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Under the Microscope: Factors Influencing Student Outcomes in a Computer Integrated Classroom

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Researchers continue to argue that more research is needed concerning how teachers actually integrate instructional technology into their curriculum. This qualitative study examined the incorporation of interactive multimedia science software into a grade two classroom over a six-week period. There was growth in various social and thinking skills that were developed and reinforced within the computer-supported learning environment. Several factors that contributed to these outcomes are identified: the software's instructional design, enthusiasm, on-task behavior, cooperation and collaboration among the students, improved cognitive learning outcomes, attitudes toward science, the teacher's pedagogical approach and attitudes toward incorporating technology into the curriculum, and an integrated curriculum. In addition, the results indicated increased positive attitudes towards science by the girls after using the software. Implications for computer integration are provided.

During the last decade an increasing number of researchers have demonstrated the contribution of educational interactive multimedia to children's learning (Bialo & Sivin-Kachala, 1996; Gregoire, Bracewell, & Laferriere, 1996). However, the integration of information technology in school curricula has continued to lag behind expectations. Many (Drazdowski, 1997; Maddux, Johnson & Willis 1997; Szabo & Schwarz, 1997; U.S. Congress, 1995) have tried to explain this gap, usually in terms of a failure by colleges of education to train students adequately, budget limitations, the teachers' fear of, and reluctance to, incorporate computer technology in their classrooms, and infrastructure organizational difficulties. An additional explanation involves the mismatch between available software and teacher requirements. Because teachers have increasingly integrated commercial multimedia products into the existing curriculum, the products can inadequately fulfil the teacher's specific learning objectives. This study reports what occurred when this mismatch was eradicated. A further explanation for the limited success of incorporating educational technology within classrooms is inappropriate teacher implementation of educational technology, regardless of whether the software is producer-tailored or teacher-retailored, to meet the needs of the curriculum.

Selwyn (1997) declared that what is still necessary are research studies of what actually happens when educational technology is used in real contexts over time because, regardless of the match between software and curriculum, the use of educational software rarely works as well as planned in the non-clinical classroom. Thus, in keeping with the literature (Glenna & Melmed, 1996; Jonassen, 1998; Reeves, 1997; Selwyn, 1997), our investigation was not concerned with ascertaining whether learning with particular software produced better test scores than learning without the software. Rather, the research examined outcomes of the implementation of interactive multimedia science software as part of an integrated curriculum in the "messy" environment of a classroom over a period of six weeks.

Like much qualitative research, we identified various factors that contributed to the students' affective, social, and cognitive outcomes from the data. These factors are: the software's instructional design, enthusiasm, on-task behavior; cooperation and collaboration, improved cognitive outcomes, attitudes toward science, the teacher's pedagogical and philosophical approaches, and attitudes toward incorporating technology into the curriculum, and an integrated curriculum.

CONTEXT

In 1993, the Plano Independent School District, Texas, decided to shift the teaching methodology and discipline-based curriculum of its elementary school system into a thematically integrated, computer-based curriculum. Edunetics, a multimedia production company, was contracted to help redesign the curriculum, inservice teachers in the area of computer technology, and develop educational computer software that would serve as the backbone of the new integrated curriculum. Thirty-five K-5 teachers were released part-time to work cooperatively with the pedagogical and content experts in Edunetics. Together they identified 36 topics based on six overarching concepts or themes stipulated in the Texas-wide elementary curriculum. Each of these topics was developed into multi-disciplinary thematic learning units, called Organizing Ideas, that are taught over a period of six weeks and include, among other activities, a computer-based learning environment, which is used through the six weeks of the unit.

Our research project investigated the incorporation of one of the 25 CD-ROMs, *Message in a Fossil*, (*MIF*), in a grade two learning community. *MIF* was incorporated into an integrated curriculum unit with "evidence" as the Organizing Idea. The major theme of the unit was gathering, interpreting, and communicating evidence to solve mysteries and problems, particularly those that increase our understanding of the past. For approximately 45 minutes each day, the class worked in stations where each small group activity integrated the Organizing Idea and theme across curriculum areas. One of these daily rotating stations was learning with *MIF*. The teacher also included *MIF* into the time allocated for reading. This meant that each student used the software each day for 20 minutes during reading, with some using it twice a day during his/her station activity time. In addition, when they finished other work children could choose to work with *MIF*, if a computer were available. The classroom had seven computers and a printer that were networked to a file server through which the children accessed the software. Whole class lessons involved such activities as constructing a digging grid in the school grounds and interviewing an archaeologist.

METHODOLOGY

The research used a qualitative interpretive methodology. Credibility and trustworthiness of the data were enhanced through site engagement for the six week duration of the integrated curriculum unit. Triangulation occurred though confirming data from researcher observations authenticated by videotaped and audiotaped data, pre and post interviews with the participants, and documents such as the teacher's assessment instruments and pre and post questionnaires.

