



Enhancing Learners' Cognitive Skills Through Multimedia Design

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ABSTRACT

This paper examines how to design interactive multimedia learning environments to provide necessary support for developing higher level cognitive skills. We looked at one approach of engaging learners as multimedia designers using a project-based learning approach. We described this learner-as-multimedia-designer environment and synthesized the research, conducted over the past several years, of the effect of such a learning environment on cognitive skills development for high school, middle school, and elementary school students. Research findings at each level were discussed and insights on designing such a learning environment were shared. Cognitive skills in this case refer to the design skills and resource management skills as needed in producing a multimedia product.

INTRODUCTION

Cognitive skills are skills that require the working of a human mind. They are mental skills and broadly ranged from memory skills to procedural skills, from language skills to thinking skills. In general, they can be categorized into lower order cognitive skills such as recalling and listing; and higher order cognitive skills such as problem solving, hypothesis testing, decision making, evaluating, and self-reflecting (Sternberg, 1998). Another way to look at the cognitive skills is to use Bloom's taxonomy: lower level skills are related to knowledge and comprehension, and higher level skills are related to synthesis and evaluation. One can also group the skills according to what cognitive skills are appropriate to be introduced at different grade levels (Beyer, 1991). For example, according to Beyer, skills of 'observing,'

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'sorting,' and 'comparing' are typically taught at Grades K-2 while skills of 'analyzing,' 'synthesizing,' and 'argument making' are taught at Grades 7-12. Unlike physical skills, cognitive skills are internal, the development of which demands a more sophisticated learning process (Kinshuk, 2000). The higher level the skill is, the more challenging it is to develop.

Because cognitive skills are concerned with analysis, problem solving, evaluating, and decision making, they are important skills to acquire for children as well as for adults. Literature indicates there are many theoretical and empirical studies in the field of cognitive skills development. However, the findings are often inconclusive, and sometimes confusing. Since developing cognitive skills is an important goal for education, and is of particular significance for life-long learners, it is an area that requires continuous attention and further research.

In this paper, we will examine the potentials of using technology to support cognitive skills acquisition. Specifically, we are interested in examining how to design interactive multimedia learning environments to provide necessary support for developing higher level cognitive skills. There are many different ways to create interactive multimedia learning environments. Here we will look at one approach based upon our research and development experience: engaging learners as multimedia designers using a project-based learning approach.

THEORETICAL FRAMEWORK

Project-based learning, deriving its theoretical underpinnings from Dewey's educational philosophy (1907) and constructivist epistemological belief, organizes learning around a project. Project-based learning typically starts with an end product, which serves as a driving question compelling students to learn about the central concepts and principles of a topic while engaging in producing the product. Its practice usually corresponds closely with what happens in the real world and requires students to play authentic roles and perform meaningful tasks. To create a product, students are engaged in such cognitive processes as problem solving, decision making, designing, and product making. These processes help students transform information and construct their own knowledge and interpretation. Throughout the process, students are encouraged to take charge of their learning and become autonomous for their decisions. When they accomplish their project, students are often endowed with a great sense of achievement.

Recently, there is a renewed interest in project-based learning for K-12 education, especially in conjunction with the use of computer technology. Research shows that technology facilitated project-based learning has great potential to enhance students' motivation, and support information gathering and presentation (Blumenfeld et al., 1991). Engaging students in hypermedia/multimedia¹ design is one type of project-based learning, focusing on acquiring the design skills.

Perkins (1986) states that the process of design promotes learners' active pursuit and use of knowledge. Newstetter (2000) says that design experiences can promote discovering and learning content. As multimedia designers, learners are given the opportunity to be creative and to become an intellectual partner with the technology in a constructive learning process (Salomon, Perkins, & Globerson, 1989). In a learner as a multimedia designer environment, the learner is typically given a challenge to create a multimedia product for a certain audience. She must find ways to collect the information and learn the skills necessary to create the product. The process of producing multimedia programs, from the inception of an idea to the finished product, is a very complicated task. It requires many steps, and "taps a diverse set of skills" (Carver, Lehrer, Connell, & Erickson, 1992, p. 388). Multiple talents such as artistic, logical, linguistic, and musical come into play. In fact, 16 major thinking skills, used by multimedia designers, have been identified (Carver et al., 1992). These 16 skills, which are related to cognitive development and success in the workplace, form five categories: (1) project management, (2) research, (3) organization and representation, (4) presentation, and (5) reflection. Each skill in these categories has its own place in the entire development process, and is needed for producing a successful product. The development process 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 successful teamwork (Liu, Jones, & Hemstreet, 1998). Whether a team member is a programmer, a graphic artist, a designer, or a manager, collaboration among team members is crucial. Although each member has her distinctive role, the success of a multimedia program depends on constant communication and understanding between team members and their working

