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Intramural, collaborative learning systems

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ABSTRACT

INTRAMURAL, COLLABORATIVE LEARNING SYSTEMS

by
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This thesis focuses on three related concepts: problem-based collaborative learning; the use of multimedia tools in learning systems; and participatory design as a software engineering methodology to create multimedia tools to be used in learning systems. A literature review of the three areas is followed by an overview of the pedagogical, technological, and business trends that affect the direction of innovation in education, including problem-based learning. A discussion of a software engineering project to develop a multimedia application that enhances the learning of geography skills and puts the programming, interface design and multimedia systems capabilities of college students into action ensues. The project results are presented, and suggestions for future research are proposed.

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This thesis is dedicated to
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TABLE OF CONTENTS

TABLE OF CONTENTS

(Continued)

Chapter **Page**

LIST OF TABLES

CHAPTER 1

THEORY AND CONCEPTS

1.1 Introduction

The purpose of this thesis is to suggest the benefits of accommodating one of the most significant shifts in pedagogy, that being from practices and heuristics based in instructivist and behaviorist theory to constructivist concepts and approaches, particularly as they take shape in the activities comprising problem-based learning. A technological shift based in multimedia tools has accompanied this change of pedagogy. Multimedia technologies in the classroom have made possible a transformation and increase in the methods of imparting information, allowing for individual discovery, and creating an active classroom.

There are three related concepts under discussion: the benefits of problem-based collaborative learning; the value of using multimedia tools in learning systems, and the efficacy of participatory design as a software engineering methodology to create multimedia tools to be used in learning systems. The thesis begins by offering a literature review that highlights seminal constructs in each of the three areas. A discussion of the pedagogical, technological, and business trends that, together, affect the direction of innovation in education follows. Here, the thesis continues with a discussion of how traditional education – campus-based, lecture-bound and faculty-driven – can benefit from the explosion of opportunities borne of technological innovation and development by adopting changes in operational models.

A discussion of a software engineering experiment follows, one that conceptually derives from problem-based pedagogy and the effective use of multimedia tools by implementing participatory design methods in a project developed to maximize the skill sets and interests of school children and teachers, educational software technologist and researchers, and college undergraduates. Elementary school children, college seniors and technology consultants invoked a design methodology within a collaborative environment to develop a multimedia software application that enhances time and space orientation abilities of children and puts the programming, interface design and multimedia systems capabilities of college students into action. The project results are presented, and suggestions for future research are proposed.

1.2 Problem-Based Learning and Constructivism

Discussions of pedagogy and instructional design often entail their impact upon the cognitive systems of learners, knowledge transfer, and efforts to organize, facilitate and evaluate learning activities (Bloom, 1956; Mayer, 1983; Gagné, 1985; Bransford and Vye, 1989; Gagné and Merrill, 1990; Gagné, Briggs, and Wager, 1992; Mayer, 1996; Greeno, 1978; Bransford and Schwartz, 1999). Learning systems have, over the past twenty years, undergone a demonstrable shift in focus from those based in instructivist theory and approaches (logical positivism and identifiable/fixed truth) to constructivist concepts (knowledge as a social construction) and practices, particularly as they take shape in the activities comprising problem-based learning (PBL) (Barrows, 1980, 1992, 1994). A technological one has accompanied this pedagogical shift. Multimedia software and hardware advances have made possible a transformation and increase in the methods of reaching great numbers of learners through computer based learning systems.

Grabinger (1995, p. 667) summarizes the differences between "old" and "new" assumptions about learning, offering a concise set of distinctions that contrast instructivist and constructivist approaches to learning. Whereas the "old" school posits that "People transfer learning with ease by learning abstract and decontextualized concepts," the "new" school of thought would have it that "People transfer learning with difficulty, needing both content and context learning." In the past, learners were thought to be "receivers of knowledge." Now, "Learners are active constructors of knowledge." Behavior, in the stimulus and response sense of the word, as the primary vehicle for learning is an old assumption, whereas cognition "in a constant state of growth and evolution" is the new assumption. Consequently, learners are not "blank slates ready to be filled with knowledge;" they "bring their own needs and experiences to learning situations," where "skills and knowledge are best acquired within realistic contexts [and] assessment must take more realistic and holistic form."

Over 30 years ago, Canada's McMaster University's School of Medicine began a program of instruction that was "student-centered [and] problem-based, [in which] small-group learning took shape" (Camp, 1996). This is the core of problem-based learning, described by Savery and Duffy (1995) and summarized below as the outcome of constructivism, consisting of the following four tenets:

- Understanding is based on experiences with content, context, the learner's goals, etc., and these factors are inextricably woven together. Thus, understanding is a construction that is unique to the individual.

- Meaning is not transmitted, although it may be tested for compatibility with the meanings of others. From another perspective, cognition may be regarded as being distributed rather than individually localized.
- Puzzlement is the factor that motivates learning.
- Social negotiation and the ongoing testing of the viability of existing concepts in the face of personal experience are the principle forces involved in the evolution of knowledge (Greening, 1998, pp. 1-2).

Savery and Duffy (1995) set out the following "instructional principles" deriving from constructivism:

- Anchor all learning activities to a larger task or problem.
- Support the learner in developing ownership for the overall problem or task.
- Design an authentic task.
- Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning.
- Give the learner ownership of the process used to develop a solution.
- Design the learning environment to support and challenge the learner's thinking.
- Encourage testing ideas against alternative views and alternative contexts.
- Provide opportunity for and support reflection on both the content learned and the learning process (pp. 32-34).

These fundamentals are relativistic and by definition opposed to the tenets of logical positivistic thought. Moreover, PBL is opposed to instructivist pedagogy and “other views of knowledge [that] would expect students to be told the ‘truth’ about what is known about science and medicine, as is done in many lecture settings, and that, because they have been told it, they would all then have the same knowledge and understanding of the content" (Camp, 1996, p. 3). Camp and others (Kamin, et al., 1999, Walton and Matthews, 1987) describe PBL as being — for the learner — "active, adult-oriented, problem centered, student-centered, collaborative, interdisciplinary, utiliz[ing] small groups and operat[ing] in a clinical context" (Camp, 1996, p. 4). This overview is consistent with Greening, who defines PBL as having an "emphasis on contextualization … [in which] learning is accompanied by reflection … [implemented] via group-based work, reflecting the constructivist focus on the value of negotiated meaning … is unconfined by discipline boundaries, encouraging an integrative approach to learning which is based on requirements of the problem as perceived by the learners themselves" (Greening, 1998, p. 2). Schmidt (1983) condenses PBL into three principles: "Activation of prior-learning via the problem; encoding specificity such that the resemblance of the problem to intended application domains facilitates later transfer (leading to an emphasis on authentic learning environments); and elaboration of knowledge via discussion and reflection to consolidate learning experiences" (Greening, 1998, p. 2). Robbs and Merideth (1994) find several advantages to PBL modes of learning that can be generalized to disciplines other than medicine.

- An increased retention of information;
- The development of an integrated (rather than discipline-bound) knowledge base;
- An encouragement toward life-long learning;

- A greater exposure to clinical experience and at an earlier stage in the curriculum;
- An increased student-staff liaison; and
- An increase in overall motivation (Greening 1998, p. 2).

There are detractors, however. Courses built on the lecture model, where students sit in large lecture halls ostensibly to assimilate a lecturer's discourse continue to thrive in even the most modern of academic settings (cf. Pereira et al., 1993; Kember and Gow, 1994; Kenley, 1995). This top-down model of dissemination of knowledge, from the instructivist point of view, takes form in textbooks and in the lecture, where an established expert retains a privileged position of power by centering the instructional activity on him- or herself. As Greening characterizes it, though,

> The high value placed on experience may support a teacher-centered model of education in which the teacher embodies experience which is transmitted to students, or it may equally support a constructivist model which encourages the exposure to such experience by students. Much of this commentary on discipline-based inherent propensity for transmissive pedagogies is like to be attributable to historic and political forces, and may more productively be associated with inherent difficulties brought about by the more general process of change itself (4).

One way of leveling the playing field is for instructors to work closely with students in the role of mentors and learning coaches, and to make peer tutors part of the infrastructure of the class. Jones et al. (1993) find that tutors play "two essential roles" in the PBL process: "facilitation of the learning process via prompting, and assisting in group processes to ensure that they maintain focus" (Greening p. 5). The tutor is an essential component in the scaffolding mechanisms built into the PBL. Tutors facilitate student control (cf. Koschmann, 1994, 1996) and contribute to the authentic tenor of the actual problem through which students learn. As will be seen below, the context for the software design experiment is the city of Newark, into which students solve authentic problems through computer-aided instruction. Honebein et al. (1991) find that an authentic task is one in which learners take ownership of a project that is generalizable to other contexts once understood. Students are also encouraged to view the facets of the problem from multiple perspectives.

According to Peterson (1997), "PBL satisfies three important criteria that promote optimal learning." The environment fosters both supportive guidance and content-related feedback from students and instructors while engaged in learning that is "functional — based on solving a real problem" (p. 1). In the move from a teacher-centered to a peer-centered instructional realm, students have a greater opportunity to establish and exercise teamwork and leadership skills. When an authentic problem is shared by a team of students, and the goal of the course is to solve the problem as a team, "it becomes necessary for all team members to be able to lead the team. This can occur when responsibility for the operation of the team is shared. ... Shared leadership leads to shared accountability and competencies" (Peterson, 1997).

There is a literature rich in its testament to the success of PBL in science education (Koschmann, et al., 1997; Kamin, et al., 1999), beginning in medical education but expanding into other ill-structured and complex disciplines (Koschmann, 1995, Norman and Schmidt, 1992). If this literature is any indication, PBL has established itself as an instructional design platform that will reshape future learning modalities. Walton and Matthews (1989, p. 544) articulate PBL methods and corresponding "assets" as they apply to medical education, the pioneering discipline in PBL. Their overview is easily transferable to other disciplines such as computer programming and English composition (see Deek, Deek and Friedman, 1999 and Friedman, Deek and Deek, 2000, Deek and Friedman 2001).

For Walton and Matthews, PBL methods stimulate and challenge the learner to "tackle realistic problems in chosen field [and] by applying prior knowledge and experience." They provide constant "practice of a logical, analytical, scientific approach to problems" that yields the development "of effective and efficient reasoning skills, and a store of relevant, retrievable knowledge" (p. 544). PBL promotes "the recognition that nothing is ever learned to finality, that learning in a variety of subjects runs in parallel for application in a mixed, interrelated way, that there exists too much for any one person to learn and that tasks need to be shared between students." In terms of methodology, PBL fosters the "practice of the application of new knowledge to the original or to new problems."

Bouton and Garth (1983), Bruffee (1984), Johnson (1981), Johnson and Johnson (1975), and Dillenberg and Schneider (1995), belief, as does Hiltz (1997), that collaborative learning is "a learning process that emphasizes group or cooperative efforts among faculty and students. It stresses active participation and interaction on the part of both students and instructors. Knowledge is viewed as a social construct, and therefore the educational process is facilitated by social interaction in an environment that facilitates peer interaction, evaluation and cooperation" (Hiltz, 1997). PBL steeps students in an active and authentic environment where there is little-to-no top-down structure. Hiltz summarizes Dillenberg and Schneider's (1995) "social-psychological mechanisms [that] make collaborative learning effective, including self-explanation, internalization, and appropriation":

- Self explanation occurs when a more knowledgeable peer explains a topic to another. One receives an explanation and the other benefits by articulating and integrating various pieces of knowledge.
- Internalization is the process of learning by verbalizing in a conversation.
- Appropriation occurs as one learns from watching and working with a more skilled partner; apprenticeship is a form of appropriation (Hiltz, 1997).

Self-explanation and internalization provide an opportunity for what Koschmann (1997) finds as "a crucial moment in the Problem-Based Learning method. Its success ... relies in part on the ability of group members to assess not only the accuracy, but also their relative uncertainty, about what they know" (p. 6).

Jonassen and Reeves (1995) refer to "technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem solving, and learning" as cognitive tools (p. 693). City Mapping, the software engineering project described below, falls into the domain of cognitive tools rather than a traditional instructional technology, that is, software that "constrains students' learning processes through prescribed communications and interactions" (p. 694). It goes a step beyond, as students use it as a "cognitive tool to organize, restructure, represent and express what we know" (pp. 694-695). It was designed to engage and support learners through the entire problem solving process, diminishing what Jonassen and Reeves (1995) find to be "the primary conclusion of programming research: that the cognitive overhead (the amount of mental effort required to use programming languages) mitigates the ability of the learner to use computer programming as an easy and effective means for solving problems or representing what the learner knows, which is the goal of using cognitive tools in the first place" (p. 702).

Grabinger (1995), summarizes "rich environments for active learning" (REALs) as "comprehensive instructional systems that:

- Are evolving from constructivist philosophies and theories
- Promote study and investigation within authentic (i.e., realistic, meaningful, relevant, complex, and information-rich) contexts
- Encourage the growth of student responsibility, initiative, decision making, and intentional learning
- Cultivate an atmosphere of cooperative learning among students and teachers
- Utilize dynamic, generative learning activities that promote high-level thinking processes (i.e., analysis, synthesis, problem-solving, experimentation, creativity, and examination of topics from multiple perspectives) to help students integrate new knowledge with old knowledge and thereby create rich and complex knowledge structures
- Assess student progress in content and learning to learn through realistic tasks and performances." (p. 668)

REALs are environments that support problem-based learning. Benor (1984, p. 94) states that in PBL, "students have to understand the problem to the extent that its constituents can be identified. The learners have then to collect, integrate, synthesize, and apply this information to the given problem, using strategies that will yield a solution." Grabinger's REALs provide such an environment by building on constructivist tenets such as:

- instilling the notion that "knowledge is not a product to be accumulated but an active process in which the learner attempts to make sense out of the world;"
- promoting the idea that "people conditionalize their knowledge in personal ways;"
- stressing the "importance of collaboration and the social negotiation of meaning" (pp. 669-670).

In REALs, the learning environment fosters authentic activities and contexts. As Grabinger states,

> Authenticity is important to REALs for three reasons. First, it encourages students to take ownership of the situation and their own learning. Realistic problems hold more relevance to students' needs and experiences, because they can relate what they are learning to problems and goals that they see every day. Second, it develops deeper and richer (indexicalized and conditioned) knowledge structures leading to a higher likelihood of transfer to novel situations. Finally, it encourages collaboration and negotiation. Complex problems require a team approach that provides natural opportunities for learners to test and refine their ideas and to help each other understand the content (p. 670).

Nkanginieme's (1997) early medical education demonstrates its theoretical basis in Bloom's (1956) taxonomy and its relationship, through application, to the cognitive domain of distinct educational objectives. Nkanginieme presents the process of clinical diagnosis as derivative of Bloom's theoretical base and the methodology as central to problem-based learning in a series of definitions of terms:

> Knowledge: To acquire, to recall, to identify, to recognize (knowledge; of specifics, of dealing with specifics) (knowledge of universals an abstractions); Comprehension: Translation, interpretation, extrapolation;
> Application: To apply, to relate, to transfer, to use;
> Analysis: To discriminate, to distinguish, to organize;

Synthesis: To constitute, to combine, to specify, to propose;
Evaluation: To validate, to argue, to appraise, to reconsider.

Savery and Duffy (1995, 32-34) offer "instructional principles deriving from constructivism." Anchor all learning activities to a larger task or problem. Support the learner in developing ownership for the overall problem or task. Design an authentic task. Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning. Give the learner ownership of the process used to develop a solution. Design the learning environment to support and challenge the learner's thinking. Encourage testing ideas against alternative views and alternative contexts. Provide opportunity for and support reflection on both the content learned and the learning process (Savery and Duffy 1995). Jonassen and Reeves (1995) make the point that "the real power of computers to improve education will only be realized when students actively use them as cognitive tools rather than passively perceive them as tutors or repositories of information" (p. 696).

Jonassen and Reeves (1995) define cognitive tools as the:

> tools are best used by students to represent knowledge and solve problems within the context of pursuing investigations that are relevant to their own lives.... Cognitive tools, as we conceive them, are unintelligent tools, relying on the learner to provide the intelligence, not the computer. This means that planning, decision making, and self-regulation are the responsibility of the learner, not the technology. Cognitive tools can serve as powerful catalysts for facilitating these skills, assuming that they are used in ways that promote reflection, discussion, and collaborative problem solving (p. 697).

CHAPTER 2

INNOVATION IN EDUCATION

2.1 Introduction

Academics will agree or reluctantly admit that change in education, particularly when issues of curricula and pedagogy are in question, is a hard-fought battle, rarely won by innovators. Yet, like most institutions, traditional education finds itself acclimating to change via pressures of the marketplace. Two of the strongest tensions between academic tradition and educational change are in the debates about constructivism as a teaching philosophy and the use of technology in the classroom, which is a growth industry in itself.

"According to Internet Data Corporation (Evans et al., 2000), which follows more than 200 electronic-learning companies, the e-learning market will grow from $550 million in 1998 to $11.4 billion in 2003" (p. 96). Peter Stokes (2000) of Eduventures.com, an education industry market research firm, writes that, "Investors are pouring ever larger sums of start-up capital into education businesses …during the 1990s education businesses received some $6 billion in private equity investments – with $2.6 billion coming during 1999 alone" (p. 5).