Participants

The research was conducted with 20 seven-year-old students in Plano, Texas, during the Spring quarter. The grade two class was chosen for three reasons. One, the teacher had been involved in the Plano computer integration project and had been part of the trial beta version of *MIF* in her classroom in the year previous to our research. Two, according to Salomon (1998), focussing on a computer literate teacher rather than a neophyte should result in findings that would better identify how technology can be diffused effectively within a curriculum. Third, the class was the most ethnically and socio-economically diverse compared with those of the other volunteering teachers; even so, it was still significantly middle America. The teacher was asked to select three, same-gender pairs based on ability. The researchers used these pairs for in-depth study. The teacher selected one pair of two high achieving female students; one of two low achieving male students; and the third comprised of two male students, one high achiever and one low achiever. As revealed during her pre-interview, the teacher had also paired the students according to the strength of their friendship. She argued that she had not used pairs before when working with *MIF* and was concerned that the students would not be disadvantaged by having to get to know each other as they worked together at the computer. Brush (1997) saw this sort of reasoning by the teacher as legitimate for research purposes, arguing that research into such multifaceted pairings could provide further insight into the effects of different cooperative pairings on computer-based activities. Based on research (Inkpen, 1997; Inkpen, Booth, Gribble, & Klawe, 1995; Upitis & Koch, 1996), it was thought that, for the scope of this investigation, mixed gender pairs would have provided one too many variables.

Data Collection

Global data were obtained from pre and post, written, and interview questionnaires with the students and teacher. The written questionnaires contained labelled and unlabelled pictures attached to some of the questions; they were administered to the whole class by the teacher who read each question as she walked around the room gauging the appropriate pacing (Brush, 1997). The second instrument, the interview questionnaire, was motivated by the belief that it was essential for grade two children to have test items that utilized hands-on activities. The aid of such physical props would provide particular insights into the child's knowledge and reasoning that were unobtainable through the written questionnaires. Thus, after the whole class written questionnaire was administered, pre and post audiotaped interviews were conducted with each child.

Pre and post audiotaped flexible open-ended structured interviews were conducted with the teacher. If the teacher introduced a topic or idea not covered in the questionnaire, the researchers followed this thread then returned to the designated questions. Data were also obtained from the teacher's assessment instruments.

In-depth data were obtained by narrowing the research focus to the small sample of six students. Each student in the three pairs was individually administered a pre and post open-ended structured interview. Additionally, each pair was videotaped and audiotaped while working together with the computer: twice in the first week and once a week for the following five weeks. A researcher sat behind the pair recording the students' specific interactions with each other (e.g., sharing control of the mouse), the software (e.g., their strategies when building the diorama), and verbatim conversation pointers to critical incidents. Based on the recorded observation notes, retrospective recall interviews were used. Because of the class's lesson constraints, these recall interviews were conducted with both students together at the end of each videotaped and audiotaped *MIF* session. The purpose was to prompt recollections of their thinking, reasoning, strategies, and feelings during the activity.

INFLUENCING FACTORS IN STUDENT OUTCOMES

The students' unanimous perceptions were that "you learned a lot" working with *MIF*, which was "cool," "lots of fun," "interesting," and "never boring." Data from the interviews, observations, videos, teacher records, and the pre and post tests confirm a consistently high level of involvement and a satisfactory growth in various social and cognitive skills that were developed and reinforced within the computer-supported learning environment. There were eight major interrelated reasons for the students' outcomes: (a) the educational software's instructional design, (b) enthusiasm, (c) on-task engagement, (d) supportive cooperation and friendly competition,

(e) improvement in understanding and usage of scientific skills and language, (f) attitudes toward science, (g) the teacher's pedagogical and philosophical approaches and attitudes toward incorporating technology into the curriculum, and (h) the computer integrated curriculum.

Message in a Fossil's interface design

MIF is a microworld simulation (Rieber, 1996) where the student is a paleontologist who excavates in virtual grid dig-sites, discovers plant and animal fossils, hypothesizes what they might be, identifies them by comparing and contrasting them with those in either the plant or animal fossil collection, and based on the uncovered fossils, reconstructs the prehistoric world by constructing a museum diorama. In this interactive environment, the student emulates a scientist and utilizes the scientific method and thinking skills.

