhere is the design of learning environments that allow students to develop their own interests, yet provide students with comprehensive skills that can be applied in a wide range of potential contexts" (Carver et al, p. 402). They point out that "...explicitness and practice are the key ingredients for success" (p. 401).

In an effort to meet this challenge, we used the cognitive apprenticeship model (Collins, Brown, & Newman, 1989) to construct a learner-as-designer environment simulating a real-world multimedia production house. Students were given with the opportunity to work with a client, a local Children's Museum and/or their school. They were provided with a four-phase multimedia design model: (1) Planning, (2) Design, (3) Production, and (4) Evaluation and Revision. This design model incorporated many steps in Lehrer's instructional model (Lehrer, 1993) and many design steps used by local multimedia developers (McDaniel & Liu). (A detailed explanation of the model was provided in *method* section.)

In this learner-as-designer environment, the explicitness of the design process was implemented in several ways: (1) direct instruction about the design process; (2) a simulated multimedia production environment in which each student had chosen or was assigned a role of being a programmer, a graphic artist, a project manager or all three; (3) direct interaction with the clients of the programs; and (4) direct communications with multimedia experts. The four-phase design model was presented to students during the first week of the class. Students were then engaged in various design activities, ranging from the brainstorming of topics for development to visiting and making observations at a children's museum to get a sense of what would worked for young children; from evaluating commercial multimedia CDs to learning various multimedia tools. Students had the opportunity to listen to several guest lectures by local multimedia experts on their experiences of designing multimedia programs. They also participated in field trips to local multimedia production houses. In addition, a graduate student and two people from a children's museum, one of them an experienced multimedia educator and the other a graphics artist having years of experience in multimedia production, worked closely with the students throughout the semester. Student learning was scaffolded in the following ways: (1) explicit design instruction; (2) learning multimedia tools; (3) coaching by the teacher, the museum representatives and the graduate student; and (4) interaction with various multimedia experts. Assessment used in the study (questionnaires and interviews) provided additional scaffolding for the students (Lehrer et al.). This collaborative design environment was meant to have an added value in that it provided an opportunity for students to design multimedia programs for a real audience and to work with multimedia experts.

The purpose of this study was to examine the learning benefits of this learner-as-designer environment and its impact on the students. Specifically, the following two research questions guided this study:

(1) What is the effect of this "learner-as-designer" environment on students' motivation?

(2) How does such an environment contribute to students' learning of design knowledge?

METHOD

Sample

Two classes of students from a high school in a mid-sized Southwestern city participated in this study. The school is an inner city high school with a large minority student population consisting of: Caucasian = 31%, Hispanics = 58%, African Americans = 11%. About 45 percent of the students are from low income families, 10 percent are qualified as Limited English Proficiency (LEP) students, and approximately 60 percent of the population are considered to be at-risk for not finishing high school. These two participating classes reflected the demographics of this minority dominant school.

The treatment class consisted of 24 10th-, 11th-, and 12th- graders from a computer class where the teacher engaged students in designing multimedia programs. Seventy-one percent of the treatment class were minority students (42% = Hispanics, 17% = African Americans, 12% = Asian Americans or American Indians), and 16% of the class were considered to be learning disabled (LD) students. The control group consisted of 22 11th- and 12th- graders from an intact computer class in which various computing tools were taught (72% minority: 54% = Hispanics, 9%= African Americans, 9% = Asian Americans). Although there were 24 students total in the treatment class and 22 total in the control class, only those who had completed all the instruments given were included in this study -- sixteen from the treatment class (14 male, 2 female) and fifteen (9 male, 6 female) from the control class.

A treatment class and a control class were used to understand the effect of the "learner-as-designer" environment on students' motivation. Students in these classes were similar in age and ethnic background. Both classes were involved in computing.

A Learner-as-Designer Environment

The treatment was a learner-as-multimedia-designer environment. The students in the treatment class were told, at the beginning of the semester, that their goal was to develop a multimedia program for other people to use. The class met everyday for 90 minutes for 18 weeks, a total of 135 classroom hours. The organization of the class followed the four-phase multimedia design model mentioned earlier. Students were given the opportunity to work with the local children's museum. During the *planning* phase, the four-phase design model was presented to the students. Lectures on how to make a successful multimedia program were given by local multimedia experts. Students were engaged in brainstorming sessions and making decisions on what to create (the content), whom to create for (the audience), and how to develop the program (the process). Many topics were proposed for inclusion. After discussic.. and negotiation considering their own interests, the desires of the museum clients, and time factor for completing the project, students formed four teams. One team decided to work on a demonstration of an electronic yearbook for the school, and the other three decided to create a virtual museum for the Children's Museum with three different topics (physics, dinosaurs and history). All groups evaluated some commercially available multimedia CDs and noted the features that they liked and the ones that did not work well. This exercise was intended to help students develop their critical judgment and learn from both the good and bad features of the commercial products. They also visited the Children's Museum to get a sense of which exhibits were effective for young children and which exhibits were not. They used this information as the starting point for their brainstorming sessions.

In the *design* phase, students were engaged in defining and refining the topic, subtopics, the age level of the audience their programs would target at and strategies to use for presenting information. Each team created a flowchart or a storyboard, detailing how each screen was related to others and the overall structure of the program. Each team member chose or was assigned the role of a researcher, a graphic artist, a programmer, a project manager, or an animator, depending on his or her background and the program's requirements. Some students assumed more than one role, while some took on different roles at different times. The storyboard/flowchart was realized on the computer during the *production* phase. They learned some of the state-of-art multimedia tools including Adobe Photoshop, and Macromind Director. Claris Works and SuperPaint were also among the programs used. Although some students had knowledge of Claris Works and SuperPaint from previous computer classes, few knew

Photoshop or Director. None had participated in a similar learning context before this class. Students drew all the graphics, recorded their own voices and created all the animation from the scratch, so as not to violate copyright laws. Then all the pieces were assembled into the final programs. Like practice in the real world (McDaniel & Liu, 1996), the *evaluation and revision* phase was intended to be a dynamic and interactive process in that the programs were being evaluated on a continuous basis by team members, members from other teams, and students in other classes. Revisions were made immediately.

The students had access to three Power Macintosh computers (received about two months after the semester started), eight Mac LCIIIs, one Mac 575, one Mac 520, a Cannon Xapshot camera, and a color scanner. The computer equipment was, however, spread in two separate rooms due to the constraints of physical layout of the classrooms. The two main programs used, Director and Photoshop, could only run on the three power Macs, the Mac 575, and two of the Mac LCIIIs because of their large memory requirements. Students in the four teams, therefore, needed to share the available computer resources.

A multimedia educator as well as a graphics artist from the Children's Museum worked closely with the three museum teams. One graduate student from a local university who had experience in multimedia development worked closely with the CD-yearbook team. The teacher acted as the project manager for the entire class overseeing the various phases of the design and production process. During the semester, students made trips to local multimedia development companies, multimedia users group meetings, and a multimedia graduate class at a university to learn and share their experiences. At the end of the semester, students had an open house to demonstrate their programs to parents, administrators, and the local industry.