With the expansion of instructional technologies throughout all sectors of the education community, research into the appropriateness, effectiveness and modalities of learning via information and communication technology (ICT) continues to grow. Relevant journals such as the *Journal of Asynchronous Learning Environments*, *Educational Technology & Society*, and *The American Journal of Distance Education* publish the results of experiments, case studies and meta-analyses that discuss theories supporting virtual learning, assess the pros and cons of conducting courses via the Internet, as well as describe the deployment of instructional technologies in a classroom. Key issues addressed in the literature include the role and importance of communication between teachers and students (Wegner, Holloway, and Wegner 1999; Carswell et al 1999), learning styles (Lumb 1999; Wheeler, Vranch and Reid 1999; Leuthold 1999); comparisons and contrasts of outcomes between classroom-based and web-based instruction (Wegner, Holloway, and Garton 1999; Wade and Power 1998; Joy and Garcia 2000; Moonen 1997; Machtmes and Ascher 2000; Smith and Hardaker 2000; Fletcher and Dodds 2001; Young and Young 1999); evaluation of online environments (Tucker and J. Cordani 1998; Moonen 1997); general impacts and challenges of distance education (Deek, Deek, and Friedman 1999; Thompson 1999; Martin 1997; Neal 1999; Ouellette 1999; Peters 2000); implementation of virtual learning (Carswell et al, 1999; Smith and Hardaker 2000; Dede 1997; Hawkins 1999; Ferguson and Wijekumar 2000; Friedman and Deek 2002) peer and faculty collaboration (Ragoonaden and Bordeleau 2000; Thomas and Carswell 2000); historical overviews (Maurer 1997; Peters 2000); quantitative and qualitative evaluations (Wegner, Holloway, and Garton 1999; Fletcher and P. Dodds 2001; Hawkes 1995; genre-specific analyses (Andriole 1997; Jones 1996; Arbaugh 2000; Hilsop 1999); and advances in digital technologies (Bell and R. Meyer 1997; Lotus Institute [n.d.]; Cadiz [n.d.])

2.2 Investment in Learning Systems

Naidoo (Farrell, ed. (2001). finds that "two trillion dollars or one-twentieth of global gross domestic product is spent on education, 20% of which is being spent by the private sector" (Farrell, 2001, p. 11). Naidoo lists the need for education and training, the desire to bridge the digital divide, and the need for individually tailored education that notes a person's capability, potential and level of maturity in terms of his or her own learning process as the driving forces for innovative learning venues. Chris Dede (1997) suggests that universities employ a business collaboration model analogous to the "competition among cable television vendors to receive exclusive franchises from communities in the early 1980s.... Similarly, during today's much larger war in the information services industry, educators who have innovative alternatives to 'talking heads' instruction can find vendors happy to share the costs in exchange for help with the regulators, legislators, and judges who are determining which coalitions will manage the nation's information infrastructures."

Mass customization is the strategy that Brian Hawkins (1999), President of Educause, suggests in an effort to "develop viable organizational and business strategies" that address factors such as library access, faculty workload and incentives to use nontraditional teaching methods, as well as ways to develop robust "faculty support structures." At least one issue stands in the way of technology filling the gap between learners and instructors: first, the current state of teaching materials available, including the diversity of access of and to computing systems that interface with these learners, is far from standardized.

Bates (in Farrell, 2001) posits that, "the technical capacity has far exceeded the capacity of governments, commercial organizations and educational communities to respond fully to the opportunities and challenges this rapid change has brought" (pp. 29-30). In-house corporate training and independent training contractors employ sophisticated communication and learning technologies to supply just-in-time education for knowledge workers (Farrell, 2001; Ferguson and K. Wijekumar 2000; Evans et al 2000), but few universities have the infrastructure, personnel and mission to provide similar content and services to their students. For Bates,

> schools, colleges and universities play a much wider role than merely transmitting information from one generation to another. They have social and cultural roles as well. Education needs to match the needs of learners. Technology should be used only if and when it contributes to those needs. (Farrell, 2001, p. 42)

Bates also finds that "there are very few convincing research and evaluation studies that indicate clear educational benefits for such an investment" (Farrell, 2001, p. 43), a claim echoed by numerous academic researchers.

Merisotis and Phipps conclude that,

> technology cannot replace the human factor in higher education ... [and] technology is not nearly as important as other factors, such as learning tasks, learner characteristics, student motivation and the instructor. The irony is that most of the research on technology ends up addressing an activity that is fundamental to the academy, namely pedagogy – the art of teaching. (1999)

Wegner, Holloway, and Wegner (1999) suggest that, "educational institutions [should] provide integrated instructional management systems as a platform for the delivery of course content and instructional communication" (p. 9). For Bates, however, many "administrators lack both the vision to use [technology] for strategic change and the willingness to reallocate sufficient resources to ensure success" (Farrell, 2001, p. 34), intimating that the onus is on the administration of many university campuses to lower their inhibitions to employing technology-centric pedagogy that drastically alters how teachers teach. A fundamental conflict between the traditional classroom instruction modalities that champion technology in education is whether the class is teacher-centric or technology-centric. In the traditional model, the teacher maintains control of the information flow, sets the learning outcomes and assesses the progress and success of students. It is safe to say that this *modus operandi* has been in place for at least 150 years. Training faculty to teach effectively in a technological environment, maintaining dedicated equipment, and ensuring adequate technical support likely will be both time-consuming and expensive.

Some researchers add to the traditional vs. technological debate by examining how learning styles are affected by computer-based education. Leuthold (1999), for example, administered a Gregorc Learning Style Delineator test to identify the basic learning style (concrete or abstract, sequential or random) of students in an undergraduate economics course. "According to the results, students with sequential learning styles used computer-based instruction techniques more frequently and prefer them to traditional instructional techniques when compared with students whose learning styles are random."

An on-going sub-question in the arena of "media comparison research is … whether media alone influence learning outcomes." Richard E. Clark argues that media *per se* do not influence learning. Rather, "learning is caused by the instructional methods embedded in the media presentation." Robert Kozma, on the other hand, posits that "media and methods are inextricably interconnected….both media and methods are part of the instructional design" (Farrell 2001, 35).

2.3 Business Trends

Bates finds that "the development of alternative organizational and management structures for the new knowledge-based industries is also relevant to virtual education, which is not only dependent on an extensive and reliable ICT infrastructure, but also requires a post-industrial approach to organization and management" (Farrell, 2001, 30-31). An estimated 160 million people are expected to be involved in higher education alone in the year 2025 (Farrell, 2001, p. 31), and to service them, publishing houses are teaming with universities and education corporations to develop and distribute both new content and new delivery systems. Moving away from the premise that tools, content and systems of education comprise "a self-contained process," the services that make up the virtual educational experience can be distributed to those entities that can best provide courseware, instruction and support.

The business/university alliance model calls on each entity to supply assets historically ascribed to them. "Businesses see the universities as sources of intellectual assets needed to develop distance education offerings. Universities recognize that the businesses are experienced in developing, distributing and marketing products to mass markets. Both sides are struggling to devise relationships that would draw on the strengths of each to create and deliver new products to meet the perceived needs of vast populations of adult learners" (Farrell, 2001, p. 111). However, Bates cautions that, "It is imperative that educational organizations, particularly virtual education institutions, realize that a content management system is a requirement for success in this milieu" (Farrell, 2001, p. 58).

2.4 Technological Trends

For John Chambers, the CEO of Cisco, "the next big killer application for the Internet is going to be education – one that would make the pervasiveness of e-mail look like a rounding error" (Farrell, 2001, 31). How that application will manage the content millions of students' desire and demand is the focus of several research projects. One of the more significant areas of inquiry is a systematic tagging system for digital data, leading to content for courses becoming available via the Internet as learning objects. The learning object approach uses the

> underlying principle of Napster … the retrieval of music content from a distributed network of servers powered by a common metadata packaging scheme. In educational terms, the analogue would be the provision of access to instructional units, learning resources, assessment and accreditation mechanisms using a common packaging schema for the granular components of learning. Building an educational repository that provides access to learning object requires standards and structures that can facilitate object storage, retrieval and aggregation to suit the needs of learners or the pedagogical intentions of instructional developers (Farrell, 2001, p. 48).

"Examples of collaborative sharing models based on learning object attributes are already visible in the public education space. The Multimedia Educational Resource for Learning and Online Teaching (MERLOT) is one example of a consortium approach to providing online resources for faculty and students" (Farrell, 2001, p. 57). Challenges ahead vary for different institutions with different histories and capabilities in distributed learning, and both research and teaching institutions that, over the years, have acquired "large stores of legacy content and learning resources" (Farrell, 2001, p. 57). Each institution has to identify content it considers to be valuable, create modules out of that content, then ascribe a metadata tagging system that "allows for efficient storage and retrieval. For most organizations, the move to a learning object model could be labor-intensive and expensive" (Farrell, 2001, p. 57).

David Porter finds that, "While the Web world focuses its attention on knowledge management, customer profiling, and e-business practices, many education institutions continue to automate traditional instructional and administrative practices.... Very few have considered that idea of component-based instructional units, 'learning objects,' and complementary business systems and student service models that have the potential to revolutionize instructional practice." Can educational institutions involved in or embarking on virtual learning programs meet the demands of "the masses in a convenient and user-driven manner," given the resistance to change these same institutions demonstrate through their

> hierarchical ... organizational structure ... their buildings, through their academic calendars, or even through their Web sites [?] Instead of identifying a learner's goal and then describing potential pathways to achievement, many institutions deal more with their own institutional requirements to qualify the learner to be enrolled. This position can be attributed in part to the historically autonomous nature of institutions of higher learning, where the power resides in the hands of the institution. (Farrell, 2001, pp. 47-48).

Content providers must consider the implications resulting from the development and implementation of "metadata standards to ensure that their databases and repositories for print, audio, video and computer-based materials are accessible both for internal and external purposes. It is also imperative that they have a plan for converting any analogue assets (primarily video) for use within a learning object economy" (Farrell, 2001, p. 49). This requires that all those involved in the development and distribution, not to mention the use of learning objects and databases agree "a protocol [and] the standards for locating and operating interactive platform-independent materials" (Farrell, 2001, p. 50).

For David Porter, "The key to understanding structured information is the concept of separating content from its presentation, which can be done using standard generalized markup language (SGML) or extensible markup language (XML). These are meta-languages that can be used to develop print or Web-based products that follow this separation" (Farrell, 2001, p. 54). "Instead of seeing content of course authoring as a standalone activity in an educational organization, the Web-centric trend is to see the operation of an educational organization as an integrated whole that can provide customized service to all of the organization's learners and clients … To accomplish the goals outlined above means that instructional developers need to become familiar with learning object theory, metadata classification standards, instructional material packaging schemes, content management systems, authoring tools and instructional delivery tools" (Farrell, 2001, pp. 57-59).

Ongoing academic research also includes contributions to the "current debate about the role of hypertext and hypermedia [that] centers mainly around the use of hypertext as a cognitive tool for purposeful learning of complex material" (Arbaugh 2000). Hutchings et al. (1992) claim that hypermedia offers users "greater learning control; improved access to multimedia learning materials; and a variety of new modalities of interaction for use with learning material." Jonassen (1993) posits that representing content architectures via a GUI will not help students map those structures to a useful degree. Barker (1993) states that, "if hypermedia material is to be educationally effective, considerable thought should be given to firstly the learning goals and activities that it must support; how the nature of the underlying knowledge corpus relates to these requirements; and how learners differ from each other. … The more deeply a learner processes information, the more likely it is that the person will remember material to be learned. Carswell et al. (1999) ask whether "the Internet supporting student needs or technology vanity?" (p. 7).

Peters (2000) sets multimedia technology within the context of pedagogy, suggesting that, "When carrying out experiments with multimedia in a digital learning environment it may be advantageous if the teacher has an idea of other specific pedagogical functions which this method of intensified illustration can have" (p. 5). Smith and Dillon (1999) focus on "Branching [as] an attribute of media. ... Individual learners can select or be directed to different instructional events depending upon interest, need, or competency level. Learners learn at different rates, and individual learners may process information differently. Therefore, learning efficiency can be increased if the instruction can be tailored to the individual requirements of the learner" (p. 18).

In a white paper published by the Department of Defense, (Fletcher and Dodds 2001) analysts agree that

> A successful shareable courseware objects reference model (SCORM) must meet three primary criteria: It must support full articulation of guidelines that can be understood and implemented in the production of shareable courseware objects; It must be adopted, understood, and used by as wide a variety of stakeholders as possible (courseware developers, courseware tool developers, and courseware customers, for example); It must permit mapping of any stakeholder's model for instructional systems design and development into itself.

Judith Boettcher [quoted in Worley, 2000] concurs, finding that "the concept of a university course as an instructional unit will be weakened and replaced by the concept of 'knowledge clusters' that focus on developing competencies in specific disciplines."

Microsoft's Collaboration & Multimedia Group (Cadiz, n.d.) has been working on the implementation of two widely-used application, Windows Media Player and

NetMeeting, to create an environment in which "A distributed lecture video viewing system with shared VCR controls" could be merged with "A communication system for discussion around the video content" but among geographically dispersed participants These software leaders concur that, "Online training is becoming a commonplace solution as marketing professionals strive to achieve the perfect work-life balance" (p. 140).

2.5 Technology Policy Issues for Education Leaders

For analyst Peter Stokes (2000), "If there is a mandate to rethink the relationship between education and technology, it is not because technology – by itself – makes people smarter. Anyone who presents such an argument is simply hawking 'the new new thing.' The real reason to rethink education around the question of technology is that the technology is here – and it is embedded in our lives" (p. 2).

"Methods change but standards of quality endure," according to Hope. "The key areas affecting the quality of technology-mediated learning are common to all of the published benchmarks and guidelines and relate to: Institutional support; course development; teaching and learning; course structure; student support; faculty support; and evaluation and assessment" (Farrell, 2001, pp. 132-133). The Institute for Higher Education Policy (IHEP) report of 1999 acknowledges that "technology is not nearly as important as other factors, such as learning tasks, learner characteristics, student motivation, and the instructor" (IHEP, 1999, p. 8). It also finds in the literature a conviction that faculty, who combine the roles of "content experts, learning process design experts, process implementation managers, motivators, mentors and interpreters" cannot be replaced by technology "without significant quality losses" (IHEP, 1999, p. 8). "Policy-makers opting for technology-mediated learning solutions must factor in the cost of designing quality management systems which use the data collected as part of a constant quality improvement process" (Thomas and Carswell, 2000, p. 134).

CHAPTER 3

LEARNING SYSTEMS AND SOFTWARE DESIGN

3.1 Introduction

Malone and Lepper (1987) have developed heuristics that concern "the design of instructional environments that are intrinsically motivating, that is, environments in which people are motivated to learn in the absence of obvious external rewards or punishments" (p. 223). Most would agree that this is the optimal environment for learning, formal or informal, at any age. For children, a game environment for learning activities proved to be successful provided "the game had an explicit goal" (p. 225). The children they experimented with selected and successfully navigated activities that had audio and visual effects, automatic scoring, randomness in terms of choice of activities, as well as those games in which speed of response made a difference. "Children chose the activity for roughly 50% more time when the material was presented as a game, rather than a drill" (p. 227). They suggest developers use techniques such as variable levels of difficulty, multiple levels of goals, and having information that is hidden.

In their experiments, they measured performance feedback, as it "provides the information necessary for the reformulation of goals that govern an activity's challenge, activities will be more intrinsically motivating when the feedback they provide is (a) frequent, (b) clear, (c) constructive (i.e., providing useful information concerning the direction and nature of one's errors), and (d) encouraging" (p. 232). Their taxonomy of relevance includes "Instrumental relevance: the functional utility of learning can be stressed; Fantasy Relevance: The material might be embedded in an imaginary context that is familiar to the learner or in a fantasy that the learner finds emotionally appealing;

Social Relevance: The material may be presented in a social context that elicits interpersonal motivations, such as cooperation, competition, or recognition, that make performance goals meaningful to the learner" (p. 233). As will be seen below, the software was designed to yield all three types of relevance.

What proved to be the most important intrinsic motivation for Malone and Lepper – curiosity – can be examined from two distinct views. Sensory curiosity "involves the attention-attracting value of variations and changes in the light, sound or other sensory stimuli of an environment" (p. 235), while "Cognitive curiosity … is evoked by the prospect of modifying higher-level cognitive structures. … Completeness, consistency and parsimony are also characteristics of well-formed cognitive structures" (p. 236). Fantasy is a characteristic of the activity environment that "evokes mental images of physical or social situations not physically present" (p. 240). Malone and Lepper make an important distinction between an "exogenous fantasy in an instructional environment … in which the fantasy depends on the skill being learned, but not vice versa," and an "endogenous fantasy in which the skill being learned and the fantasy depend on each other. … Endogenous fantasies can also provide useful metaphors for learning new skills (e.g., spatial metaphors and mathematical concepts), and they can provide examples of real-world contexts in which the new skills could be used (e.g., a simulation of running a lemonade stand)" (p. 240).