¹In this paper, the terms "multimedia" and "hypermedia" are used interchangeably.

together to reach the goal. Such collaboration and group interaction provides a concrete and meaningful context for enhancing cognitive development through social negotiation (Blumenfeld et al., 1991; Lehrer, Erickson, & Connell, 1994; Newstetter, 2000).

Recent research on engaging learners as multimedia designers has shown some encouraging results in promoting high level cognitive skills. Lehrer et al. (1994) conducted a study in which ninth-graders created hypermedia presentations on American history for other students. They found that the design process helped students to internalize various design skills. Students reported increases in mental effort and involvement, interest, planning, collaboration and individualization. Supporting their findings, Spoehr's study (1993) showed that designing hypermedia programs could help students develop more complex knowledge representations and assist the development of their thinking skills. While finding students' self-esteem was greatly enhanced in doing multimedia projects, McGrath and her colleagues noted that not all students were ready for design (McGrath et al., 1997). They found the sense of responsibility was absent at the elementary level, very mixed at the middle school level and very impressive at the high school level.

In our attempt to construct the learner-as-multimedia-designer environment, we used cognitive apprenticeship model (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989). Differing from other studies on the topic, the design process under study simulated the multimedia industry practice as closely as possible. This paper describes this learner-as-multimedia-designer environment and synthesizes the research, conducted over the past several years, of the effect of such a learning environment on cognitive skills development for high school, middle school, and elementary school students. Cognitive skills in this case refer to the design skills and resource management skills as needed in producing a multimedia product. They are of particular interest to our research, because of their nature of transferability to other situations.

A LEARNER-AS-MULTIMEDIA-DESIGNER ENVIRONMENT

Over the past few years, we have conducted a number of studies using this model, though each varies a little depending on the age level of the students and related curriculum (Liu, 1998a, 1998b; Liu & Hsiao, 2002; Liu & Pedersen, 1998; Liu & Rutledge, 1997).

Table 1. Activities Associated With Each Phase of the Development Process.

Phases	Activities associated	Intended goals
Phase I: Warm-up	<ul style="list-style-type: none"> ● learning software programs ● getting used to the hardware ● doing exercises related to software ● creating small projects ● researching ● evaluating commercial programs ● instruction by the teacher/experts 	<ul style="list-style-type: none"> ● learning software & hardware ● getting used to this "new" learning environment
Phase II: Development	<ul style="list-style-type: none"> ● all activities related to design and Production (see Table 2) 	<ul style="list-style-type: none"> ● understanding ● doing ● receiving needed guidance
Phase III: Continued practice	<ul style="list-style-type: none"> ● working on a different project ● going through the same four-stage model as in Phase II ● refining and tuning the design model depending on the needs 	<ul style="list-style-type: none"> ● reinforcing and internalizing ● becoming more independent

In general, the entire project process consists of three phases. Phase I is for learning multimedia tools and getting used to the environment. Phase II focuses on design and production following an industry used four-stage design model and Phase III repeats the process in Phase II with a new focus, providing additional opportunities for students to be independent and internalize the design skills acquired. Table 1 describes the activities related to each phase. Typically, Phases I and III take one third of the project time each, and Phase II takes the rest.

During Phase II, students are given the opportunity to work with a client, and design for a real audience. Students are introduced to a four-stage design model of *planning*, *design*, *production*, and *evaluation and revision*, which is based upon the multimedia industry practice (Liu et al., 1998) and Lehrer's instructional model (1993). Each phase consists of several design activities devised and implemented in correspondence to the various higher order thinking skills stated by Carver et al. (1992) (see Table 2).