The user interface design of *MIF* is simple and user friendly with meaningful navigational icons. It fulfills the criteria identified as applicable to a microworld simulation. A microworld is characterised as a complete small version of some domain that is found in the world (for example, a playground can be a microworld for learning about force and motion) or artificially constructed (*LOGO* and the *Sim* series are probably the most well known examples). Microworld software is designed to encourage children to play and discover concepts and cause-effect relationships through exploration and experimentation (Papert, 1993). A simulation attempts to mimic an imaginary or real environment and content that cannot be experienced directly, for such reasons as cost, danger, accessibility, and time. Thus a microworld simulation presents the learner with the simplest case of the domain so that little training is necessary to begin using it usefully (Rieber, 1996). Although there were examples of random clicking and frustration (Student 1: "Now what do we do?" Student 2: "I don't know; I wasn't the one who wrote this program!") about how *MIF* worked in the first day or so, before the end of the first week the students exhibited satisfactory usage (Anecdotal records; researcher observations). A microworld simulation also, and important for cognitive growth, allows the learner to reshape the microworld simulation to explore and manipulate increasingly more complex processes and concepts (Rieber, 1996; Thurman, 1993). There are three levels of expertise in *MIF*—beginner, advanced, and expert. Differently worded certificates that emphasize the student's advancement are awarded at each level for the correct completion of a diorama. However, *MIF* is more than a microworld simulation; it also includes various databases with extension material, such as textual information about the environment where the living organism used to exist and videos of past fossil expeditions.

According to Rieber (1996) and Pellegrini (1995) microworld simulations can provide learning environments consistent with serious play which they defined as an activity demanding those learning situations that require creative higher-order thinking and a strong sense of personal commitment and engagement. The teacher in our study supported the notion of serious play for Grade 2: "Truly a child's work is their play and their play is their work. So I don't really have a problem with that" (Teacher post interview). To exemplify, she quoted that the children were saying that *MIF* was fun and, in the next breath, commenting that "I am a real paleontologist." *MIF* contains that "careful blending of attributes … where structure and motivation are optimized without subverting personal discovery, exploration, and ownership of knowledge" (Rieber, 1996, p.44).

It is the learner interface that has contributed to the learning outcomes in the grade two class. The "learner interface," as opposed to the "user interface," contains the pedagogic elements of interactive multimedia instructional design (Reeves, 1993). *MIF* incorporates a pedagogy that adopts a cognitive apprenticeship approach utilizing authentic problems and contexts. Cognitive apprenticeship attempts to enculturate learners into authentic practices in similar ways to craft apprenticeship; it supports learning in a domain by enabling students to acquire, develop, and use computer tools in authentic domain activities (Brown, Collins, & Duguid, 1989). Authentic problems and contexts do not have to be those that are part of the child's everyday experience but they do have to have a reality that is legitimate. For instance, paleontology is not part of the grade two children's lives but paleontologists belong to the world in which the children live. As well, problems based on gathering evidence and the generic scientific method utilized by paleontologists are both integral to *MIF* and the children's personal and school life. The software is a "realistic or virtual surrogate of the actual work environment" (McLellan, 1994, p. 30). This means that the children in the study were involved in legitimate authentic science activities when learning to gather, interpret, and communicate evidence to solve paleontological mysteries that assist in our understanding of the past.

The children loved the central character, Mr. E. Solver, the mystery solver; they modeled his scientific methodology, along with the chant, "Mr. E. Solver's plan," whenever appropriate in their other class activities (teacher post interview). He was the "helper," the guide who intervened and provided scaffolding tips, reminders, and suggestions that provided opportunities for self-directed decision-making—such as the coach in cognitive apprenticeship (McLellan, 1994) or the "more capable other" in socio-constructivist pedagogy (Gallimore & Tharp, 1990; Henderson, 1996). Mr. E. Solver provided praise, gave reasons for that praise, reiterated the concept of evidence informing our interpretation of the past, and constantly used "professional" scientific language. Deconstruction of one statement highlights these apprenticeship characteristics: "The habitat you chose for the diorama is perfect [praise containing two instances of correct terminology]. It matches your fossil evidence [explanation as to why it was perfect; reiterates the importance of evidence and its role in proving their hypothesis]. You did a fine job as a paleontologist [praise; professional terminology]." Through the creation of this character, the instructional designers ensured that students gained scaffolded support, reinforcement, appropriate language usage, and recognition of their learning achievements, that is, ingredients found in a cognitive apprenticeship.

The learner interface also provided the necessary intrinsic motivational ingredients for an effective simulation: challenge, curiosity, fantasy, and control (Malone, 1981; Rieber, 1996). One of the paired students commented that some dioramas were "challenging because we didn't know much about the dinosaur" and, thus, their curiosity was motivated as they had to find out about its living environment in order to create an accurate museum diorama. During their post interviews, all the paired students argued that, because of the increased expectations, it was appropriate to commence at the beginner level and progress through advanced to expert level. They could articulate the increased cognitive demands of the expert level and their enjoyment with meeting the challenge. According to the teacher, the children were "actually in control; they had so much ownership of it" (teacher post interview). This sense of personal ownership was also reported in a study of 25 grade two children working with the simulation, *KidSim* (Howland, Laffey, & Espinosa, 1997). As various quotes and data affirm, the children "felt like they were scientists doing it. It was very real life for them. They were immersed in it." (teacher post interview).