Mapper, the helpful character developed for the software discussed below, is an example of an "imaginary characters with whom the [learner] can identify." The character adds a cognitive aspect to the mapping software's endogenous fantasy by offering a "gateway to analogies or metaphors that may provide the learner with leverage for better understanding new information by relating it to past knowledge" (p. 241). Table 3.1 provides an overview summary of Malone and Lepper's findings:

Table 3.1 Heuristics for Designing Intrinsically Motivating Instructional Environments

Individual Motivations	Challenge: The activity should provide a continuously optimal (intermediate) level of difficulty for the learner	Goals: The activity should either (a) present clear, fixed goals or (b) provide an environment in which it is easy for students to generate goals for themselves at an appropriate level of difficulty The activity should provide short-term, as well as long-term, goals
		Uncertain outcomes: Uncertainty of outcomes may be produced using (a) Variable difficulty levels; (b) Multiple levels of goals; (c) Hidden information, selectively revealed; (d) Randomness
		Performance Feedback: Performance feedback should be frequent, clear, constructive, and encouraging
		Self-esteem: The activity should employ graded difficulty levels and positive feedback techniques to promote feelings of competence
	Curiosity: The activity should provide an optimal (moderate) level of informational complexity or discrepancy from the learner's current state of knowledge and information	Sensory Curiosity: Sensory curiosity may be enhanced by variability in audio and visual effects
		Cognitive Curiosity: Curiosity may be promoted by instructional techniques that cause learners to be surprised and intrigued by paradoxes, incompleteness, and potential simplifications Cognitive curiosity will be enhanced when activities deal with topics in which the

(Table 3.1, continued)

		learner is already interested.
	Control: The activity should promote feelings of self-determination and control on the part of the learner	Contingency: The activity should provide a responsive learning environment
		Choice: The activity should provide and emphasize moderately high levels of choice over various aspects of the learning environment
		Power: The activity should permit the learner to produce powerful effects
	Fantasy: The activity may promote intrinsic motivation through the use of fantasy involvement	Emotional Aspects: Fantasies should be designed to appeal to the emotional needs of learners Fantasies should encourage identification with imagined characters or contexts
		Cognitive Aspects: Fantasies should provide appropriate metaphors or analogies for the material presented for learning
		Endogeneity: Fantasies should have an integral, endogenous, relationship to the material to be learned
Interpersonal Motivations	Cooperation: The appeal of the activity may be enhanced by enlisting the motivation to cooperate with others Endogenous cooperative motivation may be produced by segmenting the activities into inherently interdependent parts	
	Competition: The appeal of the activity may be enhanced by enlisting the motivation to compete with others Endogenous competitive motivation may be produced by creating an activity in which competitors' actions affect each other	
	Recognition: The appeal of the activity may be increased if the learner's efforts receive social recognition Endogenous recognition	

	motivation may be produced by activities that provide natural channels for students' efforts to be appreciated by others	

[Note: Heuristics for Designing Intrinsically Motivating Instructional Environments (Malone and Lepper, 248-249)]

Malone and Lepper (1987) have also researched intrinsic motivation and instructional effectiveness in computer-based education, finding that

> The computer provides immediate feedback and sustained attention to the child. … It provides the opportunity for feedback of several sorts not typically available in the classroom, such as immediate feedback concerning the quality of one's individual performance relative to normative standards or one's own past efforts, or the speed of one's response. … The computer encourages highly individualized and tailored instruction, in which the problems to be selected, the questions to be posted, and the additional instruction to be provided are made contingent on the child's immediately prior performance and some diagnosis of his or her strengths and weaknesses (p. 257).

3.2 Constructivism and Learning Systems

From a theoretical perspective, Marton and Booth (1997) distinguish between those of the rationalist tradition, such as Plato, Descartes, Kant, Piaget and Chomsky, who would have it that "knowledge comes from within, from the powers of mind," and those of the empirical school of Bacon and Locke, who "claim that knowledge comes from the outside, from the world around us" (p. 8). Constructivists bring these two positions together through theories of "situated action," a distillate of "studies of learning and thinking in everyday situations outside educational institutions," HCI and Vygotsky's sociocultural psychology. Marton and Booth (1997) "use 'social constructivism' as an umbrella term for a rather diverse set of research orientations that have in common an emphasis on what surrounds the individual, focusing on relations between individuals, groups, communities, situations, practices, language, culture, and society. The main question we ask is, "How do the surrounding social or cultural, forces mould or make certain ways of acting and certain ways of thinking possible for the individual?" (p. 11)

The main contribution of individual constructivism is its emphasis on the learner's active role in the acquisition of knowledge. The main contribution made by social constructivism is its emphasis on the importance of cultural practice, language, and other people, in bringing knowledge about." (p. 12). City Mapping, the mapping software described below was developed at NJIT with the collaboration of municipal agencies, non-profit organizations and students and teachers from an independent school. A primary purpose of the software is to familiarize children with the skills necessary to navigate an urban environment such as Newark. In that sense, the activity, mapping becomes a form of literacy that yields social benefit once acquired and practiced. As Eisner (1985) states, "Literacy, as I use the term, is the ability to encode and decode meaning in any of the forms of representation used in the culture to convey or express meaning" (p. x).

Learning, as has been described and defined above, occurs in many forms, in varied environments, at times through the use of computing tools such as interactive software in multimedia formats. Several constructivist-based software design philosophies posit that there should be collaboration between the user and the designer when creating learner tools. The differences between the design strategies described below are found in the level of involvement of each of the stakeholders in each of the activities and roles during the design and development process. This section begins with a discussion of Harel's (1991) five reasons why she finds "'learners as designers' (or 'design for learning') is a rich paradigm for learning and for research on learning mathematics, and in what ways it is different from other approaches:

1. Design motivates learning. From the very beginning of the project, the young software designers need to face serious questions, What do I know about fractions? Why do I care about fractions? What do I want to explore within this domain? What do I want to communicate and represent to other students? How am I going to do it? "Constructionist design activities can encourage motivation and "force" learners to find the relevancy of the learned domain.
2. Designers make things happen. Design substantiates learning in actual accomplishments.... Passive learning and voyeurism can hardly exist in such an environment.
3. Design evokes self-knowledge. Designers make personal connections between the affective and the cognitive. The design process is putting people, feelings, things, and situations together. ... [Designing] as an educational process leads learners toward a productive and a personal (affective and cognitive) contribution to their learning environment.
4. Designing a product promotes consideration of intended users, clients, customers – the community of others that designers serve. The difference between simply doing something and designing a real product is in the level and quality of commitment and consideration given to the task, and in how one feels while accomplishing it.
5. Design is integrative and holistic. ... [Design] is viewed here as an empowering principle, as a discipline which facilitates other learning, and which marries cultural background, school activities, thought, action, creativity, construction and reflection. ... Students learn how to integrate ideas: They experience how math relates to language, how learning relates to teaching, how art relates to science, and how communication relates to understanding. (pp. xix-xxi)

Kafai (1999) presents a similar perspective in "Children as Designers, Testers, and Evaluators of Educational Software." She distinguishing between approaches that

> have assigned users different places in the design process (user-centered design, informant design, participatory design) and assumed different perspectives on who the users are (users or learners). User-centered system design places users and their needs at the center of the design process by identifying their task demands and including their evaluations of systems in the software development process. On the other end of the spectrum is participatory design, which sees users more a partners than reactants to a system in development. In the participatory design approach, users often work together with the designers to develop systems that fit their needs. More recently, informant design has been proposed as the middle ground between user-centered and participatory design

> approaches. Informant design describes situations and interactions in which the user provides input at different stages of the design process using various methodologies such as scenarios, interface evaluations, task specifications and usability testing. (p. 125)

Kafai, however, "argue[s] for a different approach, the learner as designer, thus breaking the traditional barriers between end users and system designers. ... I propose this as an extension to the existing approaches for identifying users' needs and demands. ... I see this as a privileged way for children, in particular, to learn about various subject matters (p. 126). For Kafai, the three essential features of the software design cycle are:

- Designing educational software is crucial because it places children in the teaching situation and forces them to shift perspective between being a teacher and being a learner.
- Testing is included because children designers need to meet the prospective learners they are designing the software for.
- Evaluating other software designs is essential because students can apply the insights gained from their own design process.

Sciafe and Rogers (1999) have another variant of design methodology deriving from a constructivist base. Their

> 'informant design' framework ... involve[s] determining the different phases of design, identifying who will be the informants in these, what their inputs will be, and what methods will be used. Our emphasis is to view different people as informants through our interaction with them. In so doing, it has enabled us as a design team (consisting of an interaction/software designer, and HCI specialist, a developmental psychologist, and an educational technologist) to discover what we did not know rather than try to confirm what we thought we already knew. Such a philosophy is often overlooked by designers following a user-centered design approach in the excitement of demonstrating their own creative designs to users. (p. 35)

After defining the domain and learning problems,

> the education technologist and psychologist in the design team began by working with teachers from local schools to explicate specific learning goals, to identify the problems with current methods of teaching, and to make a comparison between conventional and interactive media for presenting material. The also interacted with children in their school

> environment, getting them to evaluate existing materials (e.g., CD-ROMs, textbooks) in that domain to identify what they found to be the main learning difficulties and obstacles to understanding. In parallel, the interaction/software designer created some preliminary sketches and storyboards for the domain space, and the HCI expert operationalized theoretical ideas on interactivity. (p. 35)

After realizing that they may not be receiving accurate information, they developed a strategy called "'informant design,' intend [as] a method for going between privileged observations from potential users and ourselves with another set of skills" (p. 40). Their experience is that "kids' ideas are most useful in helping us design the motivating and fun aspects of the educational software – a genre that we as adults are not necessarily tuned into" (p. 45).

Sciafe and Rogers (1999) came up with a few concerns for their "kid-centered informant design framework" (p. 46): How do designers select ideas from "the endless stream of suggestions" that children produce, particularly for "educational software, where interface and fun factors can conflict with learning goals?" (pp. 46-47). "Kids don't necessarily focus on details of the software that have been designed specifically to support learning goals. How do you deal with this mismatch of expectations?

Kids may not be sensitive to the learning goals of the software and overlook or use components differently from anticipated.... Therefore, involving kids both in the design and evaluation process is important to be able to detect aspects of the software where there are mismatches between expectations. Researchers and designers need to remember that "Kid talk is not adult talk, so there can be a translation problem between what they actually say, what they want to say, what we want to hear, and what we actually hear" (p. 40). Moreover, questions such as "How do we design software that caters to the learning needs of the huge variety of kids?" and "Should we just get out of the way and give kids the software tools to do the design?" arise.

Sciafe, et al. (1997) summarize informant design as a methodology that "advocates efficiency of output from different people: maximizing the value of contributions from various informants and design team members at different stages of the design process." From a utilitarian point of view, "The real issue would seem ... to be not whether involving users is good or bad but rather how to more effectively engage them in the design process." Opposed to a user-centered approach, in which users are also used as testers to evaluate the fit between software and their needs, informant design seeks to limit the amount of "feedback obtained from users [that] is exclusively based on reaction rather than initiation" (p. 343). "By informant design we mean an interplay between privileged observations from potential users and ourselves with another set of skills. Hence, in treating children as native informants, we hope to be able to discover what we did not know rather than try to confirm what we thought we knew" (p. 344).

Contextual inquiry is another methodology used when working with children. It uses ethnographic strategies of observation to assess the efficacy of design activity. As a research methodology, it is labor intensive and time consuming, for its protocols direct the researcher to:

- Go to their territory.
- Give children time.
- Wear informal clothing.
- Do not stand with young children.
- Use an object as a bridge.

- Ask about their opinions and feelings.
- Use informal language.
- The interactor must not take notes.
- Use small notepads.
- Note-takers should not move. (Druin, et al, 1999, pp. 56-57).

Beyer and Holtzblatt summarize their methods for conducting contextual inquiry in Table 3.2 below:

Table 3.2 Key Intents of Contextual Design

STEP	CUSTOMER DATA	DESIGN THINKING	TEAM AND ORGANIZATION
Contextual Inquiry	Gather detailed data needed for design Discover implicit aspects of work that would normally be invisible	Put technical experts in the customer data Stimulate the recognition of implications for design	Build the team through shared experiences Collect concrete data to resolve conflicts
Interpretation sessions	Use whole team's perspective to see what matters in the work Capture all aspects of one customer's work efficiently	Manage the flood of insight from all team members Capture design ideas as they come Share preliminary design ideas to start cross pollination	Bring multiple perspectives to bear on the data Teach team members the perspectives of other organizations Keep everyone engaged in processing the data
Work models	Create a coherent representation of work practice Record actual user data to check the system Distinguish between opinions and real data	Reveal aspects of work that matter for design Capture elements of work in a tangible form	Feed market stories, scenarios, and planning Create a culture in which concrete data is the basis for making decisions
Affinity diagram	Organize data across all customers to reveal scope of issue Provide a review of the data prior to consolidation and	Push from point fixes to systemic solutions Introduce inductive thinking Allow individuals to	Drive consensus about what the data means Make data easy to share

(Table 3.2, continued)

	visioning Identify holds in the data	develop their response to the data Share design ideas without evaluation	Make key customer issues stand out Create the first step toward corporate knowledge of their customer
Work model consolidation	Create one statement of the customer population Show common structure without losing variation across customers	Reveal implications for design through dialog with each model	Create a map of customer population for planning, sharing and reuse Make it possible to validate understandings with customers
Vision	Respond to the data with new work practice designs Shift the team's focus from tools to work practice	Create a coherent response by reacting to the data rapidly Generate divergent options before deciding on one Separate evaluation from generation of ideas	Develop design ideas together as a team Defuse ownership in ideas
Storyboards	Redesign work practices, not technology Ground redesign in consolidated data Ensure redesigned work practice hangs together	Work out details of vision sequentially Let designers think in the UI without committing to it	Create a public representation of a task for sharing and checking Enable parallel design work in small teams
User Environment Design	Design the user's experience of the system to be coherent Allow different user scenarios to be checked in the system	Make the system work model explicit Show relationships between parts of the system Find errors in system structure before coding Drive later object modeling Separate out the UI conversation	Make the system structure explicit and sharable Show the relationship between systems Provide a tool for planning and coordinating multiple systems and teams Provide a high-level specification
Paper Prototyping	Check system structure and user interface with customer Let the customer communicate in their own language Get an additional layer	Provide a fast way to check design alternatives Learn to separate UI from structural implications	Create and test ideas quickly to prevent overattachment Ensure a shared understanding of what customers find valuable

	of detailed data about actions within the system Check sales point of potential products		Share ideas in terms that customers and management can understand

[Note: The key intents of Contextual Design. From, Beyer and Holtzblatt, *Contextual Design* (1998)]

In Brouwer-Janse, et al. "User Interfaces for Young and Old," the authors find that the "challenge for designers of children's applications … is to enable children to reconstruct and build their own images of the world, to support the development of their reasoning, and to surpass repetition and rote learning of static concepts" (p. 36). They also stress the positive impacts of collaboration, including "an efficient, effective way to get a feel for how children interact with their environment and their interests, leisure activities, hobbies and preferred games" (p. 41). One difference between collaborative educational software design and other product under the domain of HCI is that "Designing for children means designing for fun. Human factors specialists, however, are trained to focus on product usability. This may be important for a fax machine, but it is less important for a computer game; that is, to a large extent, product satisfaction overshadows product effectiveness and efficiency" (p. 42).

Smith and Keep (1986) find that "it might be less than helpful to focus excessively on the computer as a motivating agent." Fearing that this point of view "tends to present the learner as passive … rather than as an active participant in learning. This is at odds with the concept of a child as an explorer of his or her world, actively seeking information and creating knowledge" (p. 83).

At the time of their writing, Kafai (1995, 1996), Druin (1996, 1999, 2000) and Scaife (1996) had not been active researchers, yielding Keep and Smith only "little evidence, other than unreliable anecdotal material, as to the criteria which young children might apply in formulating their opinions of educational software. This is not a domain where pre-constructed questionnaires and attitude scales are particularly useful tools.... The first step in any evaluation process claiming to accept the validity of young learners' opinions should be direct reference to the opinions of young learners!" (pp. 83-84).

Smith and Keep relied on Malone's data (1980) "[suggesting] ... that an important factor in the success of some games was a combination of multiple-level goals and visual effects." They summarize "children's 'core' requirements as follows:

1. The program must involve several sensory modalities, using audio and visual effects.
2. Input requirements must be simple
3. There must be an adequate but not excessive level of difficulty in the early stages.
4. There must be graded levels of progressively increasing difficulty.
5. There should be 'surprises' and things to be discovered.
6. There should be no confusion of goals and objectives. (p. 87).

Druin (1999a) has found that "children have their own likes, dislikes, and needs, which are not the same as those of adults. In fact, these likes, dislikes and needs are not even the same from young children (three to seven years of age) to preteen children (eight to twelve years of age). That is why, as user interface designers, it is critical that we stop and listen, observe and collaborate with children of all ages" (p. 18).

Druin (1999a) challenges the accepted wisdom of user interface designers that "children love bright colors. Loud garish screen colors aren't necessarily more entertaining, nor do they make learning elementary math or reading skills easier. ... We designers need to stop hiding behind the primary colors and consider interesting visualizations, with dynamic screen layouts, intelligent font choices, and quality imagery. ... They want images that make sense, fonts that are easy to read, animation and video that offer interesting characters or places that they can't find elsewhere"(19).

Druin (1999a) also challenges the notion that "children need loud sounds to make it fun." "We must ask ourselves as we would with any design problem: Does sound add to the meaning of the application? Does sound make it easier to use? Does sound make the experience more fun? If the answer is yes to any of these, then we should consider sound as an integral part of the design. If not, we should leave sound alone. Kids will understand" (p. 19). For Druin, computer mediated environments "do not replace a child's familiar surrounding; rather, they become a seamless part of them, enhancing what is already there" (p. 20). And although children love familiarity, they do not like coerced repetition.

Blomberg and Henderson (1990) promote, through participatory design, a factor essential to contextual inquiry: having "much of the interaction between developers and users takes place in the user's work environment" (354). Benford, et al. (2000) call for establishing "new development methodologies that enable us to stop and listen, and learn to collaborate with children of all ages" (1) when designing educational software. But their "research has primarily been focused on what happens with children and technology outside of the school environment" (2). Druin's methodology is an adaptation of three different design methods: contextual inquiry [observation]; technology emersion [large amounts of technology], and participatory design [partnership].