In the *planning* stage, the project goal is explained and design tasks are given. Students are engaged in brainstorming sessions and making decisions

Table 2. Design Activities and Thinking Skills Related to Each Stage of the Design Model.

Design model	Design activities used	Thinking skills aimed at*
Stage I: Planning	<ul style="list-style-type: none"> ● brainstorming & discussion ● discussing with clients ● meeting with target audience ● searching for information ● researching ● evaluating commercial programs ● instruction by teachers & other multimedia experts 	<ul style="list-style-type: none"> ● posing question ● deciding on the nature of the problem ● developing new information ● analyzing and interpreting information
Stage II: Design	<ul style="list-style-type: none"> ● storyboarding ● researching ● group discussion ● learning multimedia tools 	<ul style="list-style-type: none"> ● creating a timeline ● allocating resources and time to different segments of the project ● assigning roles ● deciding on the segmentation of information ● developing a structure
Stage III: Production	<ul style="list-style-type: none"> ● learning multimedia tools ● scanning photographs ● drawing pictures ● creating animation ● digitizing audio ● programming ● taking field trips to multimedia houses, user group meetings 	<ul style="list-style-type: none"> ● developing representation through different media ● transferring the design into a presentation medium ● developing a structure ● juggling constraints (e.g., time, equipment, etc.)
Stage IV: Evaluation & revision	<ul style="list-style-type: none"> ● peer evaluation & revision ● client evaluation & revision 	<ul style="list-style-type: none"> ● soliciting peer feedback ● articulating intentions ● public presentations

Note. *These thinking skills are those listed by Carver et al. (1992).

on what to create (the content), whom to create for (the audience), and how to develop the product (the process). They meet with the client to understand their requirements. After several brainstorming sessions, students form groups based upon their interests and proceed to work in a team. Depending on the school curriculum and the available opportunities, students had an opportunity to create a multimedia kiosk for the Texas Parks and Wildlife department (Liu, 1998b), a program for a local children's museum (Liu & Rutledge, 1997), a multimedia presentation for a teachers' job fair (Liu & Hsiao, 2002), or a

program for their peers to use (Liu & Pedersen, 1998). Evaluating commercial multimedia titles, receiving guest lectures and instruction from the teachers are also a part of the planning stage.

During the *design* stage, students are engaged in defining and refining the topics, subtopics, the age level of the audience, and strategies to use for presenting the information. Each team creates flowchart and/or a storyboard, detailing the overall program structure and how each screen will look like. At this point, each member of the team is assigned the role of a researcher, a graphic artist, a programmer, a project manager, an audio/video specialist, or an animator for their project. Often 1 student assumes multiple roles or different roles at different times. The storyboards are turned into actual products during the *production* stage. Graphics are scanned, digital video and audio clips are made, animations are created, and all pieces are programmed into the final product. *Evaluation* is an on-going process among the team and across the teams. Students receive feedback from their peers, their teachers, and the clients. *Revisions* are made immediately.

Designing a multimedia program integrates a variety of activities, and incorporates a wide range of thinking skills (Carver et al., 1992). The comprehensive nature and extensiveness of the process make it a unique learning opportunity, an opportunity that can lead to the development of highly valued cognitive skills (Newstetter, 2000).

RESEARCH FINDINGS

We have conducted research on the effect of this learner-as-multimedia-designer environment at the high school level (Liu, 1998b; Liu & Rutledge, 1997), middle school level (Liu & Hsiao, 2001; Liu & Hsiao, 2002), and elementary school level (Liu, 1998a; Liu & Pedersen, 1998). These research studies examined the effect of such a learning environment on students' motivation toward learning and on their cognitive skills acquisition.

Measures of Cognitive Skills

To examine the cognitive skills, both quantitative and qualitative measures are used. These measures are based upon the related literature and are used across the studies conducted at different levels.