Just as with television, there is some popular concern that, because interactive multimedia software provides so many visual and aural stimulations and scenarios, it truncates creativity. The following discussion from an audiotaped pair's conversation reveals that creativity is not ipso facto stultified. In *MIF*, students are required to construct a habitat with the fossils they have collected and identified. Once the fossil is placed in the diorama it changes from the fossil to the living organism. For example, a shark tooth will change into the whole shark. In this way, the program helps the student internalize the link between the fossil and the organism from which it formed, a link that could otherwise be problematic. In the following conversation, the boys are devising a scenario in which the converted fossils become the actors; this "story" was not occurring on their computer screen and nor were any small fish visible:

Boy 1: That one and the other one are fighting each other.
Boy 2: Where is the other one?
Boy 1: He is picking him ...
Boy 2: I think we have done two sharks.
Boy 1: Two shark teeth!
Boy 2: They are brother and sister.
Boy 1: They [the sharks] are trying to eat the small fish.
Boy 2: She is swimming right past them.
Boy 1: He is swimming right over them.

What is additionally important is the comment from Boy 1: "Two shark teeth!"; the statement reveals a sound schema. He understood the conversion process used in *MIF* through internalizing the concept that each fossil is a fragment representing the whole.

Enthusiasm

One of the distinctive characteristics of the students' work with *MIF* was the continuous high level of enthusiasm. When the teacher asked the following post question: "Who thought it was boring learning with *MIF,*" there was much laughter and a loud comment, "Zero!" by one child who counted the hands. The reasons they supplied for their enthusiasm included: digging, labelling, "getting to find out what fossils are," "learning new stuff; I didn't know what paleontologists were," and building the diorama. These sorts of comments give flavor to a posttest written questionnaire item that required the children to place a check beside one or more of a possible list of 13 activities incorporated in *MIF* that they enjoyed doing. The top four in descending order were "digging for fossils," "building the diorama," "printing my diorama," and "identifying fossils." Except for printing the diorama, these activities were focal to the learning objectives in the microworld simulation. Printing the diorama was an extrinsic reward, which is an integral component in computer simulations; this tangible record of achievement was obviously seen as worthwhile by the children.

What is significant was the ability of the grade two students to understand the concept of serious play as they were able to distinguish between "enjoyment" and "learning." The following question (to the one mentioned in the above paragraph) on the post written questionnaire presented the same list of 13 activities and required them to tick one or more of the activities that they "learned most from in *MIF*." The ranking of their perceptions was: "identifying fossils," "reading interesting facts about fossils," "building the diorama," and, equal fourth, "digging for fossils" and "looking at videos of, and reading about, fossil expeditions." Identification of fossils and building the diorama involved observing, inferring, analyzing, and problem solving based on evidence, that is, strategies and thinking skills involved in the scientific method. Choosing these two activities as important learning tools indicates that the students have implicitly internalised their importance for scientific literacy. The other two items were in the extension database that was not integral to the simulation. It points to the students going beyond the simulation "game" to extend their breadth of knowledge. The examples emphasize the strong link between fun and learning that is seen as a significant combination in early childhood education particularly (Haugland & Wright, 1997; Rieber, 1996).

One criterion that indicates the degree of student engagement and enthusiasm is self initiated activities that occur outside of tasks stipulated by the teacher. Although there were several instances of "taking it away from the computer" (teacher post interview), the following highlights the depth of engagement. During the last week of the integrated unit, two teacher-identified as average ability girls decided to make a fossil book:

> They had finished a small group station and were looking at the fossils; but, rather than just look at the fossils, they decided to record them. So they were being scientists. They made a list of the fossils, measured each one, and gave them a name and a description. They wouldn't have done this if not for *MIF* ... naming the fossils would have had to come from the software's database in the fossil collection section because we didn't have books with this detail in the classroom (teacher post interview).

The children had also "taken it outside the classroom" (teacher post interview). The children talked about it, particularly their dioramas, to each other and other grade two children at recess; to family members; and, some, with non-school friends (post written questionnaire). The teacher reported that other teachers commented on how often her grade two children play-acted by drawing grids in the playground, digging, sifting, and brushing in their search for imaginary fossils (anecdotal records). The challenge for self-improvement triggered further reading (anecdotal records of parent comments). A number of students researched dinosaurs and fossil-related topics at home in order to "learn more about how to put the bones together" or "know what some of the things were when I got onto *MIF*" (post student interviews).

On-Task Engagement and "Cognitive Talk"

Drawing on the approaches by Bennet and Dunne (1991) and Wild and Braid (1997), the six paired children's interactions at the computer were analyzed from their transcribed audiotaped conversations as they worked with *MIF*. We found that after the initial settling-in of who would have control of the mouse, approximately 92% of the conversations in all of the pairs were on task, even in the sixth week of the unit. Much of the remaining 8% of the conversations concerned turn-taking management of cooperative learning with computers and non-related topics.