Benford (2000) finds that "in both our CI and Technology Immersion research ... when new technology offered children limited paths of interaction, children easily became bored and uninterested. When technology offered options for varied interaction, children spent a considerable amount of time exploring and actively engaged" (p. 6). In agreement with Malone and Lepper, Benford states that, "Children like to tell stories, make up games, and build things. ... Children enjoy many different forms of expression: sound, visuals, movement, physical appearance" (p. 6). Frye and Soloway (1987) conclude from their research experience that, "Designing interfaces that will benefit educational software will require careful study of the users of these programs along with an in-depth understanding of the domains being taught. (p. 93).

Johnson, et al. (1990) restate the premises of participatory design in concrete terms. "Participatory design rejects the assumption that designers design and users use, assuming instead that unless representative users are among the designers, it is unlikely that the system will make adequate use of the users' skills and talents or provide good support for their tasks" (p. 141).

> Established models for project organization, project work, work analysis, etc. are commonly based on the implicit assumptions that the necessary knowledge somehow exists, making the process of designing a system mainly a matter of extracting the knowledge from the participants, be it users or developers. More often than not, these assumptions do not hold. Therefore, development projects need to be transformed from production processes to mutual learning processes. Learning must be built into the process, by changing the ways in which project groups work together (p. 144).

Plowman (1992), determining that participatory design is akin to exploratory learning, deems the approach as not necessarily appropriate in all cases. "An unstructured approach is not suitable for children who do not have a developed sense of their own learning style, and technological advances may seduce designers into producing programs which are too complex and sophisticated for their intended user group" (p. 271).

She cautions educational software designers against the belief that "that the more opportunities there are for machine interaction, the more 'interactive' is the experience of using a program. This is not an approach measure for group use of IMM (interactive multimedia), where valuable interactivity includes the interaction which is stimulated by the program but which is manifested within the group as discussion" (278).

3.3 City Mapping: An Experiment in Participatory Design

Alliance between academics and courseware entrepreneurs is already in vogue, and as flexibility continues to be the watchword for education providers, advances such as learning objects and other technologies that facilitate collaboration among academic institutions, courseware developers will be creating learning systems that, through sophisticated yet user-friendly software and instructional tools, provide strategies for learners and instructors that maximize the abilities of each. With these ideas in mind, IT faculty designed a software development project that would also serve as an experiment using the participatory design methodology, one involving learning systems researchers, educational technology consultants, college students studying software engineering and multimedia design, and 4^{th}-grade students. With mapping skills as the general subject of study for the children, we attempted to engineer a series of skill-building tools that would not have the appearance or effects of skills and drills software, but have more of a game-like sense to them. Below is a description of the rationale for the concept direction methodologies that supported the development of a three-tiered series of integrated games. Subsequently is described the process of activities, including the interactions between college students and primary school children that have yielded a software product that will be employed in classrooms in September 2002. An evaluation of components of the software follows, after which conclusions and suggestions for further research are offered.

3.4 The Need for Mapping Software

Familiarity with geography, the science of space and place on the Earth's surface, helps the visualization and understanding of one's home and orients people and their relationships vis-à-vis other cultures and environments. Learning about geography is the first step in understanding one's community and one's relationship to the world at large. As a community grows and changes, children must learn and master the ability to find their own way. Children become empowered when they are comfortable with their surroundings and prepared to explore the world beyond their quotidian boundaries. Maps help to show children where they are, where they've been and where they can go, while creating a sense of belonging to a community, a history and a path to the future. Without a secure sense of spatial orientation, one is directionless, and unconnected. The urban environment, in particular, is populated with many young students who cannot perceive beyond the boundaries of home.

In the early 1930's Lucy Sprague Mitchell, the founder of the Board of Experimental Education, later known as Bank Street College, began the campaign to reveal the importance of teaching geography. She pioneered the concept of *human geography,* an approach to teaching geography that uses real world experiences as the foundation for the curriculum. This approach encourages children to learn about the world not simply by immersion in facts, but by applying those facts during real world discovery (Mitchell 1991). When is the right time to teach geography and how should it be taught? Is there a role for learning technologies in geography instruction, particularly when there is an added goal of local knowledge to general mapping skills and spatial orientation? While technology cannot be considered a panacea for educational reform (Kimmel & Deek, 1995), when properly used it can effectively improve and enhance instruction and learning experiences. This section describes a software development collaboration project designed to maximize the skill sets and interests of elementary school children and teachers, educational software technologist and researchers, and college undergraduates. Through the implementation of project-based learning, problem-solving methodologies, participatory design, and community involvement, software containing interactive video, calculation programs and spatial orientation tools offers 4^{th}- through 6^{th}-grade students in Newark, NJ the opportunity to learn mapping skills while planning and conducting virtual tours of their city.

3.5 Cognitive Development and Spatial Orientation

Learning theorists have articulated unique developmental predispositions for different kinds of learning. David Sobel (1998) states that between ages five and seven, children start to move away from home and parents and explore the natural world. From ages seven to eleven, children are predisposed to merging with nature and making geographic sense of the world around them. They are ready to step out the box, their world measures beyond a mile or more, taking them out of their neighborhood and into the town and broader community.

With the passage of Goals 2000: Educate America Act in1994, geography was officially recognized as a core curriculum subject in American schools. Also in 1994, the United States Department of Education released standards for teaching geography to K-12 students. In New Jersey, the Core Curriculum Content Standards descriptive statement on geography states:

> Thinking in spatial terms is essential to knowing and applying geography. It enables students to take an active questioning approach to the world around them and to ask what, where, when and why questions about people, places and environments and to formulate answers to critical questions about past, present, and future patterns of spatial organization and to anticipate the results of events in different locations. Thinking spatially, students learn to devise their own mental maps, which relationships and students' perceptions and attitudes about the area. Thinking spatially enables students to predict what might happen given specific conditions. Spatial concepts and generalizations are powerful tools for explaining the world at all levels, from local to global. They are the foundation for geographical understanding. (New Jersey Department of Education, 1999).

Although computers cannot replace the human contact and feedback that only a teacher can provide, they are tools that can be used to significantly enhance students' educational experiences. Their expected impact in education is so meaningful that in a speech for a House of Representatives Panel on Technology and Education, MIT's Seymour Papert stated, "The presence of technology in society is a major factor in changing the entire learning environment" (Papert 1997). Developing effective mathematical and spatial orientation software that is an integrated part of a curriculum based in reasoning presupposes an understanding of the role that computers are playing in today's classroom experience. Technology plays a major function in providing stimulating learning environments. In 1994, James Kulik and his colleagues at the University of Michigan conducted research on the use of computer based instruction software ("Meta Analysis Study”). Their basic finding is that using computer-assisted instruction software results in a substantial improvement in learning outcomes and speed, perhaps 20% or more on average. Such instruction works best, of course, in content areas where the computer can tell the difference between a student's right answer and wrong answer, e.g., in mathematics or grammar exercises. Few other teaching methods have demonstrated such consistently strong results as this type of self-paced instruction.

Reeve’s finds that the use of cognitive tools such as interactive software applications engages students in “knowledge constructions rather than knowledge reproduction” (1998). He summarizes the following principles as the foundation for using cognitive tools:

- Cognitive tools will have their greatest effectiveness when they are applied within constructivist learning environments.
- Cognitive tools empower learners to design their own representations of knowledge rather than absorbing representations preconceived by others.
- Cognitive tools can be used to support the deep reflective thinking that is necessary for meaningful learning.
- Cognitive tools have two kinds of important cognitive effects, those which are *with* the technology in terms of intellectual partnerships and those that are *of* the technology in terms of the cognitive residue that remains after the tools are used.

- Cognitive tools enable mindful, challenging learning rather than the effortless learning promised but rarely realized by other instructional innovations.
- The source of the tasks or problems to which cognitive tools are applied should be learners, guided by teachers and other resources in the learning environment.
- Ideally, tasks or problems for the application of cognitive tools will be situated in realistic contexts with results that are personally meaningful for learners.

Reeves cites Lehrer (1993) as finding that

"Cognitive tools empower learners to design their own representations of knowledge rather than absorbing knowledge representations preconceived by others." Through the process of participatory design (Druin, 1999), 10-year old students will have an equal, if not greater stake in the development, testing, refinement and use of the software as compared to the college students who are interacting with the youngsters at each stage and step of the software development process. For Reeves,

> The process requires learners to transform information into dimensional representations, determine what is important and what is not, segment information into nodes, link the information segments by semantic relationships, and decide how to represent ideas. This is a highly motivating process because authorship results in ownership of the ideas in the multimedia presentation.

Carver, Lehrer, Connell, and Ericksen (1992) have determined that multimedia designers develop a variety of skills that extend beyond the use of specific software applications and programming knowledge. These include:

Table 3.5 Multimedia Project Management Skills

Project Management Skills	Creating a timeline for the completion of the project.
	Allocating resources and time to different parts of the project.
	Assigning roles to team members.
Research Skills	Determining the nature of the problem and how research should be organized.
	Posing thoughtful questions about structure, models, cases, values, and roles.
	Searching for information using text, electronic, and pictorial information sources.
	Developing new information with interviews, questionnaires and other survey methods.
	Analyzing and interpreting all the information collected to identify and interpret patterns.
Organization and Representation Skills	Deciding how to segment and sequence information to make it understandable.
	Deciding how information will be represented (text, pictures, movies, audio, etc.).
	Deciding how the information will be organized (hierarchy, sequence) and how it will be linked.
Presentation Skills	Mapping the design onto the presentation and implementing the ideas in multimedia.
	Attracting and maintaining the interests of the intended audiences.
Reflection Skills	Evaluating the program and the process used to create it.
	Revising the design of the program using feedback

[Note: Multimedia Project Management Skills (quoted in Reeves, 1998)]

Patricia Greenfield (1996) finds that "cognitive processes most often depend on interaction either with other people ... or with cultural artifacts." ... Often a cultural artifact will embody a particular symbol system, the use of which involves its own sort of representational competence. Representational competence ... is concerned with the means, modes, and modalities by which we take in, transform, and transmit information" (p. 85). Maps are an easily accessible example of a cultural artifact that demands a sufficient level of representational competence. In a different but comparable sense, video games foster skills necessary for representational competence, for "Video games are cultural artifacts that both depend on and develop ... one important aspect of iconic representation: the dynamic representation of space. ... video game experience and expertise require and develop skills in the dynamic representation of space" (p. 86).

Greenfield refers to video games as "cultural artifacts that require and develop a particular set of cognitive skills; they are a cultural instrument of cognitive socialization. ... Just as different kinds of games have, in the past, prepared children and youth for the varying adult skills required by different societies around the world ... so too do video games prepare children and youth for a future in which computer skills will become even more crucial to thriving in a technological world" (p. 87). One of the goals of our project was to use the familiarity children have with video game and other computer techniques so that they would be able to extract information from, create information with, and display information on the computer.

The software was also meant to enhance the information and instruction offered in class that relies on textbooks and other tangible materials. As Greenfield states, "The use of printed maps should add a more conceptual knowledge of space to the procedural knowledge developed by navigation through a game, if navigation through the two-dimensional representational space of a video game is cognitively similar to navigation through the real three-dimensional world" (p. 91).

3.6 Technology and Geography Skills: Background to the Project

Software companies have developed a wide range of software applications geared to geographic inquiry and map making. The current strategies used in mapping software programs permit students to be active mapmakers. Neighborhood Map Machine, Trudy's Time and Place, Carmen Sandiego, Where are We, Map Makers Tool Kit, Geo Safari –

all introduce geography skills to students grade 4–8, geared to providing geographic discovery and knowledge. What these programs cannot offer, however, is any significant or concrete local context for the user.

Little Bytes, an educational technology consulting company based in Newark, New Jersey, piloted a technology-based workshop in 2000 designed to expose geography concepts to urban youth in grades 4–6. The eight-hour workshop, conducted at schools and youth centers, focused on the students' investigating and exploring the school neighborhood while learning geography facts. Students were prompted to create a map to provide newcomers with directions as to how to get to school. A classroom of fifteen students, each viewing a self-paced Microsoft PowerPoint presentation with a link to Neighborhood Map Machine, performed classroom and computer related activities while gathering information about maps. For the first three sessions of eight, students became familiar with symbols and signs, used a compass and learned directions. Scale and distance, grid coordinates and the most popular 'walk around the block' summed up the geography skills necessary to draw a neighborhood map on grid paper. Students recreated their drawings using Neighborhood Map Machine, printed their maps onto heat transfer paper and ironed them onto T-shirts bearing their school name. The highlights of the workshop included the creation 3D paper maps, an exercise conducted in the second session. This was a group activity, using poster board as landscape and card stock paper to create building structures to represent houses and various buildings as seen in their neighborhood. A walk around the block was a significant component in the program, a real world experience, allowing students to discover their own city and neighborhoods using the compass. The workshop was well received. It was not unusual to have students re-enroll each time it was offered at their youth center or school. These students have a strong desire to enhance their knowledge and perceptions of their community.

There were several lessons learned from the experience described above. First, unless a student is fully engaged, the effectiveness of the learning process is limited. Some of the students had difficulty mapping the neighborhood after the 'walk around the block' exercise. Although mapping is a fundamental concept, it is not readily grasped. The ability to illustrate a view from a specific perspective demonstrates a level of cognitive sophistication (Jonassen et al., 1993; Stoyanov, 1997; Sobel, 1998). The progression of children's mapmaking skills exemplifies their cognitive development. Towards the end of what Piaget (1972) identifies as the preoperational stage, children can draw simple maps; however, their perspective is rather pictorial, with their own home as the main object. As children mature to the concrete operational stage (Piaget 1972), they move from pictorial maps of their homes to an elevated view of their communities. Today it is widely accepted that a child's intellectual ability is determined by a combination of heredity and environment. Children's intellectual development can be enhanced through environmental factors that provide stimulating learning materials and experiences.

Second, Neighborhood Map Machine is a software application with a great deal to offer, but it does not satisfactorily support the urban environment. Its symbols are suburban in their orientation, and many of its activities use rural landscapes as a backdrop to learn navigating skills. Third, children often do not have an opportunity to explore their neighborhoods. Urban lifestyles sometimes include dangers in neighborhoods and deplorable conditions of many buildings, causing parents to be reluctant to have their children explore on their own. Lacking funds for entertainment or travel confines the child and as a result they tend to stay at home.

If there is an innate congruence between mapping and mathematical skills of elementary school-age children, Piaget's work can inform instructional software design. In his essay "How Children Form Mathematical Concepts", Piaget states that children develop many of their mathematical concepts independently and spontaneously, without having to be taught them explicitly. Indeed, he says, "when adults try to impose mathematical concepts on a child prematurely, his learning is merely verbal; true understanding of them comes only with his mental growth" (Piaget, 1953). Another significant element of Piaget's theory is that in the elementary years math topics should be taught in as concrete and experiential manner as possible since children have not yet developed the ability to think abstractly. Therefore, actual objects should be used in class when illustrating a mathematical concept, and students should be encouraged to manipulate the objects extensively. Concepts should also be related to contexts with which children are already familiar (Slavin, 1991).

These learning theories and insights into technology's role in the classroom, coupled with a partnership among students and faculty at the New Jersey Institute of Technology, Little Bytes and St. Philips Academy, an independent primary school in Newark, serve as the foundation for a comprehensive multiyear program in multimedia learning systems that brings college seniors studying software engineering together with primary school students and teachers in an effort to provide community based educational software designed to introduce the landmarks and cultural facilities of Newark to primary school children through the collaborative development of mapping skills instructional software. A major goal of the program is to build on the participatory design model of software design, articulated most clearly by Druin (1999), and a problem-solving methodology that has been successfully implemented at NJIT and in four Newark public high schools (Deek, 1997; Deek & Friedman 2001). One of the goals of the collaboration is to test the hypothesis that integrating these two models will promote positive change in the academic climate of classrooms by incorporating teachers, students and skilled college-level software engineers to create educational multimedia applications that accommodate the specific needs of the students, provide teachers with design-level access to appropriate instructional materials, educational technologies, and give youngsters hands-on experience in the design, development, testing and use of computer software tools.

The Little Bytes workshop experience has opened the door to increased collaboration with community-based and civic organizations such as the Newark Museum, Newark Bears baseball team, New Jersey Performing Arts Center and the Newark Museum, all of whom contribute to the development of a mapping skills software application that is focused on Newark's neighborhoods and landmarks. NJIT seniors majoring in software engineering, multimedia information technology, information systems and computer science are creating audio, video, animation and interactive calculation tools so that children can create, on their desktop computers at school, virtual tours of their city's cultural and civic sights and attractions. The college students' educational experience is project-based, as it will move them out of the lecture hall and into the community, the design studio and the computer lab as they work with educational researchers, 4^{th}–6^{th} grade students and educational technology consultants over the course of a semester to implement a software design that has been created collaboratively among St. Philip's Academy 4th grade school students, their teacher and Little Bytes. Interaction with digitized seating charts, videos of routes between city landmarks and interactive programs for creating virtual tours is the backdrop for learning geography skills while providing young students with knowledge and information about their city and what it has to offer. The application is intended to expand the user's boundaries, as they will be able to experience their neighborhood and their city in a broader sense. The software application consists of three major components. 1) A fun tutorial facilitated by an animated character, during which the user learns basic geography skills; 2) interactive searches that would make use of the skills generated by using the tutorials; and, 3) the use of those skills to solve contextual and complex problems, such as designing tours of the city for visitors and building efficient routes between landmarks.