The control group came from an intact computer application class, in which various computer-related topics were taught. The topics covered included word-processing, database, spreadsheet, telecommunication, and desktop publishing. The students in the control group had access to 30 286-PCs, 1 386-PC, 4 486-Dell computers, 1 color printer and 1 black & white scanner.

Data Sources

The data sources for this study consist of both quantitative data (instruments to the treatment and control groups) and qualitative data (observations and interviews from the various perspectives, and analysis of students' multimedia programs). The triangulation of the data helps to provide a better picture of the environment under study.

Motivation Questionnaire. To assess students' motivation of working in this environment, a 26-item questionnaire was used. This questionnaire addressed five areas of motivation, and was taken from the Motivated Strategies for Learning Questionnaire (MSLQ) by Pintrich, Smith, Garcia, & McKeachie (1991). The areas addressed are (1) intrinsic goal orientation (4 items), (2) extrinsic goal orientation (4 items), (3) task value (6 items), (4) control of learning beliefs (4 items) and (5) self-efficacy for learning (8 items). Examples from this instrument are "In a class like this, I prefer course material that really challenges me so I can learn new things," and "I am confident I can learn the basic concepts taught in this course." A seven-point Likert scale was used with 1 being "not at all true of me" and 7 being "very true of me." This instrument was given both to the comparison and treatment groups at the beginning as well as at the end of the semester.

Project Design Questionnaire. A 60-item questionnaire on various design activities developed by Lehrer, Erickson, and Connell (1994) was used.[1] It uses seven-point Likert scale with one being "not describing me at all" and seven being "describing me very well." These 60 items address nine categories of design: planning (8 items), searching information (8 items), presenting information (8 items), connecting ideas (5 items), audience (3 items), collaboration (8 items), mental effort and involvement (8 items), interest (8 items), and individualization (4 items). Examples of this questionnaire are "I make sure I understand all of the topics before I start putting my presentation together," "I often use illustrations and other pictures in my projects," and "Overall, I feel positively about working with others on a project." This

[1] The original list consists of 66 statements. Six items were not included because of their irrelevance to this study.

questionnaire was administered to the treatment group as a pretest and as a posttest. The Cronbach alpha reliability coefficient for this questionnaire was .97.

Design Task Listing and Ranking. Students were asked to list the tasks they needed to do to create their multimedia programs (Lehrer et al, 1994). For each task, they were asked to list what had helped them to accomplish the task and what had hindered them. They could list as many tasks as they wanted to. For example, one student listed "storyboarding" as a task needed for the project. "Working in a group" was listed as a helpful strategy for completing the task and "taking a lot of production time" was listed as an obstacle for the task. After completing the design task listing, students were given a list of 18 tasks relevant to their project development and asked to rank the tasks according to their relative importance (Lehrer et al). Examples of the given tasks are "Think about the best way to present an idea," "Make video clips," and "Discuss with your team what information to include." These two instruments were given to the treatment group at the end of the semester.

Observations and Interviews. Observations of the class activities for the treatment group were made throughout the semester. Observations by the teacher, people from the museum, and the graduate student were also obtained through the interviews. The observations focused on the tasks students were performing, their time on-task, communication among the team and with the teacher and the clients. During the semester, interviews were conducted six times with each of the teams on their design and thinking process.[2] Thirty percent of the interviews with each team was unstructured, allowing students to take the interviews into unanticipated directions. Seventy percent of the interviews was structured. The interview questions concentrated on the following aspects: (1) the tasks they performed during that particular period of time, (2) their time on-task in school and out of the school, (3) the various design skills they used and talked about, (4) work among the team members -- division of work, sharing among members, problems and conflicts, (5) their feelings, and attitudes, (6) the tools and techniques they learned, and (7) what they had

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[2] At first, we wanted to videotape the class activities. However, after an initial videotaping, we realized that videotaping technique would not work well in this context, because students were too mobile, moving from one room to the other constantly to share the computer resources among the teams. Focusing on one team with one video camera at a given period was not possible.

accomplished since the last time interviewed. Students were also interviewed about their thoughts and feelings toward specific activities such as field trips to local multimedia companies, talks by guest speakers, and evaluation of their products by peers. The same questions were asked with all four teams to provide commonalty across the interviews. Follow-up questions were asked whenever clarification was needed or more information was desired. The questions on many of the aspects mentioned were repeated over several interviews to provide a better and more complete picture over an extended period of time. Respective interviews were also conducted with the classroom teacher, the people from the Children's Museum, and the graduate student, once at mid-semester and once at the end of semester. The time for each interview ranged from 10 minutes to 45 minutes, depending on the available schedules of the interviewees. These interviews produced five and half 90-minute tapes, a transcript of 165 single-spaced pages.

Evaluation of Students' Programs and Their Technical Skills. The programs that the students developed were evaluated on the following categories: (1) content -- complexity of the content, and appropriateness of the content to the target audience, (2) structure -- links between various concepts, (3) screen design -- how well the message was understood through the use of color, font, and icon; screen layout, and navigation, (4) use of media -- the use of graphics, animation, audio and video, and (5) creativity -- originality of the content and design, originality of the graphics, video and animation. At the end of the semester, each team was asked to demonstrate their programs, explain the various components, rationale for using certain media, and procedures for creating certain segments of the program.

Procedures

This was a semester-long study, lasting approximately 18 weeks. At the beginning of the semester, both the treatment and control groups were given the motivation instrument. The treatment group was also given the project questionnaire. Each class then was engaged in its own instructional activities. The students in the treatment group were observed throughout the semester and each of the four design teams was interviewed approximately every three weeks for a total of six times. At the end of the semester, the motivation instrument was again given to both the treatment and control groups. In addition, the treatment group was also given the project questionnaire, design task listing, and ranking forms. Students' programs were collected and evaluated.

Analysis of the Data

To determine the effect of this "learner-as-designer" environment on students' motivation (research question 1), five two-factor mixed ANOVAs were run with the grouping (treatment vs. control) as a between-subjects independent variable and the data collection points (pre vs. post) as the repeated measure independent variable. The dependent variable for each respective analysis was the pre and post scores for intrinsic goal orientation, extrinsic goal orientation, task value, belief and self-efficacy.

To find out how such an environment contributed to students' learning of design knowledge (research question 2), nine one-way ANOVAs with repeated measure of the pre/post data collection points were conducted. The dependent variable for each respective analysis was the pre and post scores of each of nine categories in project questionnaire: planning, searching information, presenting information, connecting ideas, audience, collaboration, mental effort, interest and individualization. Data from Design Task Listing and Ranking forms were analyzed descriptively.

The interview data was first transcribed, then chunked, coded and categorized following the guidelines by Miles and Huberman (1994). A two-level scheme, as described by Miles and Huberman, was used. At a more general level, a start list of codes were constructed using the two research questions as a guide. At a more specific level, codes generated directly from the interview data were nested in the more general codes. During the coding processing, the codes were refined, revised, and new codes for emerging themes were added. Patterns from the data were extracted and relationships between coded segments were studied. The data was then sorted into categories and sub-categories according to their common themes and shared relationships. Each researcher coded the data independently. Disagreements between the researchers were discussed and resolved after reexamination of the data until a .95 interrater reliability was achieved. Observation notes were also written up and analyzed. These qualitative data were used to provide more detailed descriptions and substantiate the results from the statistical analyses mentioned above.