More important than partners being on-task are the findings concerning the quality of the paired students' dialogue. There was a very high level of "cognitive talk" (Wild & Braid, 1997). The conversations involved examples of lower order cognitive talk, such as advising what to do next and providing directions. However, there was a significantly high percentage of higher-order cognitive talk, particularly in comparison with the study by Wild and Braid (1997): predicting what the fossil was and how big it would be; strategy planning (for example, whether to obtain all the fossils and then go to the fossil collection or whether to go to the fossil collection after each find); explaining why the partner's strategy was not appropriate for a particular task; inferring the habitat; very occasionally confirming why the habitat was correct; problem solving why their choice of diorama was incorrect and then trying to infer what the habitat would be based on their fossils; and statements that revealed aspects of the scientific method. Overall, there was low level directive interaction and a substantial amount of higher level cognitive processing.

Observational data showed that if the students did not have control of the mouse and were not actively engaged in helping direct the action, their attention could be more easily drawn to what was happening elsewhere. This behavior confirms the research by McLellan (1994). When this happened their partner employed various ways to regain their involvement from gently turning the partner's head back to face the computer to promises of a reward: "I'm hurrying to find all the fossils so you can put the dinosaur and habitat together!" Such examples indicate that the children regarded collaborative on-task learning—not individualized on-task turn-taking—with the computer as a valued strategy.

Our analysis also revealed that there was no apparent difference in enthusiasm and on-task engagement between the teacher-identified low achieving pairs and the other pairs and, although the lower achieving pair were slower to verbalize their strategies, all students utilized various scientific processes and thinking skills. These conclusions suggest that pedagogically effective multimedia can act as an effective educational tool to help minimize the differences in enthusiasm, on-task behaviour, and cognitively oriented talk between low and high achieving students.

Cooperation and Collaboration

An important educational and societal issue concerning the use of computers is a perception of negative social effects of one student to one computer and the beneficial effects of collaborative studying with the computer (Maddux, Johnson, & Willis, 1997; Rowe,1993; Salomon, 1998). A reason for the sustained motivation and, according to the teacher, much of the learning was the one that the teacher singled out as probably the most significant. It was the children working with partners on *MIF*. All students worked mostly with partners and, depending on how they felt or the availability of their partner, they would choose to work with another person or, occasionally, alone. The six teacher-selected students were also allowed to choose other partners or work alone during non-research times. Irrespective of the set-up, there was discussion, requests for help, and unsolicited advise, between partners and neighbors as well as up and down the computer row.

Based on her assessments, the teacher was adamant that "[i]n comparison with previous years, working with partners made an incredible difference...it has just been amazing how much more learning took place...it kept them focused." Previously, it took the six weeks for any student in the participating Plano Independent District schools to complete a certificate and it was "really frustrating for them...I, and the other teachers, have never had anyone do expert level before." This year in the research class, there were certificates and dioramas at the end of the first week; by the end of the six-week integrated unit, a whole classroom wall was covered and all students had achieved expert level of difficulty. Partners permitted "better internalization of the vocabulary. They were not just listening by themselves [to the voice-over explanations in the simulation]; they were communicating their understandings." (teacher post interview).

The cognitive test results of the six children who probably worked more consistently with the same partners than the other students did when learning with *MIF* are worth comment. On the days when the research was not being conducted, the six students either, with few exceptions, chose the same partner or worked individually (student interviews; researcher observations; teacher post interview). There was only a slightly larger percentage of improvement in results from pre to post written questionnaire tests for the paired students (27%) compared with those for the rest of the class (22%, i.e., the percentage improvement in the results for the class minus those of the pairs). However, when we examine some individual items in the posttest written questionnaire, we find the following dramatic differences: for instance, 83% of the pairs obtained the correct answer compared with 54% of the rest of the class on a question which required inferring the habitat from a list of four choices of the fossil that the teacher held up as she walked around the classroom; on another question which required transference of problem solving skills in a new context, 66% of the paired students obtained the correct answer on the posttest but only 36% of the remaining students were able to predict where the lost mystery parcel belonged. (In this question, students were given a set of labelled pictures each depicting an item in the parcel and, based on this evidence, were required to infer where the owner might work given four choices of location. This "solve the mystery" activity, required the same sort of scientific strategy and thinking skills contained in the software as inferring the habitat from the fossil evidence is integral to building the diorama in *MIF*.) It would appear that interactions between more permanent partners when working with *MIF* contributed to their understanding and ability to apply various thinking skills. The result confirms other research findings on the benefits of cooperative learning (Abrami & Chambers, 1996; Johnson & Johnson, 1985; Nastasi & Clements, 1993; Slavin, 1996; Wild & Braid, 1997).