A fundamental element of this project is participatory design methodology supporting a team-oriented approach to K-6 educational software design (Druin, 1999). With this approach, children's interaction with technology expands beyond their end-user status and into the conceptual design, development, usability testing and debugging phases as well. Moreover, rather than limit the connection between outside environments and the classroom to children's homes and families, local colleges, community groups and cultural centers are brought together through the application of interactive video and the adoption of a multifaceted participatory design process for educational software. This approach supplies an alternative method of software design, development and evaluation, one that, through input from these multiple perspectives, is more appropriate for the quickly changing and dynamic nature of educational and edutainment software, in that traditionally software evaluation is ad hoc to the software design and development process. Through participatory design, software engineering becomes more accessible even to primary school students through the use of visually oriented software applications, increasing the opportunities to team children, teachers and software engineering students, educational researchers and software designers in the development of new applications, and making software evaluation, once the province of committees of teachers and administrators, a component to consider at each stage of development by all members of the design team.

Application development through participatory design has three main goals. First, to develop integrated learning environments that support visual and verbal literacy. Second, to encourage learners to construct their own paths to knowledge, and third, to develop methodologies that offer a better understanding of what children want and need when using technology. Druin (1999, 2000) has found that her test groups have been able to find common ground, overcome communication problems and generate helpful ideas. Having children as design partners permitted programmers to respond to and improve the parts of the software with which children had the most difficulty. One goal of the involvement of teachers in the software development process is to link those factors impacting teacher practices and beliefs in instruction with software designers so that the product instantiates the methodologies employed in the classroom. Sustained, ongoing partnerships between software engineers and classroom teachers can be considered both professional development and in-service training for teachers, key components for reform in teaching and curriculum change. It has become accepted that long-term intensive professional development programs are necessary and that short in-service programs or workshops are not sufficient to produce sustained change (Guskey, 1986).

Druin (1999) recommends the incorporation of three techniques for participatory design: contextual, which levels children and adults as they observe, take notes and interact with each other; participatory, which employs brainstorming activities with the goal of having all team members sketch out ideas; and technology emersion, which is used to observe what children do with new, unfamiliar technology. This exercise in participatory design is a systematic attempt to bring about change in classroom practice of K-6 teachers, as it provides multifaceted teams of students and teachers immediate classroom experience as well as intensive professional development in the content and skills areas. The program provides a combined laboratory and classroom environment in which participants design, develop, test and refine software tools intended to inculcate spatial awareness and mapping skills while also attaining positive results with students. Direct and successful work with children serves to enhance teacher efficacy. Simultaneously, teachers are able to reflect and receive feedback prior to returning to the classroom to implement the newly acquired skills and knowledge.

This model is consistent with other reports suggesting that a participatory design model is necessary for change in classroom practice and is a necessary prerequisite to achieve positive learning outcomes for students (Haney, Czerniak, & Lumpe, 1996). It is expected that changes observed in the students' mapping skills performance will include a greater understanding of spatial and directional concepts after using video-based, community-oriented software, inquiry-based learning approaches, and student-directed discussions.

In the traditional classroom, there is often more emphasis on solving a problem in a textbook rather than solving life based problems. Such an approach to teaching reduces the likelihood of extrapolation and generalization outside of the classroom, and limits adequate development of the cognitive and metacognitive strategies needed by many students. Instructional emphasis should be given to mastery of concepts, relationships, and skills that are essential for the subsequent acquisition and functional generalization of math and spatial orientation skills (Woodward, 1991). Students should be guided in solving complex problems and should also be given sufficient opportunities to independently to solve such problems. Through participatory design, there are extended interactive discussions among teachers, students and software engineers. Once a development strategy is chosen, however, it becomes necessary to break down large tasks into more than one component and have the programmers develop primitive models to test based on the requirements of the component, the capabilities of the intended users and the pedagogical goal of the teacher. After the process is separated into smaller pieces or components, the software engineering students then need to identify the programming languages, scripts and tools that are needed to bring each component to fruition. Students working with graphical user interface design interact with the 4th graders to determine engaging interactive elements and designs that are compatible with the software components as well as the skill sets of the intended users.

3.7 Digital Technology to Facilitate the Learning-By-Doing

The New Jersey Core Curriculum Standards finds that today's students are bored and discouraged, and they often come to believe that success is contingent on some innate ability as opposed to a skill that can be acquired. As the standards state, "Only in the United States do people believe that learning mathematics depends on special ability. In other countries, students, parents, and teachers all expect that most students can master mathematics if only they work hard enough." They also note that New Jersey students fail to see the relevance of quantitative subject such as mathematics in their daily lives beyond "shopkeeper mathematics." Therefore, the New Jersey Core Curriculum Content Standards developed a curriculum that has higher expectations of students, and goes beyond the acquisition of basic skills to include a variety of mathematical models. Additionally, it devotes more time to problem-solving and active learning. In keeping with these enhanced goals, the partnership and project described here seek to add interactive technology to the tools necessary to replace memorization and a skills and drills approach to classroom learning.

When a person has used a particular approach over time to solve a certain type of problem that becomes his or her "mental set" (Crider, Goethals, Kavanaugh & Solomon, 1989). This indicates that concepts that are learned at a young age become a part of a person's thinking process, or "mental set," providing a richer conceptual vocabulary to use in later studies. The concept behind teaching any subject as reasoning is to transmit a real understanding of the subject's concepts to students. To have students discover for themselves an idea before encountering a mathematical symbol, for example, "unmasks" the concept behind the mathematical notation. This approach may encourage students to use their creativity; for only once a formula is *understood* can it be creatively applied. Furthermore, once students understand concepts they can create their own schemes. They will assimilate new methods and thinking patterns into ones with which they are already familiar. In terms of the software applications being developed, students will learn how to plan alternative routes to destinations when they encounter unexpected roadblocks, establish a variety of itineraries of landmarks and cultural centers for visitors to their city.

By setting roadblocks, students will find the process of learning mapping skills to be a reasoning process, one whereby the child discovers concepts experientially. Students are presented with tools and situations and through interacting with these tools the students come to discover foundational principles. In this process, the teacher takes the role of a guide, rather than that of an instructor. This is in concert with the educational theory of *constructionism*, an outgrowth of Piaget's theories, which states that students take an active role in constructing their own paradigms of understanding. Learning is largely a function of action (Kafai, 1996).

NJIT students brought digital technologies to this process by providing video of route segments to be called up in a graphical user interface in which students will create tours of their city and give directions to "lost" visitors. Through such interactivity, students will be situated in a context that corresponds closely to the way that children learn naturally. As Nicholas Negroponte, Mitchel Resnick and Justine Cassell state in "Creating a Learning Revolution," computers can "enable children to become more active and independent learners, taking charge of their own learning through direct exploration, expression and experience." This process can continue throughout their educational experience. As Negroponte believes, "Our goal is to develop digital technologies that enable children to continue to learn ever more advanced ideas by direct exploration and experimentation" (Negroponte, Resnick & Cassell, 1997).

Software can also be made to simulate phenomena that would otherwise be impractical in the classroom experience. This will not only broaden the student's educational experience, but will also provide a more meaningful context within which to integrate knowledge that they learn. This can be used to great advantage in the elementary school years when children need to learn from contexts with which they are familiar. By assembling videos in which students navigate their city, explore museums, concert halls and a baseball stadium, they are accessing civic assets from their classrooms.

When students explore a given program at will, they are in effect designing their own lesson plan that is based on their own interests. The concepts that students learn through this process are therefore placed in contexts that the students will find more meaningful. When students are doing something they find interesting and enjoyable they can learn a great deal (Shank & Cleary, p. 98). Software that is designed with these aspects in mind can significantly enhance students' educational experiences by providing contexts that will give more meaning to children's explorations.

3.8 Initial Requirements Analysis

In September 2001, the preliminary project team, which included a technology consultant, a fourth-grade teacher, the author and a research assistant, compiled the list and sequence of learning activities that appears below. The original timeline for implementing the project was one 15-week semester, as the project was run as a problem-based course for undergraduates in NJIT's College of Computing Sciences. Due to many factors that will be explained in this and the following sections, alterations to product components and new software tools added an additional twelve- week period was allotted for the completion of the course, with several new students replacing some of the students who were not able to attend the summer session in 2002.

The overall objective of City Mapping was to produce an interactive software program designed to engage children grades 4–6 to learn facts about the city of Newark, its landmarks and special interest sites; navigate various types of maps; understand basic geography concepts and develop critical thinking skills; all while participating in a fun tutorial, solving mysteries and applying geographical skills to create tours for visitors of Newark. There would be three components to the software: Navigator, Search and Create a Tour.

The purpose of the Navigator module is to review and reinforce basic mapping skills while investigating real places. Through fun and adventurous activities, users explore and practice a particular skill. The skills to be enhanced include being able to identify map tools and resources, identify many different types of maps, and identify parts of the map (scale, legend/key, title, symbols and compass); use map keys find directions on a map, identify and use a road map, street map seating chart and floor plan; locate places on a grid and use a map to locate places. See Appendix A for the original requirements analysis and Appendix B for the timeline of activities, which derives from the storyboard and adds information regarding the software and programming tools anticipated to be used, the roles of the college students and a time-on-task overview.

3.9 Discussion of Project

The primary goals of the project included the development of mapping software that would serve as an educational technology tool to be used by primary school students and teachers. The design methodology employed was participatory design, as described above. In this case, children were partnered with college students, all of whom worked collaboratively with educational technology consultants and a learning systems researcher. Mumford and Henshall (1983), pioneers in the field of participatory design techniques, recommend that, "we help visualize ideas by … [writing] a script [as] the first translation of ideas into a concrete medium that can be shared by everyone. … The next step is to translate the interface ideas defined by the script into a visual medium" (p. 440).

3.10 Process

During the initial meeting with the fourth-graders, the discussion included what our helping character, Mapper, might look like, and the children were asked to share with the rest of us their drawings of their ideas. The graphic designers collected these drawings and came up with a composite is used throughout the exercises. This is commensurate with the methodologies of participatory design (Mumford and Henshall 1983, Kafai 1996, Druin 1998, 1999, 2000); informant design (Sciafe 1999), and contextual inquiry (Beyer and Holtzblatt 1998). As Mumford and Henshall (1983) put it, "To best understand system functionality, the software designer should interact with user-oriented and visually oriented team members to integrate results from the task analysis and scenario-building processes in their software design. By knowing the user goals ahead of time, the software developer need not guess at the desired functionality" (p. 441).

Meetings among design teams and fourth-graders, between the researcher and the consultant, between the consultant and the fourth-grade teacher, as well as meeting of all participants, occurred throughout the initial 15-week period. During that time, components in the original requirements were modified, based on the iterations of game modules developed and presented to the children. Their reactions, comments and suggestions were balanced by the abilities and limitations of the designers and the tools they were using, as well as the requirements that the core standards placed on the components.

During the implementation time, teams of programmers and videographers discussed ways of implementing the preliminary requirement, deciding on Macromedia Flash 5 to create the animations, 3D StudioMax to create the simulations, C++ to create the programs that would recognize users' names when one logged in, and store data regarding navigation success, progress through the software and time spent during each task. The videographers created individual storyboards for each tour then began to shoot video of each component of each of five tour scenarios.

After two weeks of work, the NJIT students decided to move away from HTML as the environment in which all designs would be rendered and use Macromedia Flash as the graphic design tool. This was agreed to by the programming team, as Flash contained the database capabilities and scripting that would be necessary to generate the Mapper' license that users would receive once they complete the Navigator portion of the software.

Ten weeks into the project, prototypes had been developed for the following components: Opening screen with logo; Login screen; Credits, Space scene introducing

Mapper; Eleven Navigator games; Three Search games; and Three video tours. During these weeks, several difficulties and several new tools were encountered, forcing alterations and modifications to the original requirements and storyboard, but also solving technical problems that were holding up progress.

On the positive, Macromedia developed a new version of Flash, which permits the importation of video into its own movies. As the major difficulty was constructing a user interface that would accommodate all the different games, including the tours, the release of Flash MX proved quite beneficial to each of the design teams. The negatives included the faulty operation of high-end PCs being used for program development in our lab, delays on the development of a universal interface, as well as personnel becoming overwhelmed by the time-on-task necessary to complete the project on time. Several NJIT students took on extra work to cover their teammates, and the scope of activities for several of the games, searches and tours were modified.

Continuing the project through the summer session of 2002 was necessary in order to procure a working prototype that met the needs of the end user. While the structure of the project components remained quite similar to the original specifications, the functionality and graphic design of the components surpassed the basic original requirements. The project resulted in a unified piece of software, a copy of which accompanies this thesis, containing the following components:

An animated introductory screen, with audio;

The 3-dimensional space scene, with audio;

A user logon screen, with supporting database;

A credits screen, with scrolling text of individual and agency participants;

A main screen from which users choose to enter Navigator, Search or Tour functions;

Within Navigator, a map room in the Newark Library with animated maps; two compass games, a scale games, two map key and legend games, two grid games, a direction-following game, a seating chart game, an interactive puzzle, and a scale game. All of these operate within a single interface containing a help feature and an exit option.

Within Search, a timed grid game called Michael Recycle, in which the user must locate the proper grid coordinates throughout Newark into which to drag and drop recycling bins before the an animated sun sets; a legend and direction game called Where's Ruppert, in which the user receives a series of clues that are beneficial in locating the trail of the Newark Bears' mascot, Rippin' Ruppert, and ultimately finding him so that he can be returned to the stadium; and a sequenced series of problems to solve, called Hazell Hold-up, in which all the materials necessary to host a dinner in the NJIT student center can be delivered to their proper locations at their proper time.

In the Tour component, users must assemble a series of video clips, represented by thumbnails of identifiable locations, based on the requirements of visitors to Newark. There are three tours: the 19th century building tour; the church tour; and the Newark landmark building tour. Once the user has placed the thumbnails in the most expeditious order for the tour group to take in all locations, the interface displays a music video of the actual tour.

3.11 Usability

Following the principles of participatory design, as best articulated by Druin (1996, 1999, 2000), the fourth-graders who began the project as our design partners and informants took on the role of testers as well. Although future work will include a complete series of usability tests that include Likert-type scales, semantic differential surveys, and protocol analyses that will yield quantitative data with which to judge the effectiveness of our product and design methodology, the fourth-graders did participate in usability testing on several of the components of Navigator: the bridge scale game; the Branch Brook Park grid game; the legend sorting game; the parade scale game; the compass speed game; and the floor plan legend game.

Questionnaires were developed, comprised of 3- and 5-point Likert-type scales, yes/no questions and open-ended questions requiring short answers. These surveys appear in Appendix A. Analysis of responses indicate that of the 64% of the respondents to the question, "Were the instructions to the activity clear?" answered affirmatively. For level of difficulty, 66% found the games "easy," 25% found them "medium," and 9% found them "hard" to play. 77% of the respondents found the games "easy to navigate," and on a 1-5 scale, with 5 being high, 73% or the respondents found the games to be "cool" or "very cool."

CHAPTER 4

CONCLUSION

Kafai (1996) suggests that, "One underlying premise of most research is that providing students with multiple representational formats in a content domain helps to build their understanding and addresses the diversity found in students' learning and thinking approaches (p. 117). For the elementary school children, the goal was to meet this requirement of educational software by providing as many game environments as possible in the development time we had, each containing different activities that address the curriculum standards sought by teachers. For the college students, "Learning through designing software … stresses the importance of students' knowledge reformulation, personal expression, and collaborative project management (Kafai 1996, p. 118). The designers became practiced in altering design concepts to meet a shifting set of demands from both the teachers and the students, as well as the programming capabilities of the variety of software applications used to develop our product. The experience was in concert with Kafai's conclusion that, "Designing the multimedia application provided students with some valuable lessons in interface design. Students' experience as multimedia consumers did not necessarily have them factor in the user's perspective into their designs." (p. 124).

Described in this thesis are the underlying theories, activities of participants and results of our work involving three principal partners in an ongoing educational software development project. Elementary school children work with college seniors and technology consultants within a collaborative working environment in order to design, develop and implement a multimedia software application that enhances time and space orientation abilities of children, puts the programming, interface design and multimedia systems capabilities of college students into action, all while increasing the levels of interaction between and understanding of several Newark community groups, cultural centers and the city's children. The work was a requirements-driven software development process that is congruent with Druin's participatory design methodology, and resulted in each participant realizing the benefits of combining these methods as they, together, develop an educational software tool that offers each access to and a new view of their shared city. This work will continue with new NJIT seniors and new St. Philip's students working together to build learning systems for computer programming, mathematics and physics.

APPENDIX A

PROJECT STORYBOARD

A step-wise description of the project.

Welcome Screen

Screen Description: The welcome screen automatically displays upon entry into the program. It indicates that the program is loading and dissolves to display the main menu after the program has loaded.

Objective: To allow the user to view the title of the software program and to view credits.

Screen Display: This screen simply displays the welcome and credits and dissolves to display the main menu.

Screen Activity

1. This screen automatically displays upon entry into the program.
2. If user clicks on credits the credit screen will display.
3. If user clicks or after programs are loaded the program will automatically display the main menu.

Program Activity: User can select credits and view or click and go directly to main menu.

Login Screen

Screen Description: This is the user log in screen. The user must enter their name in order to continue. The user name will be stored and used to print on certificates of mastery. Student progress/game information will be stored in a database.