RESULTS

Findings from Quantitative Data Sources

Motivation

The results of the two-factor mixed ANOVAs indicated that there were significant two-way interactions between the grouping (treatment vs. control) and the data collection points (pre vs. post) for intrinsic goal orientation, task value and self-efficacy: $F(1,29)_{intrinsic} = 6.11$, $p< .05$; $F(1,29)_{task} = 2.84$, $p< .05$; $F(1,29)_{self\text{-}efficacy} = 9.71$, $p< .01$ (see Table 1). The treatment group increased its intrinsic scores from pre to post whereas the control remained the same; the treatment group increased its task value scores from pre to post whereas the control group decreased its scores; and the treatment group increased its self-efficacy scores from pre to post whereas the control group remained about the same (see Figure 1). In other words, the treatment group had significantly increased its scores of intrinsic goal, task value, and self-efficacy from pretest to posttest, and the differences between pretest and posttest for the treatment group were significantly greater than those for the control group. The two groups, however, were not much different in scores of extrinsic goal orientation and control of learning beliefs: $F(1,29)_{extrinsic} = .83$, $p= .37$; $F(1,29)_{belief} = .25$, $p=.62$; (see Table 1).

Insert Table 1 here

Insert Figure 1 here

Design Skills

The one-way ANOVAs with repeated measure analyses showed that there were significant differences between the pretest and posttest scores for the treatment group in the following categories: (1) planning: $F(1,15) = 8.73, p < .01$; (2) presenting information: $F(1,15) = 9.12, p < .01$; (3) collaboration: $F(1,15) = 12.26, p < .01$; (4) mental efforts and involvement: $F(1,15) = 11.78, p < .01$; (5) interest: $F(1,15) = 6.67, p < .05$ (see Table 2). That is, the posttest scores in these five categories were significantly higher than the pretest scores. However, the differences between pretest and posttest scores were not significant for (1) searching information: $F(1,15) = .3, p = .59$; (2) connecting information: $F(1,15) = 3.27, p = .09$; (3) audience: $F(1,15) = 2.82, p = .11$; and (4) individualization: $F(1,15) = .06, p = .8$ (see Table 2).

Insert Table 2 here

Students listed the design tasks that, in their opinions, were needed to complete their projects, and helpful strategies as well as obstacles for the accomplishment of the tasks. The result of the descriptive statistics showed that the more frequently mentioned tasks included (arranged from the more frequent to the less frequent): (1) doing storyboards; (2) researching; (3) programming; (4) brainstorming; and (5) creating graphics (see Table 3). The tasks that were mentioned least often included (also arranged from the more frequent to the less frequent): (1) scanning pictures; (2) digitizing voices; (3) making backgrounds; (4) digitizing music; (5) taking photos; (6) testing (see Table 3). The more frequently mentioned tasks are those that require more thinking skills whereas the least frequently mentioned tasks are more mechanically oriented. Interestingly, the task "testing" was only mentioned once, and no examples were given.

Insert Table 3 here

Students were given 18 tasks relevant to multimedia production and asked to rank the tasks according to their relative importance. Students' ranking revealed their understanding of the importance of the tasks in designing and producing multimedia programs. The result of task ranking corresponded quite well with task listing assessment discussed above. Of the 18 tasks, the six tasks that received highest ranking for their importance included: (1) creating storyboard (Mean = 3.9, the lower the score, the higher the importance); (2) taking notes on what you read (Mean = 4.6); (3) discussing with the team what information to include (Mean = 4.7); (4) brainstorming the best way to present an idea (Mean = 5.0); (5) learning multimedia tools (Mean = 5.6); and (6) going to the library and finding relevant information (Mean = 5.6). Students regarded these six tasks as most important when compared to others. The following six tasks received lower ranking for their importance: (1) making very colorful graphics/illustrations (Mean = 10.0; the lower the score, the higher the importance), (2) scanning photos (Mean = 11.0); (3) making animation (Mean = 11.0); (4) making video clips (Mean = 12.0); (5) making sounds (Mean = 12.0); and (6) getting someone to try out the programs (Mean = 13.0). These six tasks, in students' opinions, are least important when compared to others. It is clear that the most important tasks for the students are those with greater emphasis on higher order thinking skills whereas the less important tasks are those more of a mechanical nature. It is noted that once more students did not give much attention to the task of getting others to evaluate their programs.

Findings from Qualitative Data Sources

Time Spent.

Class periods typically consisted of whole class activities and group work. Examples of whole class activities were brainstorming sessions, instructions from the teacher and guest lectures from local multimedia experts, field trips to local multimedia companies and instruction on multimedia tools. Group work referred to students working in their own teams, storyboarding, learning multimedia tools, and creating their projects. Classroom observations and interview data revealed that beginning from the mid-semester, the time spent on the projects in class as well as out of the class, and time on task had noticeably increased (see Table 4).

Insert Table 4 here

Interest.

Students' interests in the multimedia production process were reflected in several aspects. In addition to the increase of time spent and time on task, the data showed that students liked the class and the projects they were working on. Statements such as "It [working on the project] is good for our education," "The experience is important. And it could help us get jobs," "This is just something that I like to do. [It] will be real help in the long run," "It [the class] prepares you more for the future" occurred frequently throughout the interviews and with all groups. Students self-reported that they hardly skipped the class. The following was a sample of responses from the students when they were asked "How do you compare this class to the other classes you are taking?"

> This class is different. We let our own curiosity help us to learn.
>
> I don't think that I have ever taken a class like this one. Computer class[es], they didn't teach you anything like this.... We didn't learn anything compared with this. A lot of stuff we're learning now.
>
> I'm making a lot better grades than in some of my other classes. It's a lot of fun.
>
> It [this class] is more related to the future. Something you'll actually use.
>
> It's more at your own pace. It's different in that the teacher is not always teaching you, you teach the teacher and he helps you and you help him so everybody becomes a teacher.
>
> I think it [this class] is better and you can get more things done. People are having the chance to use their abilities and their knowledge to help other people out.

Self-Efficacy

Findings also indicated that the students' confidence in themselves had significantly increased. At the beginning, students were not sure if they could pull together as a group to accomplish the project by the deadline. They exhibited their confidence more clearly after making a field trip to a local multimedia company which had won a number of national media awards for their multimedia CD titles. The purpose of the trip was for students to show their work and to learn from the multimedia professionals. The trip was purposefully arranged during the second half of the semester when students had completed a significant amount of their projects and had a first-hand experience of multimedia production. The interviews conducted after this trip revealed students' high respect for multimedia professionals they met, a longing to be a part of that professional production team, confidence in their own abilities, and determination for the future (see Table 5).