Project Design Questionnaire

To understand how students acquire and use design skills in doing multimedia projects, Lehrer and his colleagues created a project design questionnaire. This is a 60-item self-report questionnaire on design activities that are related to various higher order thinking skills needed in producing multimedia projects (Lehrer, Erickson, & Connell, 1994). It uses a seven-point Likert scale with one being “not describing me at all” and seven being “describing me very well.” The 60 items addresses 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,” and “Overall, I feel positively about working with others on a project.” This design questionnaire has been used in other studies on the topic (Carver, Lehrer, Connell, & Erickson, 1992; Lehrer, Erickson, & Connell, 1993; Lehrer, Erickson, & Connell, 1994) and with the high school students in this case (Liu, 1998; Liu & Rutledge, 1997). The reliability coefficient for the instrument is .97. A modified version of this questionnaire, consisting of 20 items and adapted for students of a younger age, was used with the elementary school students (Liu & Pedersen, 1998) and the middle school students (Liu & Hsiao, 2001; Liu & Hsiao, 2002). The KR 20 for this modified version is .82.

Design Task Ranking

Like research of a similar nature (Lehrer et al., 1994), students were given a list of tasks relevant to their project development and asked to rank the tasks according to their relative importance. 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.”

Performance Assessment

The products the students created 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, 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. Students’ technical

skills were assessed through their completed assignments, their contribution to the products, their ability to explain the rationale for certain product components, and the ability to demonstrate certain technical procedures.

Concept Maps

In the research with the middle school students, students were asked to complete a pre-concept map and a post-concept map on the concept of 'multimedia development' (Liu & Hsiao, 2002). Students were given the core node of 'multimedia development' and were asked to create a concept map of any concepts they would link to this core node and label the importance of each link.

Resource Management Strategy Questionnaire

The research with the middle school students also examined students' strategy use (Liu & Hsiao, 2002). Four scales were selected from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991) with regard to resource management strategies. These scales are: (1) time and study environment management (four items, $\alpha = .76$), (2) effort regulation (four items, $\alpha = .69$), (3) peer learning (three items, $\alpha = .76$), and (4) help seeking (four items, $\alpha = .52$). Sample questions included "I make good use of my study time for this course," "I work hard to do well in this class even if I don't like what we are doing," "I try to work with other students from this class to complete the course assignment," and "When I can't understand the material in this course, I ask another student in this class for help."

Interviews, Observations, and Response Logs

Interviews were conducted with the students, the teachers, and in some cases with the parents and the clients at various times of the project process. Depending on the focus of the study, different questions were used. Sample questions included, "What do you think of the project so far?," "How do you compare this project (working on multimedia authoring) with other projects?," "How do you see the teacher's role in this setting as compared to a regular classroom?" "Did you like the multimedia project? Why?," "What have you learned from doing this project?" "Of all the things we have done this semester for this multimedia class, what activities do you like the most? Why?," "What activities do you like the least? Why?" Observations on the process were also made.

Findings

Detailed results of each study can be found in the published articles. Here is a summary of the findings relating to cognitive skills only. *At the high school level*, it was found that the participating high school students acquired and internalized several important design skills after being involved in the project. Specifically, the results indicated students' understanding was significantly increased for planning, searching information, connecting ideas, importance of audience, and collaboration. Students were able to distinguish the tasks that required more thoughts from those of a more mechanical nature. They had a better appreciation of the tasks that, though not very fun, were critical for the success of the products. For example, the learner-as-multimedia-designer experience changed students' perception toward storyboarding (Liu & Rutledge, 1997). Initially, many students wanted to get on the computers as quickly as they could. The task of planning 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. Storyboarding received the highest ranking for its importance. Several elements of the 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.

The findings showed that the experience of working with a client and designing for a real audience helped to bring about bigger changes in the students' acquisition of design skills (Liu, 1998b). The extended treatment of 1 year brought significant changes in the categories of searching information, connecting ideas, and importance of audience (Liu, 1998b), while no changes in these categories were observed in the previous study which lasted for one semester (Liu & Rutledge, 1997). The data on the experienced students versus novices showed that the more experienced students had internalized some of the design skills (Liu, 1998b). They were more self-directed and were more ready to apply the skills they learned.

At the middle school level, the analyses indicated that the increase in the students' design knowledge was significant from the pre- to post-semester. After 18 weeks working intensively as a multimedia designer, these middle school students became aware of the different steps involved in creating a multimedia product, and realized the significance of planning, designing, and testing (Liu & Hsiao, 2002).