Objective: To use the user name as a way to store progress and to print such information on certificates of mastery.

Screen Display: The screen will display blank lines with the cursor blinking on the first line. A message displays instructing the user to enter their name or click on their name.

Screen Activity: Student enters his/her name or selects one name from a list.

Program Activity: If a new user enters his/her own name, the program will go directly to the main menu. If the user selects his/her name from a list, the program will restore their saved game.

Main Menu

Screen Description: The main menu automatically displays after the user logs on. This screen allows the user to select the desired program: Navigator, Search or Tour.

Objective: This screen allows the user to select the desired program.

Screen Display: Main menu (program) options: Navigator, Search or Tour.

Screen Activity: If the user does not select an option with 15 seconds, Mapper, the help tool, will ask the user to select or press Help. If the user selects Help, Mapper will describe each program module. If the user moves the cursor of the menu item, a bubble will automatically display describing the menu item. If user selects The Tour or The Search the user must have a Mapper's license, issued as a certificate of mastery upon the completion of the Navigator component.

The Navigator

The purpose of this module is to review and reinforce basic mapping skills while investigating real places. Users are introduced to and practice different geography skills by completing educational yet adventurous activities. Through the activities, the user explores and practices a particular skill. The skills are to identify map tools and resources, identify many different types of maps, identify parts of the map (scale, legend/key, title, symbols and compass), use map keys, find directions on a map, identify and use a road map, street map, seating chart and floor plan. Locate places on a grid. Use a map to locate places.

Navigator screen: Mapper descends from the solar system to a street in Newark. This screen begins with picture of the solar system and Mapper dressed in a space suit, twirling through space, then a picture of the earth displays, then the hemisphere, then the United States, then New Jersey and then Newark. It ends with Mapper landing on the streets of Newark

Objective: To show the relationships between the solar system and Newark.

Screen Display: Animated motion picture of the universe panning down to the streets of Newark.

Screen Activity: Screen begins with an animated picture of the Solar System, then displays a view of Earth spinning, a view of the hemisphere, then the United States amidst the clouds, then New Jersey, then Newark with Mapper on the scene dress in space suit. The name of the location will display as the screen display changes.

Program Activity: The user can access this module at any time – with or with out a Mapper's license. User can click an ESC button to exit. The system should display, Do you want to quit: Yes or No? If Yes, return to the main menu; if No continue.

Core Curriculum Standards: Standard 6.7 Indicator 3 – Use mental maps to identify the locations of the earth's continents and oceans in relation to each other. Indicator 4 – Use mental maps to identify the locations of major physical and human characteristics in the US and on earth.

Navigator Part 2: A graphic of Mapper moving from Washington Park to the Newark Museum.

Scene: Mapper begins walking toward the curb, facing upwards and looking up at the buildings somewhat absentmindedly. He almost steps in front of oncoming traffic. Mapper takes his maps out of this backpack. He unfolds each one.

Screen Description

This screen begins with Mapper landing on a street near Washington Park. He's in a very busy section of Newark and realizes he needs help finding his way around. Mapper goes through his backpack in search of a map. He finds a street map and realizes he could use a little help learning to use it.

Objective: To get the user to realize maps help us get around and find our way.

Screen Display: Washington Street Park area and towards the Newark Library.

Screen Activity: Mapper has dialogue with the user as he walks from the street curb and through Washington Park. He goes through his backpack and pulls our various types of maps. Then he walks toward the Library.

Program Activity: User can click and ESC button to exit. The system should display do you want to quit Yes or No. If Yes, return to the main menu if No continue.

Core Curriculum Standard: Standard 6.7 Indicator 2 Use mental maps to identify the locations of places within the local community. Indicator 5 Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Navigator 3 – Washington Park to the Newark Library

Screen Description: This screen begins with Mapper at Washington Park and he sees a sign "Library Straight Ahead". Mapper walks towards the Library

Objective: To show the user, that the community Library is one way to seek knowledge.

Screen Display: Washington Park with a view of the Library.

Screen Activity: Mapper standing on a path in the park, reading the sign. Then Mapper walks towards the library and sees the library building ahead.

Program Activity: User can click an ESC button to exit. The system should display: Do you want to quit, Yes or No? If Yes, return to the main menu; if No, continue.

Core Curriculum Standard: Standard 6.7 Indicator 2 Use mental maps to identify the locations of places within the local community. Indicator 5 Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Navigator 4 – Inside the Library

Screen Description: Mapper walks inside the building and views a sign offering a free class.

Objective: To have Mapper walk from the front of the building to the New Jersey Room.

Screen Display: Inside the Library to the front desk to the New Jersey Room.

Screen Activity: Mapper walks inside the building, views a sign offering a free class on "How to get around Newark in 1Hour!" asks the front desk how to get to the room, walks up the steps to the New Jersey Room. The user can access this module at any time – with or with out a Mapper's license. User can click an ESC button to exit. The system should display, Do you want to quit, Yes or No? If Yes, return to the main menu if No, continue.

Navigator 5 – Inside the New Jersey Room in the Library

Screen Description: This screen begins in the New Jersey Room at the Library with a professor prepared to provide instructions. The maps on the walls are scrolled up and keep un-scrolling – they are sort of alive and are anxious to be clicked on to tell what they know.

Objective: To discuss different types of maps and to learn the parts of a map.

Screen Display: The New Jersey room in the Newark Library. The maps on the wall are all interactive and animated.

Screen Activity: The user is able to click on any one of the maps to get a description of the map and the purpose of its use.

The user can access this module at any time – with or with out a mapper's license. User can click an ESC button to exit. The system should display, Do you want to quit, Yes or No? If Yes, return to the main menu; if No, continue.

Navigator 6 – Inside the New Jersey Room in the Library

Screen Description: This screen begins in the New Jersey Room at the Library with a professor discussing the parts of a street map.

Objective: To discuss parts of a street map and perform exercises.

Screen Display: The New Jersey room in the Newark Library. The maps on the wall are all interactive and animated. The professor is focused on explaining the purpose of the street map and its parts: the legend, scale, grid coordinates, compass rose. When clicked, user gains access to the respective activities.

Screen Activity: The user is able to click on any one of the maps to get a description of the map and the purpose of its use. The user can access this module at any time – with or with out a Mapper's license. User can click an ESC button to exit. The system should display, Do you want to quit, Yes or No? If Yes, return to the main menu; if No, continue. If the user completes all exercises, the user gets a Mapper's license. If the user exits before completing all exercises, the system will display a save dialogue box.

Navigator Part II Activities

Map Key: A floor at Science High

Key	Location
A	Reception
B	Computer Lab
C	Wet Lab
D	Snack Stand
E	Dinosaur Bones
F	Restroom
G	Elevator
H	Solar System
I	Electricity Lab
J	Exit to stairs

A series of questions prompting user to find the location by identifying its key coordinates. User clicks the down arrow next to the answer line. Four possible answers will display. User selects one. If user selects correct answer the letter on floor plan turns green. If user selects incorrect answer the letter stays same color. Correct answer prompts and audiovisual reward.

Missing Map Keys: A map of Iron Bound district

Key/Icon	Location
Image of building	Name of tall building
Image of street	Name of main street
Image of storefront	Name of popular retail store
Image of fire helmet	Name of fire company
Image of place setting	Name of popular restaurant
Image of steeple	Name of large church
Image of train	Name of train station
Image of trees	Name of popular park

Core Curriculum Standards: CCS 6.7 Indicator 2: Use mental maps to identify the locations of places within the local community. Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Navigator 3: Map Symbols and Routes

Objective: User clicks image on map and drag down to proper place on Key/Legend.

Screen Display: A map of Newark with all landmarks.

A series of questions prompts users to identify objects on the map and respond, stating the proximate location of the object to other objects. Student inputs correct answer to receive an award. If incorrect, prompted to try again (3 times, then correct answer is displayed).

Navigator Symbol 1

Activity: User clicks the down arrow next to the answer line. Four possible answers will display in a drop-down menu. User selects one. If incorrect, the line will remain blank. If correct the line will fill in with the correct answer. Core Curriculum Standards 6.7 Indicator 2: Use mental maps to identify the locations of places within the local community. Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Seating Chart: Help characters find their seats at the Newark Bear's stadium.

Activity: User clicks the appropriate seat on seating chart. Animated character rushes to seat. If the user clicks on wrong seat animated character gets mad or sad.

Scale: Discover the size/distance ratio between actual objects and their representations.

Screen: A map of three parks, with a legend displaying distance: 1 inch = 1 mile

Activity: Questions regarding the relative distances between parks and the sizes of parks. The user must measure the distance between parks. When the cursor moves onto the map it turns into a little ruler. A counter displays on the left side of the screen so user can remember total distance. When the user clicks on the down arrow next to the answer line a drop down list displays - display 4 possible answers. If the user selects the right answer the distance line lights up and the answer get recorded on the answer line. If the user selects an incorrect answer "try again" displays on the screen.

Core Curriculum Standards 6.7 Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement. Indicator 8: Answer geographical questions regarding major physical and human characteristics.

Navigator Scale 2

Screen: Graphic of a marching band moving down Broad St. past City Hall. There's a float, jugglers, clowns and fire trucks.

Activities: A series of questions requiring users to measure distances and convert measurements based on scale. User clicks mouse and cursor turns into a ruler. This allows user to measure items. Core Curriculum Standards 4.7 All students will develop spatial sense and an ability to use geometric properties and relationships to solve problems in mathematics and in everyday life.

Core Curriculum Standards 4.9 All students will develop an understanding of and will use measurement to describe and analyze phenomena.

Navigator Scale 3

Activities: User clicks mouse and cursor turns into a ruler. This allows user to measure items. User measures height of bridge and height of boat.

Core Curriculum Standards 4.7 All students will develop spatial sense and an ability to use geometric properties and relationships to solve problems in mathematics and in everyday life.

Core Curriculum Standards 4.9 All students will develop an understanding of and will use measurement to describe and analyze phenomena.

Using the Compass 1

Screen: Image of compass.

Activity: Click and drag to directional points to proper location on compass.Core Curriculum Standards 6.7 Indicator 1: Using Maps, globes and other graphics to answer geographic questions. Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Using a Compass 2

Screen: Map of Branch Brook Park

Activity: Key in the direction one must go from a central location to reach various locations within the park in order to deliver compasses to students camping out at Branch Brook Park.

Navigator Compass 2: Identifying directions

Screen: A compass with no direction indicators

Activity: User clicks on the name appropriate to the position of the arrow as fast as possible to beat the clock

Core Curriculum Standards Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Navigator Compass 3: Matching directions

Screen: Graphic of arrows in a hub and spoke arrangement.

Activity: The arrows display one at a time at random. The user clicks the corresponding directional label appearing randomly in a box below the graphic. User clicks the down arrow next to the answer. Four possible answers will display. User selects one. If incorrect the, line will remain blank. If correct, the line will fill in with the correct answer.

Core Curriculum Standards Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Using the Compass 3

Screen: A graphic of arrows leading toward six different finishing boxes.

Activity: User follows directions to get the right box of compasses to be delivered to Branch Brook Park.

Core Curriculum Standards Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Using the compass 4

Screen: Map of Newark around Penn Station.

Activity: Finding the shortest route from Penn Station to Military Park. Several different sets of directions are given in a dialog box. User determines the shortest route. User clicks the down arrow next to the answer. Four possible answers will display. User drags and drops one answer. If incorrect the line will remain blank. If correct the line will fill in with the correct answer.

Grid Coordinates

Screen: Newark map overlay

Activity: User inputs the grid location for a series of landmarks.

Core Curriculum Standards 4.7: All students will develop spatial sense and an ability to use geometric properties and relationships to solve problems in mathematics and in everyday life.

Core Curriculum Standards Indicator 8: Develop the concepts of coordinates and paths, using maps, tables, and grids.

Navigator Map Reading 1

Screen: A Newark subway map

Activity: User reads map and answer questions about locations on the map. When the user clicks on the drop-down box, a list displays four possible answers. If the user selects the right answer, the distance line lights up and the answer get recorded on the answer line. If the user selects an incorrect answer, "try again" display on the screen.

<u>Core Curriculum Standards</u> 6.7 Indicator 5: Demonstrate an understanding of the spatial concepts of location, distance, direction, scale and movement.

Part 2: The Search

The theme of this component is for the user to take on a detective role to uncover a series of random clues required to solve mysteries. Solving the mystery requires the user to figure out which of the provided resources, such as a street map, stadium seating diagram, museum visitors guide telephone book, train schedule, road map or subway map will best assist them in uncovering each clue until they have successfully reached the goal. When the user clicks on The Search of the Main Menu a sub-menu will display listing three adventure searches: 1) In Search of the Lost Mascot; 2) Who Stole the Tibetan Artifact?; and, 3) Hazell Holdup. This component should put to use all of the skills gained in Navigator.

Part 3: The Tour

Taking on the role of a tour guide, the user is responsible for helping visitors to Newark, New Jersey reach their destinations. There have various types of transportation available to them, e.g., taxi, limo, the loop, subway, bus, and ambulance. The objective of this component is for the user to apply all the learning experience in other components as they help visitors reach destinations within Newark by constructing valid routes based on the conditions of individual tours, then compiling corresponding video clips to match the most efficient route, based on the criteria of a tour.

APPENDIX B

TIMELINE OF ACTIVITIES

Appendix B is the timeline for 14 NJIT undergraduate students majoring in Information Technology who took on the task of implementing the initial requirements. In Table B1, "G" refers to graphic designer; "P" to programmer, and "V" to videographer.

Table B1 Activity Timeline

Activity	Primary Resource	G/P/V	Start	Stop
Welcome Screen	Dreamweaver	G	1/25	2/4
Credits	Dreamweaver	G	1/25	2/4
Login Screen	Dreamweaver	G	1/25	2/4
User Database	Access	P	1/25	2/4
Main Menu				
Select Navigator	Dreamweaver	G	1/25	2/4
Select Search	Dreamweaver	G	1/25	2/4
Select Tour	Dreamweaver	G	1/25	2/4
Time out default to Help	C++	P	1/25	2/11
Navigator Part 1				
Create Mapper	Dreamweaver/Flash	G	2/4	2/11
Solar System Image	Dreamweaver/Flash	G	2/4	2/11
Navigator 2				
Mapper moving from Washington Park to the Newark Museum	GIF editor	G	2/4	2/11
Mapper finds street map in pack	GIF editor	G	2/4	2/11
Mapper finds road map	GIF editor	G	2/4	2/11
Mapper finds weather map	GIF editor	G	2/4	2/11
Mapper finds tax map	GIF editor	G	2/4	2/11
Mapper finds historical map	GIF editor	G	2/4	2/11
Navigator 3: To Newark Museum				
Mapper locates Newark Museum on map	Dreamweaver/Flash	G	2/11	2/18
Mapper walks to Newark Museum	Dreamweaver/Flash	G	2/11	2/18
Navigator 4: To New Jersey Room				

(Table B1, continued)

Mapper reads course sign	Dreamweaver/Flash	G	2/11	2/18
Mapper walks from main entrance to the New Jersey Room	Dreamweaver/Flash	G	2/11	2/18
Create front desk with people in room	Dreamweaver/Flash	G	2/11	2/18
Navigator 5: Inside New Jersey Room				
Create wall of maps	GIF editor	G	2/18	2/25
Create legend	GIF editor	G	2/18	2/25
Create scale	GIF editor	G	2/18	2/25
Create grid coordinates	GIF editor	G	2/18	2/25
Create compass	GIF editor	G	2/18	2/25
Create activities for above	GIF editor	G	2/18	2/25
Navigator Part 2				
Map Key/Missing Key				
Create map key	Dreamweaver/Flash	G	2/25	3/4
Create map of Ironbound	Dreamweaver/Flash	G	2/25	3/4
Create map of Science High floor	Dreamweaver/Flash	G	2/25	3/4
Create drag and drop map	Dreamweaver/Flash	G	2/25	3/4
Create map of Newark Landmarks	Dreamweaver/Flash	G	2/25	3/4
Seating Chart				
Video Rupert	Adobe Video Suite	V	3/4	3/11
Digitize Rupert	Dreamweaver/Flash	G	3/4	3/11
Digitize Bears Stadium Chart	Dreamweaver/Flash	G	3/4	3/11
Animate Rupert	GIF editor	G	3/4	3/11
Nav Scale 1				
Create map of 3 parks	Dreamweaver/Flash	G	3/11	3/25
Create ruler cursor	GIF editor	G	3/11	3/25
Create counter	C++	P	2/11	2/25
Create drop-down option list	Dreamweaver/Flash	G	3/11	3/25
Nav Scale 2				
Create Broad St. image	Dreamweaver/Flash	G	3/11	3/25
Create marching band	Dreamweaver/Flash	G	3/11	3/25
Nav Scale 3				
Create bridge and boat	Dreamweaver/Flash	G	3/25	4/1
Compass				

(Table B1, continued)

Create compass	Dreamweaver/Flash	G	3/25	4/1
Compass 1				
Create drag/drop labels	Dreamweaver/Flash	G	3/25	4/1
Create map of Branch Brook Park	Dreamweaver/Flash	G	3/25	4/1
Compass 2				
Create beat the clock program	C++	P	2/11	4/1
Create arrow labeling program	C++	P	2/11	4/1
Compass 3				
Create direction box program	C++	P	2/11	4/1
Create connect arrow program	C++	P	2/11	4/1
Compass 4				
Create arrow key program	C++	P	2/11	4/1
Create map around Penn Station	Dreamweaver/Flash	G	4/1	4/8
Create route map to Military Park	Dreamweaver/Flash	G	4/1	4/8
Create route answer program	C++	P	3/25	4/8
Grid Coordinates 1				
Create Newark map w/grid	Dreamweaver/Flash	G	4/1	4/8
Create grid program	C++	P	3/25	4/8
Subway map				
Create digitized subway map	Dreamweaver/Flash	G	4/1	4/8
Create subway stop program	C++	P	3/25	4/8
Search 1 Lost Mascot				
Animate Rupert	GIF editor	G	4/1	4/8
Hot spot Bears seating chart	Dreamweaver/Flash	G	4/1	4/8
Create scripts for clues				
Create answer program	C++	P	3/25	4/8
Search 2 Tibetan Artifact				
Video Newark Museum	Adobe Video Suite	V	2/25	3/25
Create artifact image	GIF editor	G	4/1	4/8
Create scripts for clues				
Create answer program	C++	P	3/25	4/8
Search 3 TBA				

(Table B1, continued)

Tour				
Video routes	Adobe Video Suite	V	1/25	2/25
Create tour compiler program	C++	P	3/25	4/8

Table B1 Activity Timeline

APPENDIX C

A survey of users' responses to the floor plan activity

City Mapping Acceptance Testing

Floor Plan Activity

User Information

Four 4^{th} grade level students were observed while playing the Floor Plan Activity. Comments made by the students were manually recorded by the member of the NJIT Acceptance Team Members. The students were not coached during their interaction with the activity. NJIT Acceptance Team Members only asked questions that related specifically to the difficulty of the activity and changes that the students would recommend. The NJIT Acceptance Team members recorded the time it took each student to complete the specific activity. This is a compiled version of the Acceptance Testing results.