Insert Table 5 here

The statement "I want to work there" was echoed by most of the students. Their excitement and determination in getting multimedia production experience, and their confidence in their own capabilities were observed by the teacher, as well as the museum people. One of the museum people said:

> The kids were very excited about what they had seen. So when asked if they wanted to work there, a lot of hands went up. I do. I do. ... These kids were showing their stuff and they [the professionals] were watching and they were very interested in it. They [the professionals] were looking at this and that. They were asking each other what [software] they [students] were using. Some expressed a desire that they could have had this [the experience of producing multimedia CD] when they were in school, then they would have known what to do with themselves.

Students' enthusiasm and confidence were also shown during the open house where they demonstrated their final products to their parents, local multimedia experts, university professors, and students from other classes and high schools.

Brainstorming and Storyboarding

The observation field notes indicated that the process of narrowing down the development scope due to the time constraint and limited resources was not easy for the students during the initial brainstorming sessions. Because this was a new experience to all the students, they did not realize that producing multimedia programs took a tremendous amount of time. Their enthusiasm was high and it was painful for them to drop some wonderful ideas they came up with for development. One student said, "we had too many good ideas and we couldn't use all of them, because of time and computer memory. It was hard picking those few things we could do in one semester." The need for more time also existed with each group when it started to develop its own project. "We've only got an hour and half each day to work on it. The deadline is getting closer and there is so much to do... ," one student stated. "I wish we had more time. Then we can redo some of the graphics and add more stuff," another student commented.

One of the interesting findings was the change in students' perception toward storyboarding. Each team was asked to do a storyboard for its project, mapping out each screen, as one would do in a professional environment. It turned out that this task was very difficult for the students to accept. The students had these comments initially: "We just do not understand why we need to do this [storyboarding]." "It takes so much time and so boring. I want to work on the computer." The teacher said: "It was very difficult to get them [students] to do the storyboards. It was like pulling teeth for some groups. But once we got onto the actual software itself and started to put the stuff together, we've had kids come in during lunch and stay after school." However, interestingly, during the production phase, storyboards were a common sight in the classrooms where students consulted them from time to time. The following is what they had to say about storyboarding toward the end of the semester:

> It [storyboard] helps us when we get on the computers. It also helps when we are explaining what we are doing to other people [other team members]. They can be looking at that while we are explaining it to them.
>
> [Do you think the storyboard helps you?] Oh, definitely. We were lost. We didn't know which way the program was going to go. We didn't know who was going to do what. Now that we have the storyboard, we can separate the program into different pieces and give certain people assignments like to lay all the text out, and to draw, or to put it together. Now we have an idea of what we have to do.
>
> It is very [necessary]. We wouldn't have known how to separate all the work and we wouldn't have known exactly how it was going to flow.

When students were asked, "what have you learned from the field trip [to the professional multimedia development house]?," some had this to say:

> The main thing we got was we need more storyboarding, planning out better before we start.
>
> I think we should plan it out to the last detail.

> They [the professionals] had everything planned out. I would have planned it out completely before I started working on it.
>
> Storyboarding, planning them out more thoroughly before we begin.
>
> Probably the brainstorming, storyboarding and everything. You don't want to go straight into it and start making all that stuff, [be]cause then you don't know what you are going to use. You want to know exactly what you need, that way you can get it finished as quick as you can. ... You could make something really cool but then you can't use it because you find out you don't need it. You just want to do things you need to do for the CD program.

Students' perception change about storyboarding was observed by the museum people. One said:

> At first they balked and they didn't want to do it [storyboarding], but then they understood and we brought in some storyboards from freelance jobs we were working on too, to show them. That helped as well. So I think they understand it now, and they quit complaining. Their stuff is so much more directed and cohesive... They checked them [storyboards] a lot. It's like their blueprint.

The teacher also reported, "Initially they did not want to do the storyboard. But then, I saw them grabbing their blue books [notebook containing storyboards] and referring to them 'OK, we need to do this or that.. What images do we need? Well, we'll go look and find out' ..."

Teamwork

Multimedia production is more of a team work than an individual's effort. From the beginning, the importance of teamwork had been emphasized and the process of using teamwork had been implemented. A group of students worked on one project, rather than an individual. Each member of a team was assigned a role by the team project manager or volunteered for a role because of his or her background and interests. Students' understanding of the team effort and their collaboration among teams were reflected in several aspects: (1) sharing in a team, (2) helping each other, (3) appreciating other's work, (4) taking other's suggestions, (5) deciding together, (6) getting along with each other, and (7) exerting peer pressure (see Table 6). It was clear that the students had a good understanding of the role a team should play in multimedia development. Although conflicts did exist, students were able to resolve them and worked together to accomplish the project.

Insert Table 6 here

Learning Multimedia Tools

The software that the students needed to learn were among the state-of-art multimedia tools. Programs such as Macromedia Director and Adobe Photoshop are the choice of multimedia professionals. These programs allowed students to use their imagination and create what they wanted. But the learning curve was very steep. Although the very basic tenets of the programs were provided by the teacher and the graduate student, students learned, on their own, many techniques and details of the programs by using the manuals and helping each other. One student said, "D came in and taught us the basics. Then you just keep adding on because you can learn by yourself." Another student said, "[Learning by] Hands on. Look at all the options you have. Just try to learn, try to figure it out." Helping each other within a team and often among the teams was a common practice. When a student learned a certain technique and people in other teams wanted to use this technique, he/she would share it with them. As one said, "Usually if we don't know it already, [a] classmate teaches you." A student was commenting on a 3-D program he was using, "I figured [it] out some and got help from other students."

Throughout the semester, the graduate student was in class almost everyday except for a couple of weeks. One museum person came to the class three times a week and the other two times a week. Although the teacher, the graduate student, and the museum people worked very closely with the students, their roles were more of assisting and facilitating than directly teaching. They provided feedback and suggestions to students, and they helped students when they had questions. "He [the graduate student] leaves us alone to figure out the basics. But if we get stuck or have a question about it, we'll call him over and he will help us out. He likes to leave us to learn on our own," one student said. Group interaction and students' comments showed that students had taken on the responsibility of "figuring out ourselves." In fact, they enjoyed the challenge.

Researching

The research aspect of the process took the forms of (1) evaluating commercial multimedia CDs, (2) searching for and collecting relevant information and (3) preparing the data for presentation in the programs. At the beginning of the semester, the class was asked to evaluate critically a number of commercial multimedia programs available, and discuss the strengths and weaknesses of each. This activity helped students to see what was available, the ideas and techniques that they could incorporate in their programs as well as what they should avoid. Each of the four teams had assigned researchers to collect information about their topics. They went the school library to search for the relevant information and wrote up what they found to give other team members to put on the computers. The CD yearbook team designed a survey to give out: "We made surveys and passed them out. It was more of a group idea, because it told us what the public wanted to see in our yearbook." The physics group got some help from the physics teacher in the school about illustrating the concept of gravity. They said that by working on the project for young children, they had an opportunity of reviewing what they had learned in physics. A student commented on their research process:

> We went to [the] library and did research on a lot of topics and found pictures we could possibly scan or draw. Then we talked to some teachers and found out a little more information. After our research was finished, we went back three or four times to get more in-depth research. I thought I was done the first time, but I wasn't.... If we didn't do any research then it would have been hard to base what we are doing.