In terms of cooperation, student ability, and learning outcomes, our research revealed that on the questionnaire test items, the teacher-identified low achievers demonstrated a significant improvement in their pre to posttest results (42%) compared with the results (14%) of the teacher-identified high achievers. If the low achievers are categorized according to their type of grouping, heterogenous or homogenous, the teacher-identified low achiever who was paired with the higher achiever (i.e., a heterogenous group) demonstrated a lower improvement while the two teacher-identified paired low achievers (a homogenous grouping) showed a higher improvement result. The high achiever paired with the low achiever demonstrated a slightly higher percentage improvement than the homogeneous grouping of the two teacher-identified high achievers. These results do not support findings of meta-analysis research (Lou, Abrami, Spence, D'Apollonia, Chambers, & Poulsen, 1996; Slavin, 1996). According to their research, low ability students learned significantly more in heterogeneous ability groups than in homogeneous ability groups; this was not so for our study with respect to the pre-post test items. Besides the small number, influencing factors in our study may have been the partnering of students on a friendship basis and the fact that the paired students did not work with the same partners or with a partner every time they worked with *MIF*.

Our observations of the pairs' interactions while using *MIF* provided examples of peer assistance within the pairs. In these interactions, the roles between the students constantly changed. The teacher-identified low ability students alternated between what Wild and Braid (1997) identify as "cognitive action talk" and "higher-level cognitive talk." For example, the low ability student directs his high ability partner: "Brush it. Drag the magnifying glass and see it. [pause] Now label it [action talk]…that fossil matches your bones" (higher-level cognitive talk whereby he confirms they have the appropriate dinosaur based on the evidence of the fossil). This is followed by further instructions. According to the teacher, this assertiveness was something new in the friends' in-class relationship; she believed it beneficial to both boys. When researching cooperative and collaborative learning, the affective and social dimensions need to be examined along with the cognitive.

The following contention by the teacher exemplifies the class outcomes involved in collaborative negotiated learning. She argued that working with partners with *MIF* promoted:

> [e]fficient methods to solve difficulties and provided security so they could take risks in their decision-making.…Knowing where to go next, when to proceed to the next level of difficulty and what to do if they couldn't finish their diorama at a single sitting, they totally took care of that themselves. And I've never had a class like that before. Usually, I spend the first few weeks hovering, giving directions. They also solved problems about whom to work with and how to work together equitably. (teacher post interview)

This raises the notion that it is worth researching if the cooperation when learning with *MIF*, or any other software, also affects other class activities which require cooperative decision-making.

One common problem that the pairs had to confront while working together with *MIF* was the question of who would have control of the mouse. There were a number of strategies used by the pairs to take control and be the more proactive partner. Swapping chairs in order to have control of the mouse was a typical strategy. Another involved negotiating turn taking according to time and tasks: "You dig and I will identify the fossil in the data base" (audiotaped *MIF* sessions). Turn taking was renegotiated amicably between the two high-achieving females and the high/low achieving male pairs. Fighting was another strategy resorted to but only once: in the second week the low achieving male partners took their shirts off and threw a few unconnected punches. As commonly reported in the literature (Inkpen, Booth, Gribble, & Klawe, 1995), one of them explained that “we were trying to fight over control;” each took credit for solving their dilemma by being the one to establish taking turns on the mouse after each fossil find (retrospective recall interview). Other frustrations occurred: for instance, one girl constantly squirmed and tapped her feet over the slowness of her partner (who, for this partnered session, happened to be one of the teacher-identified low achieving males in our paired students); another student was observed looking away whenever his partner had control of the mouse (researcher observations). Unfortunately our research was not designed to follow-up the non-paired students to ascertain the duration and effects that this type of negative behavior may have had on the affective and cognitive learning outcomes of the recipients.

Even though there were numerous negotiations over control, there were as many instances of joint ownership of working together. The following is but one example:

> Student 1: And now we need to put the shark’s tooth in.
> Student 2: We just found it. We found those two, [pointing to the screen] those two.
> Student 1: I found both of them.
> Student 2: We found his tooth.
> Student 1: We have to identify this one.

Later, Student 1 tells the teacher when she comes by that “We found two shark teeth, Mrs J…” (Transcripts of audiotaped conversations; our underlining to highlight Boy 1’s move to joint ownership.). Unlike most educational simulations, *MIF* has been designed for collaboration; for instance, it allows multiple ownership when the students log-on and all the names then get printed on their diorama and certificate.

This collaborative attitude was reflected in the classroom learning culture (teacher post interview; researcher observations):

> They all wanted to get the dioramas and they wanted to get the certificates. But when someone put up a diorama everybody would hover around them: ‘What did you get?’ ‘What did you put in it?’ ‘Where did you find it?’ You know, they really were interested in a very positive way, a very supportive way. There was not so much a competition as a collaboration. (teacher post interview).

From observational data, we noticed that it was not an uncommon practice for the children to decide not to print their certificate of expertise. The certificate is awarded if the diorama is correct. Nevertheless, one student maintained that “there was a kind of friendly contest to be the first one to complete a diorama that no one else did” (post interview). Our observational data and audiotaped transcripts confirm the teacher’s overall perceptions that there was a pleasing extent of peer tutoring and supportive advice and that there seemed to be no jealous guarding of knowledge by individuals or pairs.