The analyses on concept maps showed that there was a significant difference in the number of concepts accurately listed by the students from their pre-concept maps to the post-concept maps. Students listed significantly more relevant concepts in the post-maps. In the pre-concept maps, most of the nodes were about the production and only 12 nodes were about some aspects of planning, or designing. This number increased to 41 in the post-concept maps. More importantly, the concepts of "storyboarding," "designing," or "testing/evaluating" were not mentioned at all in the pre-maps while they were listed for 27 times in the post-maps. It was also interesting to notice that "needing a storyboard," "leaving more time for revising," and "having a better interface" began to be part of the vocabulary for these middle school students.

To be a successful multimedia developer, one needs to be able to manage time well, meet deadlines, work well with team members, and solve potential conflicts. We looked at how well the middle school students managed the available resources. The results indicated that the students overall had trouble dealing with the time and environment constraints. Managing time well and effort regulation were not easy tasks for the middle school students.

At the elementary school level, a comparison was made between a designer group (where the students worked as designers in a team) and a non-designer group (where the students worked individually in a more traditional, teacher-directed environment). Both groups were fourth graders. The results showed that the students in the designer group had a significantly better understanding of the importance of planning and collaboration than the non-designer group (Liu & Pedersen, 1998). Their ranking of the design tasks showed they valued the tasks requiring thinking as more important than the tasks of a mechanical nature. They cited the importance of planning in a more elaborate and detailed way than the non-designer group did. Such findings suggested that the experience of being multimedia designers had some positive impact on students' understanding of the design process. No differences, however, were found in the two groups on mental efforts and presentation. Although designing for an audience was emphasized for the designer group and additional evaluation activities were implemented, the two groups showed no difference in their understanding of the importance of audience as indicated by the project design questionnaire. It is possible that because both groups participated in the open houses and the grade assembly (both activities provided a purpose and an audience for the design), the distinction of having an audience or not was blurred. The audience in this case was another fourth

grade class. It is also possible that this audience was not "authentic" enough, as in other studies where an outside group such as a local children's museum became the client (Liu & Rutledge, 1997).

The research with the elementary school students also investigated the effect of the learning environment on students' creative thinking skills as measured by the Torrance Tests of Creativity Thinking (TTCT; Torrance, 1990). It was found that after engaging in an extended period of multimedia authoring, the fourth graders increased their creativity scores in a number of areas (Liu, 1998a). The low and intermediate ability students appeared to benefit from the multimedia authoring environment more than the high ability students and working collaboratively on the multimedia authoring projects enabled students to demonstrate higher creativity scores than when working individually.

DISCUSSION

Developing higher level cognitive skills is a challenge to everyone, especially to students at a younger age. In support of other research on the topic, these studies on learner-as-multimedia-designer suggest the following: (1) such a learning environment can have a positive impact on students' motivation toward learning, (2) such an environment can encourage creativity and enhance the development of cognitive skills, and (3) such an environment can help students learn design skills in addition to the content and computer knowledge.

Two factors underscore the value of acquiring the design skills. First, the skills in solving problems in a design situation are transferable; and learning these design skills can help students become better problem solvers. The findings have shown that through various design activities as those listed in Table 2, all 21 core cognitive skills, as defined by Vockell and Van Deusen (1989, see Table 3), can be exercised. Second, the ability to reflect and evaluate, both individually and collaboratively as necessitated by the process of creating a multimedia project, encourages students to be better learners as they become aware of their own thinking and monitor their own learning process (Flavell, 1979; Paris & Winograd, 1990). It is the transferability of the design skills and their metacognitive aspects (Flavell, 1976) that make them desirable to acquire for the students, especially when they are to become life-long learners. The 'inherent situatedness' of the learner-as-multimedia-

Table 3. Twenty-One Core Cognitive Skills as Defined by Vockell and Van Deusen (1989, p.11).