Evaluation of Students' Technical Skills and Their Programs

Students' Technical Skills

The teacher's assessment, as well as the observation and interview data showed that students made good progress in learning and mastering the multimedia software used. All of the students had a good command of Claris Works and SuperPaint by the end of the semester. Many of them developed sufficient competency in using Adobe Photoshop and Macromind Director. A number of the students also learned on their own SoundEdit 16 for digitizing audio, Ofoto for scanning, and the Cannon Xapshot camera. Two students learned by themselves Virtus WalkThrough, a 3-D program, and Adobe Premiere for digitizing video. Students' command of the multimedia tools were reflected in the programs they developed, as well as in the statements made by different people (see Table 7).

Insert Table 7 here

Multimedia Programs Students Developed

Students developed four multimedia programs: (1) CD yearbook demo, (2) a history adventure, (3) a dinosaur adventure, and (4) a physics demonstration for five-year-olds. All of the programs were composed from scratch. That is, all components (graphics, audio, animation, video) were made by the students. The media used by all four teams included text, graphics, audio, and animation. Video was used only a few times as the computers that they had were not equipped to do any high quality digital video. The scope of these programs was quite extensive considering these were projects completed in one semester. For example, the CD yearbook demonstration consisted of five subsections: sports, clubs, school life, hang-outs, and student portraits. The student portraits section contained several hundred scanned photos of individual students. The Dinosaur program consisted of three subsections: picture show, game, and check test. The History program consisted of three periods of history: Pirates of the Caribbean, the War of the Roses, and King Tut's Egypt. The simplest program of all was Physics for five-year-olds, which expounded upon the concept of gravity and has (1) the gravity building, (2) the clock, and (3) click-clack. Figure 2 shows several screens of these programs.

Insert Figure 2 here

DISCUSSION

Multimedia Production and Motivation

Interest and Involvement

The ANOVA results showed that the treatment group had significantly increased their scores of intrinsic goal orientation and task value, but not the control group. The insignificant result in extrinsic goal orientation for the treatment group showed that students' interest in doing multimedia projects was not necessarily dependent upon getting a better grade.

The results suggested that students who were involved in designing multimedia programs were more motivated toward learning than those who were not. Students' interest and involvement in the projects were reflected in the increase of their on-task behavior and the amount of time spent working on the project. As the qualitative data showed, many students spent their lunch period, and time before school and time after school working on the project. Some students took work home, some came early in the morning, and some spent part of their spring break and Easter weekend working on the projects. Instead of being reminded by the teacher, students began to remind each other of being on task. They exhibited strong motivation to get the projects done.

The results also indicated that students enjoyed this multimedia design experience, which allowed them to be creative and "let [their] own curiosity help [them] to learn." They felt that the experience was valuable as it prepared them for the job market. They saw relevance in what they were doing. It was quite obvious that the real-world implication of the task and its usefulness to the future became important motivational sources.

This finding supports other studies which have found that designing multimedia programs is a motivational task for students and can help students to be more on task (Beichner, 1994; Hays, Weingard, Guzdial, Jackson, Boyle, & Soloway, 1993; Lehrer et al., 1994). The results showed that this learner-as-designer environment did have a positive impact on these at-risk students' motivation.

Although the general pattern of time spent increased significantly throughout the semester, some fluctuations existed. It was observed that sometimes, particularly during the earlier portion of the semester, some students would be "playing" on the computers rather than working directly on the project. The teacher acknowledged that some software was so intriguing that "some [students] would spend the whole period playing with filters [in Photoshop]." "Playing" on the computer and figuring out what filters could do was part of the learning experience and could typically contribute to development of the project. However, due to time constraints, the students did not have the luxury to "free" play and find out all the details of the software. Multimedia production was a new experience for the students. The task of producing a multimedia program was demanding and time consuming. The regular class period of an hour and half a day appeared to be too short and insufficient for multimedia development. One semester was hardly enough for these beginners who had to learn not only the multimedia tools, but also all of the design concepts and skills. It became also obvious that time management was an important skill that these students were yet to learn.

Confidence and Self Image

Both the ANOVA analyses and the qualitative data have shown that students involved in designing multimedia programs have significantly increased their self-efficacy and have a much more positive image about themselves than the control group. This finding is in line with other studies conducted on the same topic (Beichner, 1994; Lehrer et al., 1994).

Students' confidence in themselves was most clear both after a trip to a multimedia company and during the open house. A possible explanation for this was that going to a professional multimedia company, having their products judged by other people, and receiving positive feedback gave the students an opportunity to compare their work with the professionals' work and see how their work stood in comparison. Most of these students were average or below average academically. Several of them had learning disabilities, and quite a few were among the at-risk population. However, designing and producing multimedia programs allowed them to use and develop their own abilities. The design process they were engaged in was similar to what was used by multimedia professionals. The software they used were the choices for professional multimedia development. Their work had received positive feedback from the professionals and impressed many visitors at the open house. The students realized that what they lacked was time and experience. If they continued to gain experience in multimedia development, they could eventually reach a professional level of competency. The statement "I think the only difference [between ourselves and professionals] is [the] experience" reflected their thinking. This realization excited many students. The authentic aspect of the experience helped to increase their confidence and set their goals for the future. Before taking the class, many students were working in fast food places and had no higher goals in life. At the end of the semester, close to 50% of the students talked about working in multimedia industries after graduation from the high school. In fact, four were hired by the Children's Museum and local multimedia companies as summer interns or paid employees as a result of this experience. This multimedia design experience has made a positive influence on these students who belong to the at-risk population.

Multimedia Production and Design Knowledge

Importance of Storyboarding

This learner-as-designer experience changed students' perception toward storyboarding. Initially, many of these students wanted to get on the computers as quickly as they could. The task of planning out every screen and its relationship with the other screens was not only difficult, but was also very boring for them. However, students changed from being impatient and reluctant in doing storyboards to readily using storyboards in their production process. Complaints about doing storyboards were replaced by a desire to do better and more detailed ones. As the design task listing and ranking analyses indicated, storyboarding was the most frequently cited task the students performed and it received the highest ranking for its importance. Several elements of this learning environment helped to bring about this change: (1) the actual production experience, (2) the scaffolding by multimedia professionals, and (3) close working relationship with their clients (i.e., people from the museum).