Average Time to Complete

- **First Stage:** 6 minutes
- **Second Stage:** 6.5 minutes
- **Third Stage:** 6 minutes

Level of Difficulty

- The student feels it is kind of easy and needs more questions
- The zoom in and out is good and makes it easy to get the answers
- The student feels it is difficult because of how he/she had to search for the answers
- The student had trouble finding some locations for certain questions
- The student almost gave up after one question
- The student felt that he/she knew the answer to one question, but overconfidence led him/her to misspell the answer three times

User Comments

- The font should be different
- It also needs sound for correct and wrong answers
- The game should be made harder and more questions
- Don't know all of the terms being used in the game (ie "stack one")
- The letters MIS look like MLS
- This is hard

- I know every single answer after searching so long for that one
- The game was fun

What changes would you make

- The game should have levels
- The game is fine
- The game should have more colors and more sound
- I would not make any changes

APPENDIX D

A survey of users' responses to the compass activity

City Mapping Acceptance Testing

Nainsi's Compass Activity

User Information

Four 4th grade level students were observed while playing Nainsi's Compass Activity. Comments made by the students were manually recorded by the member of the NJIT Acceptance Team Members. The students were not coached during their interaction with the activity. NJIT Acceptance Team Members only asked questions that related specifically to the difficulty of the activity and changes that the students would recommend. The NJIT Acceptance Team members recorded the time it took each student to complete the specific activity. This is a compiled version of the Acceptance Testing results.

Average Time to Complete

- **First Stage:** 1 minute — **Average Score:** 1/8
- **Second Stage:** 1 minute — **Average Score:** 3/8
- **Third Stage:** 1 minute — **Average Score:** 3/8

Level of Difficulty

- It was way too fast!
- Even after you press the button, it still goes fast!
- It is very hard because I can't remember where the buttons are
- It was really, really, really fast! That made it really, really hard!

User Comments

- The colors and shape are good
- It took like 5 – 6 times to finish the game. If the game goes slow, then we'll be able to finish in the first try
- This game is really hard
- I can't find the buttons.
- The person in the compass should move a little slower
- Sometimes when I click the right answer, it said that I was wrong

What changes would you make

- The buttons should be in a circle on the right hand side
- When you get the right answer, the icon breaks and its face disappears; instead if a person gets a correct answer the icon should have a smile on the face
- Buttons that are similar should be together – like everything relating to North should be together (ie northeast, northwest)
- Maybe the buttons should be like a compass on the game

APPENDIX E

A survey of users' responses to the parade activity

City Mapping Acceptance Testing

Parade Activity

User Information

Fourteen 4th grade level students were asked to interact with the Parade Activity. After the students were finished interacting with the activity, they were given a survey to complete. The survey contained ten questions. The questions asked students to rate the various aspects of the activity, as well as garnered user comments about specifics of the activity. Students were asked to complete the surveys independently and to give the survey to a NJIT Acceptance Team Member when they were finished completing the survey. This is a compiled version of the Acceptance Testing results from the student surveys.

How do you rate this activity?

Easy	Medium	Hard
8	1	5

Were the instructions to the activity clear and understandable?

Yes	No
13	0

How would you rate the level of difficulty?

Easy	Medium	Hard
8	3	3

Is the program easy to navigate?

Yes	No
11	3

On a scale of 1 – 5, 5 the highest, 1 the lowest, does the activity look cool?

1	2	3	4	5

0	1	1	6	6

Would you like to share this program with a friend?

Yes	No
9	5

What did you learn while playing this activity?

- How to measure (10 responses)
- I really didn't learn anything
- Nothing much (3 responses)

If you could change this activity in any way, what would you change?

- I would make it easier (6 responses)
- Make it more challenging (2 responses)
- Change the map
- Change the questions
- Nothing (4 responses)

What do you like about this program?

- The color (2 responses)
- Everything (5 responses)
- It is challenging (2 responses)
- The map
- The questions
- The buttons
- Nothing (2 responses)

Other Comments

- We need more questions
- None (13 responses)

APPENDIX F

A survey of users' responses to the legend activity

City Mapping Acceptance Testing

Legend Activity

User Information

Fourteen 4th grade level students were asked to interact with the Legend Activity. After the students were finished interacting with the activity, they were given a survey to complete. The survey contained ten questions. The questions asked students to rate the various aspects of the activity, as well as garnered user comments about specifics of the activity. Students were asked to complete the surveys independently and to give the survey to a NJIT Acceptance Team Member when they were finished completing the survey. This is a compiled version of the Acceptance Testing results from the student surveys.

How do you rate this activity?

Easy	Medium	Hard
8	6	0

Were the instructions to the activity clear and understandable?

Yes	No
13	1

How would you rate the level of difficulty?

Easy	Medium	Hard
10	4	0

Is the program easy to navigate?

Yes	No
13	1

On a scale of 1 – 5, 5 the highest and 1 The lowest, does the activity look cool?

1	2	3	4	5
0	3	3	0	8

Would you like to share this program with a friend?

Yes	No
11	3

What did you learn while playing this activity?

- I learned my legends
- Signs and symbols (9 responses)
- That there is a US highway
- I learned what pictures look like if I can't know where they are
- Learned information about Newark, NJ
- I learned more about feet

If you could change this activity in any way, what would you change?

- I would have more legends, more 3D
- Time limit (2 responses)
- The info
- Change the background color to turquoise
- Make it harder (5 responses)
- Add candy store sign
- Change the boarder (2 responses)
- Nothing

What do you like about this program?

- I liked how it was easy
- The noises
- It's fun (4 responses)
- That I could match the things in Newark
- It's challenging
- The picture and activity
- It's educational (2 responses)
- Amount of signs
- That the matching doesn't get stuck
- Everything (2 responses)

APPENDIX G

A survey of users' responses to the walk in the park activity

City Mapping Acceptance Testing

A Walk in the Park

User Information

Fourteen 4th grade level students were asked to interact with the Walk in the Park Activity. After the students were finished interacting with the activity, they were given a survey to complete. The survey contained ten questions. The questions asked students to rate the various aspects of the activity, as well as garnered user comments about specifics of the activity. Students were asked to complete the surveys independently and to give the survey to a NJIT Acceptance Team Member when they were finished completing the survey. This is a compiled version of the Acceptance Testing results from the student surveys.

How do you rate this activity?

Easy	Medium	Hard
11	2	1

Were the instructions to the activity clear and understandable?

Yes	No
10	4

How would you rate the level of difficulty?

Easy	Medium	Hard
10	2	2

Is the program easy to navigate?

Yes	No
10	4

On a scale of 1 – 5, 5 the highest and 1 the lowest, does the activity look cool?

1	2	3	4	5
1	1	2	2	9

Would you like to share this program with a friend?

Yes	No
9	6

What did you learn while playing this activity?

- How easy it is (2 response)
- Directions (4 responses)
- How to follow directions (2 responses)
- The different direction
- Nothing (2 responses)
- When I get lost have a compass
- How to use N, S, E and W

If you could change this activity in any way, what would you change?

- Nothing (5 responses)
- Make it any way you could
- More directions
- I would like if the directions went away after I did it
- The difficulty
- Change questions

What do you like about this program?

- The clicking
- It was challenging
- It requires concentration
- Everything
- Nothing (2 responses)
- The North, South, East point
- It's easy (3 responses)
- The pots

Other Comments

- Why can't we do this any way we want
- Nothing (12 responses)

APPENDIX H

A survey of users' responses to the bridge activity.

City Mapping Acceptance Testing

Bridge Activity

User Information

Fourteen 4th grade level students were asked to interact with the Bridge Activity. After the students were finished interacting with the activity, they were given a survey to complete. The survey contained ten questions. The questions asked students to rate the various aspects of the activity, as well as garnered user comments about specifics of the activity. Students were asked to complete the surveys independently and to give the survey to a NJIT Acceptance Team Member when they were finished completing the survey. This is a compiled version of the Acceptance Testing results from the student surveys.

How do you rate this activity?

Easy	Medium	Hard
9	4	1

Were the instructions to the activity clear and understandable?

Yes	No
14	0

How would you rate the level of difficulty?

Easy	Medium	Hard
9	5	0

Is the program easy to navigate?

Yes	No
10	4

On a scale of 1 – 5, 5 the highest and 1 the lowest, does the activity look cool?

1	2	3	4	5
1	3	2	2	6

Would you like to share this program with a friend?

Yes	No
8	6

What did you learn while playing this activity?

- Learned to do math (3 responses)
- I learned inches
- I did not learn that much
- Floats are tall
- Fractions
- How much height was the bridge
- The US highway sign
- I learned math with a ruler
- The height of the bridge and float, creative skills
- I did not learn anything (2 responses)
- I really didn't learn much. It was really easy

If you could change this activity in any way, what would you change?

- I will like
- I would change the hardness of it
- Nothing
- I'd make it a bit harder
- I would not change anything
- I would make it much harder (2 responses)
- I would make it a lot, very, very, very harder
- I would change the difficulty (3 responses)
- The fraction multiplication
- I would make cars going down the purple road

What do you like about this program?

- Everything (2 responses)
- I like that it is math because I love math
- The float

- It's easy (2 responses)
- It's challenging
- The math
- It makes you use your mind
- It's fun
- The bear and spa sight
- SPA Sign
- The blimp

Other Comments

- Nothing (6 responses)
- It needs to be harder
- No

REFERENCES

Andriole, S. (1997). Requirements-Driven ALN Course Design, Development, Delivery & Evaluation. *Journal of Asynchronous Learning Networks* 1(2): 57-67.

Arbaugh, J. (2000). Virtual Classroom Characteristics and Student Satisfaction with Internet-Based MBA Courses. *Journal of Management Education* 24(1): 32-54.

Barrows, H. S. and Tamblyn, R. M. (1980). *Problem-based Learning: An Approach to Medical Education.* New York: Springer Publishing Co.

Barrows, H. S. (1992). *The Tutorial Process.* Springfield, IL: Southern Illinois University School of Medicine.

Bell, B. and Meyer, R. (1997). Distributed Learning by Distributed Doing. Available at: http://www.tc.columbia.edu/~academic/cite/papers/distdo/Distlrn.htm (Accessed on April 10, 2001).

Benford, S., Bederson, B., Akesson, K-P., et al. (2000). Designing Storytelling Technologies to Encourage Collaboration Between Young Children. *CHI Letter* 2(1): 556-563.

Benor, D. (1984). An Alternative, Non-Brunerian Approach to Problem-Based Learning. In H. G. Schmidt and M. L. D. Volder, (Eds.), *Tutorials in Problem-Based Learning: New Directions in Training for Health Professionals*, pp. 48-58. Assen/Maastrict, The Netherlands: Van Gor Cum.

Beyer, H. and Holtzblatt, K. (1998). *Contextual Design: Defining Customer-Centered Systems*. San Francisco, CA: Morgan-Kaufmann.

Blomberg, J. and Henderson, A. (1990). Reflections on Participatory Design: Lessons from the Trillium Experience. *Proceedings of CHI'90*, 4: 353-359.

Bloom, B.S. (Ed.) (1956). *Taxonomy of Educational Objectives*, Handbook I: Cognitive Domain, New York: McKay.

Bouton, C. and Garth, R. Y. (1983). Learning in Groups. *New Directions in Teaching and Learning*, no. 14. San Francisco: Jossey-Bass.

Bransford, J. D. and Vye, N. J. (1989). A Perspective on Cognitive Research and its implications for Instruction. In L. B. Resnick & L. E. Klopfer (Eds.), *Toward the Thinking Curriculum: Current Cognitive Research.* Alexandria, VA: ASCD Yearbook.

Bransford, J. S. and Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Educational Research*, (24): 61-100.

Brouwser-Janse, M.D., Sari, J.F., Yawitz, M., de Vries, G., Fozard, J.L., and Coleman, R. (1997). User interfaces for the young and old. *Interactions* ¾: 34-46.

Bruffee, K. A. (1984). Background and History to Collaborative Learning in American Colleges. *College English*, 46(7): 635-652.

Cadiz, J., Balachandran, A. and Sanocki, E. (no date). Distance Learning Through Distributed Collaborative Video Viewing. *Microsoft Research, Collaboration and Multimedia Group*. Available at: http://research.microsoft.com/scripts /pubs/query.asp (Accessed February 21, 2001.)

Camp G. (1996). Problem-Based Learning: A Paradigm Shift or a Passing Fad? *Medical Education Online* 1(2). Available at: http://med-ed-online.org/f0000003.htm (Accessed November 17, 2000).

Carswell, L., Thomas, P., Petre, M., Price, B., and Richards, M. (1999). Understanding the 'Electronic' Student: Analysis of Functional Requirements for Distributed Education. *Journal of Asynchronous Learning Networks* 3(1): 7-18.

Carver, S., Lehrer, R., Connell, T., & Ericksen, J. (1992). Learning by hypermedia design: Issues of assessment and implementation, *Educational Psychologist*, 27(3): 385-404.

Crider, A., Goethals, G., Kavanaugh, R. & Solomon, P. (1989). *Psychology*, 3/e. Boston: Addison, Wesley, Longman.

Dede, C. (1997). Distance Learning to Distributed Learning: Making the Transition. NLII Viewpoint 2(1). Available at: http://www.educause.niss.ac.uk/nlii/articles/ dede. html (Accessed on September 9, 2000).

Deek, F.P. (1997). An Integrated Environment For Problem Solving and Program Development, Unpublished Ph.D. Dissertation, New Jersey Institute of Technology.

Deek, F.P., Deek, M. and Friedman, R. (1999). The Virtual classroom experience: Viewpoints from computing and humanities. *Journal of Interactive Learning Environments*, 7(2/3): 113-136.

Deek F.P. and Friedman R. (2001). Computing and Composition: Common Skills, Common Process, *Journal of Computer Science Education - ISTE SIGCS* 15(2). Available at: http://www.iste.org/sigcs/jcseonline/2001/12/index.html.

Deek, F.P. and McHugh, J.A. (2002). SOLVEIT: An Experimental Environment for Problem Solving and Program Development. *Journal of Applied Systems Studies*, Special Issue on Distributed Multimedia Systems with Applications, in press.

Dillenberg, P. and Schneider, D. (1995). Collaborative learning in the Internet. *Proceedings of the Fourth International Conference on Computer Assisted Instruction*, Taiwan, S10-6 to S10-13.

Druin, A., and Solomon, C. (1996). *Designing Multimedia Environments for Children: Computers, Creativity and Kids*. New York: John Wiley & Sons.

Druin, A. (1999a). A Place Called Childhood. *Interactions* 3(1): 17-22.

Druin, A. (1999). Cooperative inquiry: Developing new technologies for children with children. *Proceedings of CHI'99*, ACM Press, pp. 592-599.

Druin, A. (2000). The Role of Children in the Design of New Technology, Submitted to *ACM Transactions on Human Computer Interaction.* Available at: http://citeseer.nj.nec.com/druin99role.html (Accessed February 11, 2002).

Eisner, E. (1985). *The Educational Imagination: On the Design and Evaluation of School Programs*. New York: MacMillan.

Evans, T. Lyons, J., Newman, A. and Rynearson, K. (2000). Trends and Drivers in the Education Industry: Markets and Opportunities. White Paper, Eduventures.com.

Farrell, G., Ed. (2001). The Changing Faces of Virtual Education. White Paper, The Commonwealth of Learning, London, UK.

Ferguson, L. and Wijekumar, K. (2000). Effective Design & Use of Web-based Distance Learning Environments. *Professional Safety* 45(12): 28-32.

Fletcher, J. and Dodds, P. (2001). All About ADL. *American Society for Training & Development.* Available at: http://www.asdt.org (Accessed 02/21/01).

Friedman, R., Deek, F.P., and Deek, M. (2000). Bridging technology and pedagogy: Interdisciplinary computing and composition. *WebNet Journal: Internet Technologies, Applications and Issues*, 2(1): 60-67.