Cognitive Outcomes

The pre and post written and hands-on interview questionnaires enabled detection of changes in students’ thinking skills resulting from the use of *MIF* within the integrated curriculum. The focus of the questionnaires was to ascertain the children’s ability in a variety of thinking skills—not content skills—utilized in scientific inquiry: identification; recall; inference from evidence; classification; logical sequencing; and ability to transfer understandings. These outcomes are reported in detail (Henderson, Klemet, & Eshet, in press). The data is summarized here to provide an understanding of what was accomplished as measured by the pre-posttests in order to have a comprehensive view of “the computer integrated classroom.” At the end of the six week unit, there was an overall improvement of 24% in the number of correct responses tapping these, mainly higher level, thinking skills between the pre and posttests.

From the data, it is clear that all the children could correctly identify and classify fossils at the end of working with *MIF* and the other integrated curriculum activities. This is not surprising given both the numerous examples of plant and animal fossils in the software and the numerous rocks and far fewer fossils brought in by the children for identification and classification by other class members.

There was an improvement from pretest (27%) to posttest (60%) in the students’ ability to logically sequence a chain of events. Each student was handed a fossil during the hands-on questionnaire and asked to explain how the fossil was formed. Instead of having a number of photos, each portraying a stage in the cause-effect progression of fossil formation, which they could arrange in a logical sequence, our participants only had a fossil to hold and examine. Therefore the question demanded mental envisaging of the logical steps of fossil formation and the result is pleasing given the complexity of the activity, especially for grade two children (Temple, 1997).

The research was interested in the children's ability to apply scientific classificatory principles as these were addressed in *MIF* within the integrated unit. The children were asked to sort different items into meaningful groups (hands-on activity interview questionnaire). The items were small duplicate cards, each of which depicted a picture of a plant or animal that was familiar to the children, either through real life experience or the media. Given multiple cards of each picture, the children were told that they could use the same picture more than once in different groups.

The students' answers were analyzed in terms of their scientific classifications. In the pretest the students mostly used descriptive, general knowledge type classifications, such as "can fly." In the post grouping test, all students used more scientific classification terminology. It was generally either by places where animals live or according to the biological classification of organisms. Examples include, "forest habitat," "mammal," and "cold-blooded," and were indicative of utilizing terms that were used in *MIF*. There was also improvement in the students' ability to sort the items into logical categories. Logical categories included such things as "reptiles" and "cats [sic] family" while illogical groupings were given labels like "butterfly" and "cat and bear sleep." Illogical groupings are those that indicate an inability to group or classify coherently. For instance, "butterfly" is an illogical classification because the group has only one member so, too, is "cat and bear sleep" because the criterion applies to all the animals (examples from post hands-on interview questionnaire). The classifications they used in the posttest were scientifically appropriate with only two students providing illogical groups in the posttest. There was internalization of what constitutes logical and scientific criteria and how to appropriately categorize that criteria.

In the case of *MIF*, students infer the ancient habitat from the fossils they find and the information presented when they correctly identify their fossil by matching it with its replica in the fossil museum database. We therefore expected a greater improvement on two written questionnaire items based on inference from data: one required the children to chose the correct habitat from four choices of a large shell fossil that the teacher held up as she walked around the classroom and the other item presented three labeled fossil pictures and required the children to choose "how the place would have looked in ancient times" from a choice of three habitats. There was minimal improvement on the first question and a back-sliding on the second. A possible reason for the results is that the *MIF* simulation made it easier for the students to infer the correct habitat because they could see that the fish fossil would not have lived in the forest and were able to change their diorama. Improved results could probably have been obtained from having the questions as part of the hands-on interview questionnaire where the children could have been provided with pictures of the habitats and asked to place the fossils in their correct habitats and/or given three fossils that lived in the same habitat and be required to point out the correct habitat.

These two questionnaire items also sought to ascertain the children's ability to transfer understandings gained through learning with the simulation, *MIF*, and other activities involved in the integrated curriculum unit. On these items, transfer was poorly achieved. Applying acquired knowledge or skills obtained in one context to new instances or problems is a matter of transfer and critical to scientific educational situations (Price & Driscoll, 1997; Salomon, 1997). As discussed above, the questions were abstract, lacking pictures that could have helped the students envisage the habitat. Additional support for this conclusion is provided by the fact that the students produced a significant number of dioramas at the expert level. This suggests that there was an improvement in their ability to make inferences but within the environment of the simulation; their transference to the unfamiliar situations was not as proficient.

There was internalization of content and use of scientific language. Data were obtained from documents (an assessable writing activity and the teacher's anecdotal records), the teacher's post interview, and the pairs' conversations while using *MIF*. An analysis of an individual writing activity on dinosaurs and fossils that was set by the teacher at the end of the six weeks reveals internalization of content. As the teacher pointed out, the topic was of "very high interest to them" so the quantity was no real surprise. Their answers did not reflect a traditional grade two focus of listing the names of dinosaurs and related facts. They wrote more generally, even the lower achieving students. They talked about evidence and problem solving as well as correctly using (though sometimes misspelt) paleontologist, diorama, communicating, evidence, and interdependence (a "buzz word for them"). Their writing included such things as: using a digging grid and appropriate tools; measuring and labelling fossils; fossils were evidence that dinosaurs existed; and "if you want to find out about them you can look at fossil remains." Their writing overall contained a high level of information and embodied concepts presented in *MIF* and the other integrated activities.