Discussions were conducted in class on the importance of using storyboards. Some local multimedia developers showed the storyboards they made, helping students to realize that storyboarding was a critical part of multimedia development. On several occasions during the semester, some students could not remember what to do next or what they had agreed upon initially. Storyboards became the blueprint with which they consulted to ensure they were on the right track. When the deadline was getting closer toward the end of the semester and time could not be wasted, having a well-planned storyboard appeared to be particularly important. In addition, seeing the finished storyboards in a professional multimedia house and the CD programs based upon these storyboards helped students understand the significance of doing a storyboard and the necessity for doing it well. The comments by students such as "the main thing we [learned from visiting the multimedia company] was we need more storyboarding, planning out better before start" was a sharp contrast to their complaints and reluctance at the beginning of the semester. Moreover, storyboards became an efficient way to communicate their ideas with their clients from the museum. The results of this perception change illustrated the importance of providing an authentic design experience and apprenticeship to the students when designing a learner-as-designer environment. Simulating the classroom learning as a mini-multimedia production house and allowing students to interact with multimedia experts as well as their clients seemed to have contributed to this positive change.

Collaboration Among Team Members

Working with others who were different from oneself and working together in a team to accomplish a project in time are important aspects for successful multimedia development (McDaniel & Liu, 1996). Many of the students had strong personalities, and many did not know each other before the class. Although differences did exist, students in general exhibited their understanding of the importance of collaboration in a team: there was a significant increase in the design skill of collaboration from pretreatment to post-treatments as indicated in the ANOVA analysis. According to these students, "discussing with the team what information to include" and "brainstorming the best way to present an idea" were among the most important tasks. Students shared ideas and helped each other with multimedia tools, regardless of the teams. It was encouraging to note that many students, during the interviews, complimented on their teammates' work rather than their own. Although competitions existed among the teams, the students competed in a positive way, such as getting the project finished ahead of the other teams.

Such a positive atmosphere was partly attributed to the fact that the importance of collaboration among a team was emphasized by the teacher from early on. The teacher had assumed the role of a mediator for any conflicts. It was also attributed to the simulated multimedia production environment where each student had a distinctive role to play (whether it was a project manager for a team, a programmer, an artist, or a researcher). Working in this environment helped students to see the importance of each role and to understand that the success of a project depended on whether a team could work together (McDaniel & Liu, 1996). Involvement in production allowed students to gain a first-hand experience in team collaboration.

The complex nature of multimedia production gave students an opportunity to learn from each other's differences and develop the ability to solve conflicts. The students negotiated among themselves what role(s) to play and which task(s) to perform. The team project managers tried to ensure everyone was on task and motivate those who were not. Students began to exert peer pressure on those who tended to neglect the project. They solved the conflicts and differences through voting and group meetings. In short, designing multimedia programs provides students a meaningful learning environment in which group decisions and collaboration were exercised.

Use of Multimedia Tools for Presentation

Learning multimedia tools comprised a significant part of this learning experience. At the production phase, students began to use the multimedia tools to create what they set out to accomplish. Students divided the tasks among themselves: Some drew the pictures, some scanned the photographs, others made animations, and still others programmed. A topic for continuous discussion was how to present their ideas in an effective and interesting way. Since the audience for the three museum teams were mostly young children, it was important to make their programs both educational and entertaining. The Dinosaur program was game like: driving through a "Jurassic" like forest and into an ancient time when dinosaurs lived. The Physics team used a discovery approach for young children to find out how gravity worked. Students in the History team learned, on their own, a 3D modeling program to create a three-dimensional museum room for young users to browse. There were paintings on the wall that a user could click and obtain further information of the painting and its representative historical age. To make their electronic version different from the print-based yearbook, the CD yearbook team used a variety of techniques (animation, video, audio, graphics and text) to represent many aspects of students' life in a colorful and vivid way.

In support of other research studies (Beichner, 1994; Heys, Weingard, Guzdial, Jackson, Boyle, & Soloway, 1993; Lehrer, et al., 1994; Spoehr, 1993), this study shows that multimedia tools have become a way to scaffold students' learning of design skills. Although the multimedia software used in this study allowed students the freedom to create what they desired, the students had the challenge of determining which media to use and for what purpose. They brainstormed, researched, and discussed how to best present their ideas. For those students who tended to sit at computers and create without planning, this exercise "forced" them to see the importance of careful selection of the media for the target audience and with a clearly defined objective.

It is important to point out that many students had taken on the challenge of figuring out certain techniques for presenting information and then shared with others. The awareness of everyone being a learner including the teacher and other multimedia experts encouraged students to pursue independent and self-directed learning (Collins, Brown, & Newman, 1989). One student stated that "the teacher is not always teaching you, you teach the teacher and he helps you and you help him so everybody becomes a teacher." Judging from the limited time available in one semester, the technical skills these students developed and the fine quality of the accomplished projects were quite satisfactory according to the evaluation by the teacher, the museum people, and the graduate student (see Table 7). During an end-of-semester interview, all teams were asked to describe their projects, objectives, audience, choices of media, and techniques used. Students' mastery of the tools was obvious as they demonstrated and explained in detail how certain part was created. However, it was also clear that some students paid less attention to some of the details. For example, several screens were cluttered with many fonts and colors used without a clear purpose. The text on these screens was, therefore, difficult to read.

Challenge of Designing for a Real Audience

One benefit of this "learner-as-designer" environment was that students worked closely with their clients (the Children's museum) and were creating programs for young children. Students' awareness of the needs of a target audience was expected to increase. The interview data showed that during the planning and design phases, the students had explicitly expressed the desire to satisfy the needs of their audience. For example, in presenting the concept of gravity to five-year-olds, students in the Physics group decided to use "the length of a football field" to explain the expression of "98 meters" as a distance of a falling object. They felt that for young children, the metaphor of a football field was more concrete and understandable than the concept of 98 meters. In another case, the students purposely used child-like handwriting to present the information in hope of making the program more attractive to young children. One student stated that "it is very important [that the kids like our program], because that's who we are making it for, and they are our target audience." However, the ANOVA results showed no change in the students' understanding of the "audience" (see Table 2). According to the results of the design task listing and ranking (which listed the tasks the students actually performed and the relative importance of each task), "testing" and "getting someone to try out the programs" seemed to be of low priority to the students (see Table 3).

What appeared to happen was that although the students were aware of the needs of their target audience and the importance of satisfying them, the step of testing was neglected in the actual implementation due to the lack of time. Because testing by the target audience was the last step in the production process, it was not addressed when the time was insufficient toward the end of the semester and finishing the projects became the primary goal. Although informal evaluations occurred among team members and between the teams, no systematic evaluation, especially evaluation by the audience, was performed.

For many students, creating a program of their own ideas was very important. They perceived that multimedia design provided a way for them to be creative and express themselves. They developed a very strong sense of ownership for what they created. However, sometimes they were so involved in using their own ideas that they tended to forget about their audience.

When the students were asked if they took suggestions from the others (especially the clients), several of them replied that they would consider them if they liked them, not necessarily because the suggestions would be good for the intended audience. In other words, although the students were aware of the audience, their sense of ownership and individualization was strong. This finding suggests that it was not easy for the students to achieve a balance between designing for the intended audience and designing from their own ideas. They needed more assistance in performing the evaluation by target audience, especially when time is a factor.