Friedman, R. and Deek, F.P. (2002). Problem-Based Learning and Problem-Solving Tools: Synthesis and Direction for Distributed Education Environments, *Journal of Interactive Learning Research* Vol. 13 (3): 237-255.

Frey, D. and Soloway, E. (1987). Interface Design: A Neglected Issue in Educational Software, In J.M. Carroll and P.P. Tanner, Eds., Human Factors in Computing Systems – IV and Graphics Interface. Amsterdam: North Holland, pp. 93-97.

Gagné, R. M. and Merrill, M. D. (1990). Integrative goals for instructional design. *Educational Technology Research and Development*, 38(1): 23-30.

Gagné, R. M. (1985). *The Conditions of Learning*, New York, NY: Holt, Rinehart and Winston.

Gagné, R.M., Briggs, L. J. and Wager, W. W. (1992). *Principles of Instructional Design.* New York, NY: Holt, Rinehart and Winston.

Grabinger R. S. (1996). Rich environments for active learning. In D.H. Jonassen (Ed.), *Handbook of Research for Educational Communication and Technology*, NY: Simon & Schuster Macmillan, pp. 665-692.

Greenfield, P.M. and Cockling, R.R., Eds. (1996). *Interacting with video.* Norwood, NJ: Ablex.

Greening, T. (1998). Scaffolding for success in problem-based learning, Medical Education (Online) 3(4). Available at: http://www.med-ed-online.org/ f0000012.htm# f0000012. (Accessed November 17, 2000).

Greeno, J.G. (1978). Natures of problem-solving abilities, in W.K. Estes (Ed.), *Handbook of Learning and Cognitive Processes*, Hillsdale, NJ: Lawrence Erlbaum, pp. 239-270.

Guskey, T. R. (1986). Staff Development and the Process of Teacher Change, *Educational Researcher*, (15): 5-12.

Haney, J., Czerniak, C., & Lumpe, A. (1996). Teacher Beliefs and Intentions Regarding the Implementation of Science Education Reform Strands, *Journal of Research in Science Teaching*, (33): 971-993.

Harel, I. (1991). *Children Designers: Interdisciplinary Constructions for Learning and Knowing Mathematics in a Computer-Rich School.* Norwood, N.J.: Ablex.

Hawkes, M. (1995). Criteria for Evaluating School-Based Distance Education Programs. *North Central Regional Educational Laboratory.* Available at: http://www.ncrel .org /tandl/ disted.htm (Accessed April 2, 2001).

Hawkins, B. (1999). Distributed Learning and Institutional Restructuring. *Educom Review* 34(4). Available at: http://www.educause.niss.ac.uk /ir/library/html/ erm9943 .html (Accessed on September 28, 2000).

Hilsop, G. (1999). Anytime, Anyplace Learning in an Online Graduate Professional Degree Program. *Group Decision and Negotiation* (8): 385-390.

Hiltz, S. R. (1997). Impacts of College-Level Courses via Asynchronous Learning Networks: Some Preliminary Results. *Journal of Asynchronous Learning Networks*, 1(2): 1-19.

Honebein P. C., Duffy, T. M., and Fishman B. J. (1991). Constructivism and the Design of Learning Environments: Context and Authentic Activities for Learning: In, T. M. Duffy, Lowyck, J., Jonassen, D. H., (Eds.). *Designing Environments for Constructivist Learning*. Springer-Verlag: Berlin, pp. 87-108.

Institute for Higher Education Policy (1999). What's the Difference? A Review of Contemporary Research on the Effectiveness of Distance Learning in Higher Education. Available at: http://www.ihep.com/Pubs/PDF/Difference.pdf (Accessed on July 9, 2001).

Johnson, D. W. (1981). Student-Student Interaction: The Neglected Variable in Education. *Educational Research*, January: 5-10.

Johnson, D. W. and Johnson, R. T. (1975). *Learning Together and Alone: Cooperation, Competition, and Individualization*. Englewood Cliffs, NJ: Prentice Hall.

Johnson, J., Ehn, P., Grudin, J., Nardi, B, and Thoresen, K. (1990). Participatory Design of Computer Systems Panel. *Proceedings of CHI'90*: 141-144.

Jonassen, D.H., Beissner, K., and Yacci, M.A. (1993). *Structural Knowledge: Techniques for Conveying, Assessing, and Acquiring Structural Knowledge*, Hillsdale, NJ: Lawrence Erlbaum.

Jonassen, D. H. and Reeves, T. C. (1995). Learning with Technology: Using Computers as Cognitive Tools. In, D. H. Jonassen (Ed.), *Handbook of Research for Educational Communication and Technology*, pp. 693-724. NY: Simon & Schuster Macmillan.

Jones, D. (1996). Computing by Distance Education: Problems and Solutions. *Proceedings of ACM Integrating Technology into C.S.E.* Barcelona, Spain, pp. 139-146.

Jones, R. O., Donnelly, M. B., Nash, P. P., Young, B. and Schwartz, R. W. (1993). The Ongoing Development of a Problem-Based Surgery Clerkship: Year three. *Medical Teacher*, 15(2/3): 207-215.

Joy, E., II and Garcia, F. (2000). Measuring Learning Effectiveness: A New Look at No-Significant-Difference Findings. *Journal of Asynchronous Learning Networks* 4(1): 33-39.

Kafia, Y. (1995) *Minds in Play: Computer Game Design as a Context for Children's Learning*. Hillsdale, NJ: Lawrence Earlbaum.

Kafai, Y., Resnick M. (Eds.) (1996). *Constructionism in Practice: Designing, Thinking, and Learning in a Digital World*, Mahwah, NJ: Lawrence Erlbaum.

Kafai, Y. (1999). Children as Designers, Testers and Evaluators of Educational Software. In Druin, A. (ed.), *The Design of Children's Technology*. Morgan Kaufman, pp. 123-145.

Kamin, C., Deterding, R, Wilson, B., Armacost, M., and Breedon, T. (1999). Medical Education Online. Available at: http://www.Med-Ed-Online.org (Accessed November 17, 2000).

Kember, D. and Gow, L. (1994). Orientations to Teaching and Their Effect on the Quality of Learning. *Journal of Higher Education*, 65(1): 58-74.

Kenley, R. (1995). Problem Based Learning: Within a Traditional Teaching Environment, AUBEA Conference, University of Technology Sydney, New South Wales. Available at: http://www.arbld.unimelb.edu.au/~kenley/conf/papers rk_a_p1.htm (Accessed December 3, 2000).

Koschmann, T., Myers, A., Feltovitch, P., and Barrows H. (1994). Using Technology to Assist in Realizing Effective Learning and Instruction: A Principled Approach to the Use of Computers in Collaborative Learning. *Journal of the Learning Sciences*, 3(3): 227-264.

Koschmann, T. (1995). Medical Education and Computer Literacy. *Academic Medicine* 70(9): 818-821.

Koschmann, T, Kelson A., Feltovitch P., and Barrows H. (1996). Computer-Supported Problem-Based Learning: A Principled Approach to the Use of Computers in Collaborative Learning. In T. D. Koschmann, (Ed.), *CSCL: Theory and Practice of an Emerging Paradigm*. Hillsdale, NJ Lawrence Erlbaum, pp. 83-124.

Koschmann T, Glenn P, Conlee M. Analyzing the Emergence of a Learning Issue in a Problem-Based Learning Meeting. Medical Education [serial online] 1997 2(2). Available at: http://www.utmb.edu/meo/ (Accessed November 17, 2000).

Kimmel, H. and Deek F. P. (1995). Instructional Technology: A Tool or a Panacea? *Journal of Science Education and Technology* 4: 327-332.

Kulik, J. (1994). Meta-analytic Studies of Findings on Computer-Based Instruction. In, *Technology Assessment in Education and Training*, L. Baker and H.F. O'Neil Jr., Eds. Hillsdale, N.J.: Lawrence Erlbaum, 1994.

Lehrer, R. (1993). Authors of Knowledge: Patterns of Hypermedia Design, in S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools*. Hillsdale, NJ: Lawrence Erlbaum, pp. 197-227.

Leuthold, J. (1999). Is Computer-Based Learning Right for Everyone? *Proceedings of the 32nd Hawaii International Conference on System Sciences*, pp. 1-8.

Lieberman, D.A. (1997). Interactive Video Games for Health Promotion: Effects on Knowledge, Self-efficacy, Social Support, and Health. In R.L. Street, Jr., W.R. Gold, and T. Manning, Eds., *Health Promotion and Interactive Technology: Theoretical Applications and Future Directions*. Mahwah, NJ: Lawrence Earlbaum.

Lotus Institute (no date) "White Paper: Distributed Learning: Approaches, Technologies and Solutions." Available at: http://www.lotus.com/services/institute.nsf (Accessed on February 21, 2001).

Lumb, J. (1999). Thinking Styles and Accessing Information on the World Wide Web. Available at http://computed.coe.wayne.edu/Vol2/lumb.html. Accessed on October 9, 2000.

Machtmes, K. and Ascher, J. (2000). A Meta-Analysis of the Effectiveness of Telecourses in Distance Education. *The American Journal of Distance Education* 14(1): 27-46.

Malone, T.W., and Lepper, M.R. (1987). Making Learning Fun: A Taxonomy of Intrinsic Motivations for Learning. In, R.E. Snow and M.J. Farr, Eds. *Aptitude, learning and Instruction III: Conative and Affective process Analyses*. Hillsdale, NJ: Lawrence Earlbaum.

Martin, R. (1997). Key Issues in Transitioning From Distance Education to Distributed Learning. Available at: http://www.fcae.nova.edu/disted/ spring98/ martin.html Accessed on April 20, 2001.

Marton, F. and Booth, S. (1997). *Learning and Awareness*. Mahwah, NJ: L. Earlbaum Associates.

Maurer, H. (1997). The Emergence of Sophisticated Distributed Teaching and Learning Environments. *ACM ITiCSE '97 Working Group Reports and Supplemental Proceedings*, pp. 112-113.

Mayer, R.E. (1983). *Thinking, Problem Solving, Cognition*. New York: W.H. Freeman and Company.

Mayer, R.E. (1996). Learners as Information Processors: Legacies and Limitations of Educational Psychology's Second Metaphor. *Educational Psychologist*, 31(3/4): 151-161.

Merisotis, J. and Phipps, R. (1999). What's the Difference? *Change* 31(2): 12-17.

Mitchell, L. S. (1991) *Young Geographers: How They Explore the World and How They Map the World.* New York: Bank Street College.

Moonen, J. (1997). The Efficiency of Telelearning. *Journal of Asynchronous Learning Networks* 1(2): 68-77.

Mumford, E. and Henshall, D. (1979/1983). *Designing Participatively: A Participative Approach to Computer Systems Design.* UK: Manchester Business School.

Negroponte, N., Resnick, M., Cassell, J. (1997). Creating a Learning Revolution. Available at http://www.education.unesco.org/unesco/educprog/lwf/doc/portfolio/opinion8. htm (Accessed November 17, 2000).

New Jersey Department of Education (1999). *New Jersey Core Curriculum Content Standards.* Standard 6.7: All Students Will Acquire Geographical Understanding By Studying The World In Spatial Terms. Trenton: NJ Dept. of Education.

Neal, E. (1999). Distance Education. *National Forum* 79(1): 40-43.

Nkanginieme, K.E. (1972). Clinical Diagnosis as a Dynamic Cognitive Process: Application of Bloom's Taxonomy for Educational Objectives in the Cognitive Domain. *Medical Education Online* 2(1). Available at: http://www.Med-Ed-Online (Accessed November 17, 2000).

Norman, D. and Draper, S. (1986). *User-Centered Design: New Perspectives on Human-Computer Interaction.* Hillsdale, NJ: L. Earlbauum Associates.

Norman, G. R and Schmidt H. G. (1992). The Psychological Basis of Problem-Based Learning: A Review of the Evidence. *Academic Medicine*, 67(9): 557-65.

Ouellette, R. (1999). The Challenge of Distributed Learning as a New Paradigm for Teaching and Learning. Available at: http://polaris.umuc.edu/~rouellet/dechallenge.html (Accessed on April 10, 2001.)

Papert, S. (1997). Remarks to a House of Representatives Panel of Technology and Education. Available at: www.cs.brown.edu/research/graphics/research/ illus/prop.html (Accessed on November 17, 2001).

Pereira, L. M. P., Telang B. V. and Butler K. A. (1993). Preliminary Evaluation of a New Curriculum - Incorporation of Problem Based Learning (PBL) into the Traditional Format. *Medical Teacher* 15(4): 351-364.

Peters, O. (2000). Digital Learning Environments: New Possibilities and Opportunities. *International Review of Research in Open and Distributed Learning* 1(1): 1-19.

Peterson, M. (1997). Skills to Enhance Problem-Based Learning. *Medical Education Online* 2(3). Available at: http://www.Med-Ed-Online (Accessed November 17, 2000).

Piaget, J. (1953). How Children Form Mathematical Concepts. *Scientific American* (189): 74-79.

Piaget, J. (1972). *The Psychology of the Child.* New York: Basic Books

Plowman, L. (1992). An Ethnographic Approach to Analyzing Navigation and Task Structure in Interactive Media: Some Design Issues for Group Use. *Conference on People and Computers: HCI'92*: 271-287.

Polya, G. (1945). *How to Solve It.* Princeton, NJ: Princeton University Press.

Ragoonaden, K. and Bordeleau, P. (2000). Collaborative Learning via the Internet. *Educational Technology and Society* 3(3): 361-370.

Reeves T.C. (1998). The Impact of Media and Technology in Schools. Available at: http://www.athensacademy.com/instruct/media_tech/reeves0.html (Accessed April 10, 2001).

Robbs, J. and Meredith, S. (1994). The Problem-Based Learning Curriculum at Southern Illinois University School of Medicine. [Online]: http://www.suimed.edu/pblc/ pblcur. html [no longer available].

Savery, J. R., Duffy, T. M. (1995). Problem Based Learning: An Instructional Model and its Constructivist Framework. *Educational Technology* 35(5): 31-37.

Schmidt, H. G. (1983). Problem-Based Learning: Rationale and Description. *Medical Education* 17: 11-16.

Scaife, M., and Rogers, Y. (1996). External Cognition: How Do Graphical Representations Work? *International Journal of Human-Computer Studies* 45: 185-213.

Scaife, M., and Rogers, Y. (1999). Kids as Informants: Telling Us What We Didn't Know or Confirming What We Knew Already, In, Druin, A., Ed., *The Design of Children's Technology.* San Francisco, CA: Morgan Kaufman, pp. 27-50.

Shank, R. & Cleary, C. (1995). *Engines For Education.* Hillsdale, NJ: Lawrence Erlbaum.

Slavin, R. (1991). *Educational Psychology*, 3/e. Englewood Cliffs: Prentice-Hall, Inc.

Smith, D and Hardaker, G. (2000). e-Learning Innovation through the Implementation of an Internet Supported Learning Environment. *Educational Technology & Society* 3(3): 422-432.

Smith, D., and Keep, R. (1986). Children's Opinion of Educational Software. *Educational Research* 28(2): 83-88.

Smith, P. and Dillon, C. (1999). Comparing Distance Learning and Classroom Learning: Conceptual Considerations. *The American Journal of Distance Education* 13(2): 6-23.

Sobel, David (1998). *Map Making With Children.* Portsmouth, NH: Heineman.

Stokes, P. (2000). E-Learning: Education Businesses Transform Schooling. White Paper, eduventures.com, pp. 1-11.

Stoyanov, S. (1997). Cognitive Mapping as a Learning Method in Hypermedia Design, *Journal of Interactive Learning Research* 8(3/4): 309-324.

Thomas P. and Carswell, L. (2000). Learning through Collaboration in a Distributed Education Environment. *Educational Technology & Society* 3(3): 373-383.

Thompson, H. (1999). The Impact of Technology and Distance Education: A Classical Learning Theory Viewpoint. *Educational Technology & Society* 2(3): 1-24.

Tucker, R. and Cordani, J. (1998). Teaching Teachers to Teach On-Line. *Proceedings of the 26th ACM-SIGUCCS Conference on User Services*, pp. 293-297.

Wade, V. and Power, C. (1998). Evaluating the Design and Delivery of WWW Based Educational Environments and Courseware. *ACM-ITiCSE '98*, Dublin, Ireland, pp. 243-248.

Walton, H. J. and Matthews, M. B. (1987). Essentials of Problem-Based Learning. *Medical Education* 23: 542-58.

Wegner, S., Holloway, K and Garton E. (1999). The Effect of Internet-Based Instruction on Student Learning. *Journal of Asynchronous Learning Networks*, 3(2): 98-106.

Wegner, S., Holloway, K., and Wegner, S. (1999). The Effects of a Computer-Based Instructional Management System on Student Communications in a Distance Learning Environment." *Educational Technology & Society* 2(4): 146-153.

Wheeler, S., Vranch, A., and Reid, F. (1999). Bridging the 'Psychological Gap' in Distance Learning through Telematics. Poster Presentation at the19th World Conference on Open Learning and Distance Education, Vienna, Austria, June 20-24, 1999. Available at http://www.fae.plym.ac.uk/tele/wolc.html Accessed 11/29/00.

Woodward, J. (1991). Procedural knowledge in mathematics: The role of the curriculum, *Journal of Learning Disabilities*, 24: 242-251.

Worley, R. (2000). The Medium is Not the Message. *Business Communication Quarterly* 63(3): 93-98.

Young, C. and Young, L. (1999). Assessing Learning in Interactive Courses. *Journal on Excellence in College Teaching*, 10(1): 63-76.