Categories	Cognitive skills
Focusing skills	1. Defining problems 2. Setting goals
Information gathering skills	3. Observing 4. Formulating questions
Remembering skills	5. Encoding 6. Recalling
Organizing skills	7. Comparing 8. Classifying 9. Ordering 10. Representing
Analyzing skills	11. Identifying attributes and components 12. Identifying relationships and patterns 13. Identifying main ideas 14. Identifying errors
Generating skills	15. Inferring 16. Predicting 17. Elaborating
Integrating skills	18. Summarizing 19. Restructuring
Evaluating skills	20. Establishing criteria 21. Verifying

designer environment provides a meaningful and concrete context for students to develop and practice a variety of cognitive skills in one setting (Newstetter, 2000).

Our experience has indicated that several factors are of critical significance in designing this environment. First, the learning environment should be as authentic as possible. For example, the classroom was a simulated multimedia production house in this case, where the students worked like multimedia professionals (i.e., working in a team, designing for a real audience, using professional tools, and having a deadline to meet). The authenticity of the environment not only is an important source for students' motivation, but also stresses the relevance and importance of acquiring the cognitive skills. Second, the emphasis on the product as well as the process, as required

by this project-based learning approach, allows students to develop cognitive skills 'just-in-time' as they are on their way to reach the final project goal.

Third, making the design process explicit and providing continuous practice are important strategies. In their study, Carver and her colleagues 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 product. 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., 1992, p. 402). In an effort to meet this challenge, we made the design process explicit by providing: (1) direct instruction about the design process from the teachers and local multimedia experts, (2) a simulated multimedia production environment in which each student chooses or is assigned a role of being a programmer, a graphic artist, a project manager or a designer, (3) direct interaction with the clients of the programs, and (4) direct communications with local multimedia experts. The research findings have shown that all these elements played an important role in bringing about the changes.

Lastly, and most importantly, the challenge of developing higher level cognitive skills calls for necessary scaffolding. Scaffolding is the support a teacher or an expert provides to a learner when she is learning a new skill so that she can achieve the goal successfully (Collins et al., 1989). Traditionally, scaffolding is provided through personal interactions between students and teachers. Now scaffolding could be provided with the assistance of interactive multimedia technology. In this learner-as-multimedia-designer environment, student learning is scaffolded in multiple ways through: (1) explicit design instruction, (2) learning various state-of-art multimedia tools, (3) coaching by the teacher, and the clients, (4) interaction with local multimedia experts, and (5) modeling by the more experienced peers. The assessment, including questionnaires and interviews, provided additional scaffolding.

To help students make an easier transition to the real world as future workers, we purposely choose to use tools multimedia professionals would use. For example, the high school students learned Adobe Photoshop, Adobe Premiere and Macromedia Director, and the middle school students learned Adobe Photoshop, Adobe Premiere, Microsoft Powerpoint, and Claris

Homepage. The research shows that multimedia tools have become a way to scaffold students' learning of design skills. Although the multimedia software used in these studies 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.

Students were not only coached by their teachers, but also by the clients and local multimedia experts. Students visited local multimedia companies, and attended a multimedia user group meeting. Seeing and listening to what experts were doing helped students understand what they should do or could have done. Another important aspect of coaching came from the peers. More experienced students became group leaders and helped the novices when they encountered difficulties. One of the novice students commented, "[having an experienced student around] takes a lot of pressure off me. They actually know the process. When you go and ask them, they give [you] good information" (Liu, 1998b).

SUMMARY

We educators have the responsibility to find ways to help our students develop their cognitive skills. Research on engaging learners as multimedia designers has shown some encouraging results in enhancing cognitive skills development for high school, middle school and elementary school students. While the instructional benefits of such an environment are obvious, the complexities of designing this a learner-as-designer environment are apparent as well. This environment is less structured and more ill defined as compared to learning in a traditional setting. Sometimes it can even be 'chaotic.' Its implementation requires teachers to be open-minded, flexible, and even 'adventurous' (Sheingold, 1991). To succeed, students must learn to be more independent, responsible, and self-directed. In addition, the process (and the research treatment) typically takes at least a semester, rather than just a few days or weeks as in some other research. A successful implementation depends on how such factors as the learners, the tasks, the context, the process, the coaches, and the outcome interact with each other. Only through practice and

research could we gain a better understanding of how to design such a learning environment more effectively. We call for more research on this topic to search for ways in designing effective interactive multimedia environments to support higher level cognitive skills acquisition.

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