CONCLUSION

This study found that the "learner-as-designer" environment described here had a positive impact on the at-risk high school students. As a result of participating in this project, the students showed a significant growth in their value of intrinsic goals. The experience helped students to acquire several critical design skills. The results of the study provided some supporting evidence to the concept of designers of knowledge (Perkins, 1986). What was most encouraging from the study was that this experience of designing multimedia programs for real audiences provided many students, who were considered at-risk and could not otherwise succeed in schools, a way to pursue their own goals. It helped them to search for their own identities and find their own meanings for learning. It also appeared that such an environment offered a promising opportunity for students to exercise and develop their higher order thinking skills.

Although the results of what the students have accomplished are encouraging, we face many more challenges. Designing multimedia programs by students offers a new way of learning and teaching. Research in this area has just begun. As Carver and her colleagues point out (1992), the challenge is for us to continue to search for ways of designing learning environments that foster knowledge construction.

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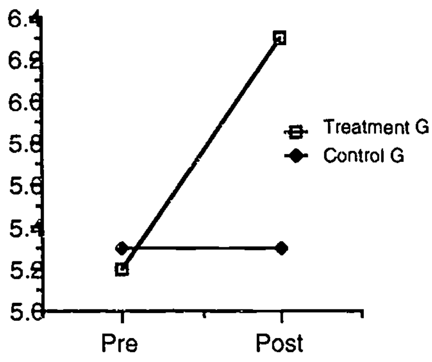
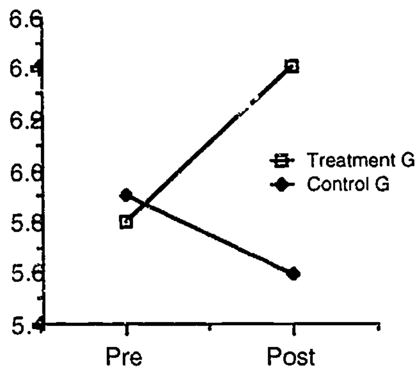
Table 1. Mean and Standard Deviation (in Parenthesis) for the Motivation Scores

	Intrinsic		Extrinsic		Task Value		Belief		Self-Efficacy	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Control G	5.3 (1.4)	5.3 (1.3)	4.8 (1.2)	4.6 (1.3)	5.9 (1.2)	5.6 (1.3)	5.4 (1.0)	5.4 (1.1)	5.1 (1.3)	5.0 (1.7)
Treatment G	5.2 (.8)	6.3* (.6)	5.2 (1.1)	5.4 (1.3)	5.8 (.9)	6.5* (.6)	5.6 (.8)	5.8 (1.0)	5.5 (.8)	6.5* (.5)

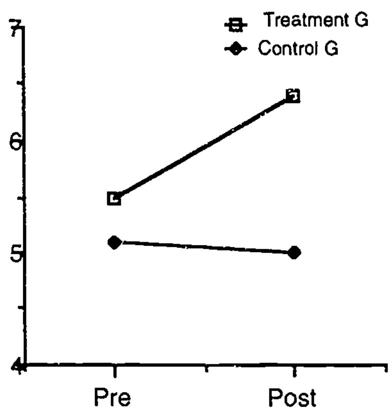
* = significantly different from the control group, $P<.05$.



Intrinsic goal orientation scores



Task value scores



Self-efficacy scores

Figure 1. Scores for treatment and control groups from pre to post.

Table 2. Mean and Standard Deviation (in Parenthesis) for the Design Skills

	Planning	Searching	Presenting	Connecting	Audience	Collaboration	Mental Effort	Interest	Individual
Pretest	4.69 (.83)	4.66 (.8)	5.03 (.86)	4.4 (.94)	5.58 (1.3)	4.7 (.94)	4.29 (.89)	5.31 (1.0)	5.0 (.83)
Posttest	5.49* (.89)	4.78 (.78)	5.84* (.88)	4.96 (1.0)	6.0 (1.13)	5.62* (1.18)	4.84* (.82)	6.13* (1.0)	5.0 (1.1)

* = significantly different from the pretest, $P < .01$.

Table 3. Frequency of Design Tasks Mentioned by the Students

Tasks	Freq.	Examples of Helpful Strategies Listed by the Students	Examples of Obstacles Listed by the Students
With highest Freq.			
Doing Storyboard	88%	• "working in groups" • "ideas from the group"	• "took a lot of production time" • "we could not understand why we needed storyboard"
Researching	75%	• "librarian and school library" • "getting information on sports from coaches"	• "boring" • "books did not contain all the information we needed"
Programming	63%	• "me and B worked together" • "got help on Director from other people"	• "computer locked up" • "crashing, crashing, and cashing, redid 3 times"
Brainstorming	56%	• "We all threw out a bunch of ideas." • "working in groups"	• "We came up with too much." • "time"
Creating Graphics	56%	• "A is an excellent artist. We all did graphics though." • "J gave me hints and clues for tools in Photoshop. D made suggestions."	• "time and not knowing programs well enough." • "time"
With least Freq.			
Scanning Pictures	19%	• "teacher taught me how to use the scanner."	• "scanner too slow"
Digitizing Voice	19%	• "I did the voice and all the lines."	• "everybody wasn't being quiet!!!"
Making Background	13%	• "I did background myself."	• " not enough people to help draw."
Digitizing Music	6%	• "M brought CDs."	(no example)
Taking Photos	6%	• "D helped me." weather."	• "It was very cold and rainy"
Testing	6%	(no example)	(no example)

Table 4. Time Spent In and Out of the Class

Time Spent	*Based Upon Observation and Interview Data*
Earlier in the Semester	
In Class	• About half of the class were on task. • From time to time, quite a few students were hanging around in classroom, talking to other students (not a part of the class), or doing nothing. • Teacher called upon students to be on task.
Out of Class	• CD Yearbook team met weekly in Denny's to discuss the project and socialize. For other groups, not much was going on.
Later in the Semester	
In Class	• During most of the observed periods, students were sitting in front of the computers working. Some sat together providing feedback. Some were discussing about the project in a circle. Most were on task. • *Museum people's comment:* "When we first started the project, [students] tended to just sit there and not be actively involved. It seems to me that they changed in the course of the semester. When one of them was going to the library, others in the group would say 'Will you check to see if they are on task.' So they started policing each other. None of them would have done that at the first of the semester." • *Museum people's comment:* "At first, as little as possible [working on the project], Then 40 or 50 percent by about half way [of the semester]. Now I'd say most of the groups are on task throughout the entire class."
Out of Class	• About half of the class spent their lunch time regularly working on the projects. A third of the class spent the morning or afternoon period working on their projects. Some spent both. During the spring break, about 50% of the class showed up on the day they talked their teacher into opening the computer rooms. • *Student's comment:* "I spend about 5 hours a day on this project. I have first and third periods, my whole lunch period, before school and sometimes after school." • *Museum people's comment:* " They come after class, they come on weekends, they take it home and work on it." • *Teacher's comment:* "For example, the dinosaur group. They came in extra a lot. I stayed with A until 6:30pm one day and gave him a ride home. A stayed on his own a couple of other times. B would come early or he would stay late. Then C came in early quite a few times. In fact that day when the school was out and she has graduated, she called me at 6:40 in the morning wanting to know when I could take her up to school so she could work [on the project] until the time she has to go to work [to earn living]."

Table 5. Students' comments about their abilities and confidence

Categories	Students' statements
About professionals' feedback to students' programs	• We got a chance to show them our stuff as well. They were impressed. • They said they liked it a lot. • They said they liked the physics group, the screens, the layout. They liked the whole. • They liked the CD control panel B made. Theirs is a little more advanced, but they liked ours. • They liked that one [the dinosaur project] a lot, thought that was funny.
About confidence in one's own ability	• We have a good head start. They [professionals] wish they had what we have. • We have basically the same [tools, comparing professionals' work with their own], but they just put more time into it. They've had more time and experience. But other than that they are pretty much the same. • I think the only difference is experience, really and truly. • They have a lot more time than we have to do our stuff. That's one of the main factors. But we use some of the same programs.
About desire to be in multimedia profession	• We liked what they were doing. Everybody wanted to go there again. • We liked their lab, laid out in such a way that you can get a lot of intense work done. • I'm amazed by what they were doing. I want to work there. • To continue making interactive CDs [after graduating from high school], and doing a lot of filming of movies. • I enjoyed the whole thing [the trip]. That is exactly what I want to do when I get out of high school.

Table 6. Collaboration in the Team

Categories	Students' Statements
Sharing in a team	• Right now we are working independently, but we all come together for group meetings. • We are all going to share the burden [scanning several hundreds of photos]. When you are working on a task of such scale, there's gonna [to be]a lot of tasks that are monotonous so we're all going to have a bite [of] the bullet. • I just got back from the other room where we were discussing our different ideas. The other four people have been working together in the other room while I was working on this [a major interface for the project]. • [How often do you talk as a group?] Just about everyday.
Helping each other	• B's helping S and J's scanning. We're all working [together]. • Though only one of us can be on the computer at a time [referring working at home], we are all chewing on ideas. That looks terrible, that looks great. It is neat. It has been interesting to see how easily we come to consensus. • [Where did you learn this technique?] M had used it with his program. He showed me.
Appreciating other's work	• The Physics group is doing stuff on falling objects. That's pretty neat. • M can do Director great. • Like S, he did a real nice QuickTime thing. He made screen actually coming towards you. He's done a real good job.
Taking others' suggestions	• J and myself were involved in programming to put imported pictures together. Other people would give their ideas on how we could make it easier and to get the project done faster. We would think about them. We would use them if we thought it would speed things up.
Deciding together	• We all decide together. • We [CD yearbook group] all brainstormed. It [giving out surveys to students in the school] was more of a group idea. • We put up what areas there are and let people choose where they want to be. If there happens to be too many people in one area and not enough in another we just tell people and ask for someone to volunteer to work in that area. So far that has worked.
Getting along with each other	• [Do you think your group gets along well?] Yes. Everything's been worked out. When people have different opinions, we just work it out, talking to each other. We take votes and stuff. • [From the graduate student] I mean there have been some conflicts, but then I think that if there are no conflicts, people are not really thinking. So I have been happy with how they have worked together. I remember one day A, B and I were working on the program and it was a really difficult task. We were all really into it. We were all debating about the best way to proceed and we got a little hot under the collar. Then we stepped back and said 'Hey, look at what we are working on. Let's just step back and do some flowcharts and see what is the best way to proceed.' So it worked out. And there have been several other little conflicts like that, people yelling at each other. And we just step back and said we are all a team. There is nothing to make enemies about.

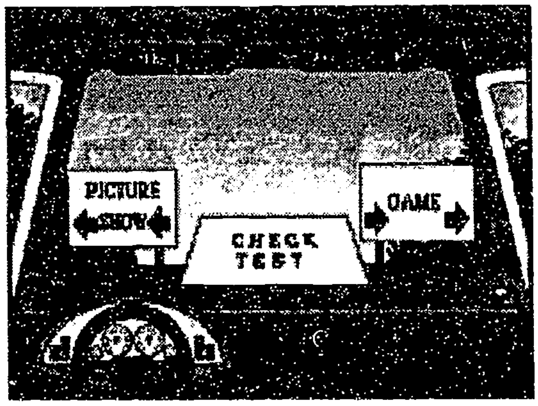
Exerting peer pressure	• [From museum people] They started exerting peer pressure on each other for those who were not holding up their end of the work. Like saying 'well, if we could just get so and so to work' and they would actually try to. They would go through their storyboard and see what they don't have and then try to get someone who is not working to do that for them. 'We need this.' They say 'we.'

Table 7. Evaluation of Students' Technical Skills

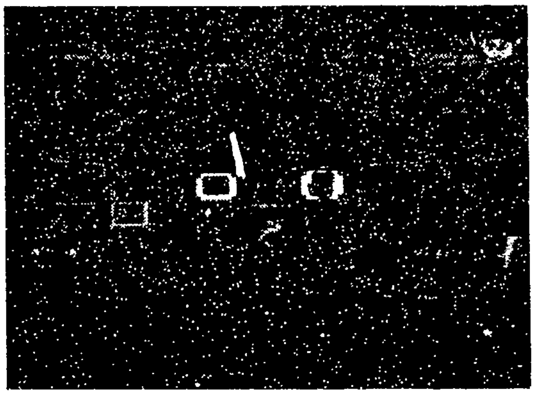
Perspectives	Comments
From the teacher	• Some [students] are far beyond me, when it comes to Director.
From the museum people	• I'm ecstatic with their work. Their work is excellent. ... I'm very happy with their work. I think it is great. It is practically production quality in one semester. Yes, I'm real happy with them.
From the graduate student	• They picked up the programs [i.e. software] very quickly. Everyone in the group has produced something that they can show. I am very happy with what they have accomplished...
From the students	• We all learned more or less Director. I mean, at the beginning of the semester, nobody knew how to turn on Director. Only a few people did. But compared to now, everybody more or less in this class has the ability to write their own Director movie. They might not be the fanciest thing, but everybody can write some lingo, know how to put the things together, and how to import graphics. That is something. • Everybody in here is very familiar with Director interface, and has the potential to keep on learning it.
From visitors at the open house	• Great! You cannot tell this is produced by high school students. That's very encouraging.

Figure 4. Screens of the Programs Students Developed

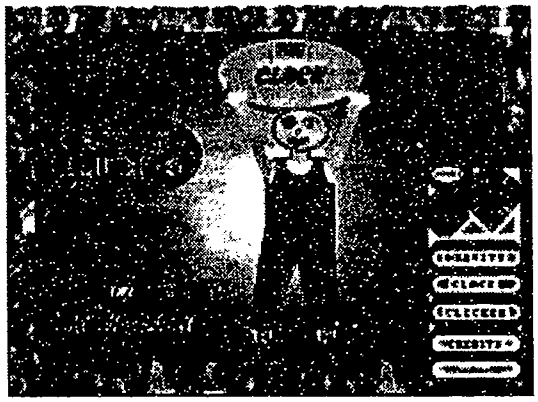
CD year book: Student life section



Dinosaur program: Main menu



History program: A 3D exhibit room



Physics program: Main menu