Gender and Attitudes Towards Science

Our study did not target gender as a specific focus; however, there are some findings that reflect changes in attitudes to science. Students were asked to pick which occupations they would "find the most interesting to be when they grew up." They could pick more than one of the 11 choices; they were also asked to go back and choose the best one. In the post questionnaire, nine out of 11 boys chose paleontologist as one of their preferences with five choosing it as the occupation they would like best. In comparison, five out of seven girls chose it as one of their options with two saying it was their best preference; one chose "scientist" as her best choice; three chose teaching and one nursing as their best preference; and, while hairdressing was still attractive to two girls neither chose it as their preferred best occupation in the post questionnaire. None of the boys chose teaching, nursing, or hairdressing, thereby highlighting their recognition that these are still considered traditional female occupations. In the pre and post questionnaires there was a distinct male bias towards the science occupations, although a few more science occupations were checked in the posttest. Compared with the prequestionnaire, in the post questionnaire the girls doubled (11:22) their choice of science-type occupations: scientist, astronaut, director of a science museum, paleontologist, pilot, and doctor. It would seem that, as one girl expressed it, "being scientists and learning science" with *MIF* helped change the girls' attitudes to what might be possible for them as careers. Not only was there more interest expressed in science-type occupations but on a question on the written questionnaire, more girls ticked more items listing books with science content in the post questionnaire compared with the pre questionnaire. In comparison, the boy's choices stayed much the same with science and sport sharing the top selections. The findings echo those in Levine's (1994) study that reported increased positive attitudes towards science by girls after using science software while those of the boys remained basically unchanged.

The grade two teachers in the Plano Independent School District do not identify science as a subject to the students. The teacher in our research study elaborated: "They're learning. It doesn't matter if they know the name of what they're learning as long as they know the content. We don't have science or social studies; we have integrated stations. It's either reading, math, or stations." Since the children did not have formally identified science classes, we can conclude that the experience with *MIF* had a significant impact on their occupation and reading choices.

Teacher Pedagogy and Philosophy

The match between the software and the curriculum theme as well as the ratio of computers to students obviously supported the integration of computer software into the classroom. Nevertheless, it is the implementation of computer technology that counts (Jonassen, 1996). This study identifies the teacher as a key component in the successful incorporation of computer multimedia into the classroom. The teacher utilized a cognitive apprenticeship approach. It demonstrated valuing the social-constructivist idea that knowledge is constructed by the learner but mediated by more capable others such as, the teacher and peers (Gallimore & Tharp, 1990). The approach thus guided the presentation of scaffolded learning experiences that took into account the learners' role in making knowledge their own (Shapiro, 1994).

The research project influenced the teacher's usual practices with respect to individual versus partnered work with the computer. Previously, all the Plano Independent School District teachers using *MIF* decided that there would be a one to one ratio of child to computer: "We have wanted everyone to have this American thing; you know, their own dig site; they had to own it." Because of our research request, the teacher changed strategies and organized for the remaining children to choose their own partners or work alone. At the end of the six weeks, the teacher was adamantly committed to using partners when working with *MIF* and other similar computer software because "I can see nothing but benefits." She contended that there were noticeable differences in learning outcomes in comparison with previous years: it produced greater internalization of scientific language and concepts; it led to the students' self-activated non-computer and out-of-class activities that were noticeably fossil related; because of the verbalization required in collaborative work, the partnered discussions affected the students' ability to explain the scientific method more proficiently; and their engagement with *MIF* and the other integrated activities was more enthusiastically maintained (teacher post interview; anecdotal records). Our research has confirmed, to varying degrees for different children, these teacher assessments based on her usual classroom evaluation of the children's work and their formal and informal discourse.

During the post interview, the teacher argued that partners allowed her to put into practice her pedagogic philosophy to maintain a facilitator role with an emphasis on student responsibility for their own decisions. As Ellsworth (1994) posited: young students can learn to think for themselves and respect the opinions and judgements of others. Besides, "it is thought that even young students who become responsible for their own learning and collaboration are more likely to acquire lifelong learning skills" (Ellsworth, 1994, p. 392). Instead of directing, observational data revealed that the teacher asked questions in response to the students' questions. Even when the low achieving students resorted to throwing punches, the teacher suggested they solve their problem in non-physical ways and (seemingly) confidently walked away.

The amount of time allocated to computer activities is relevant to a successful computer-integrated classroom culture. In Plano, as in other classrooms, each teacher can decide the time allocated to computer software. In our study, the teacher ensured that each child used *MIF* each day for six weeks. This represented a substantial commitment, particularly in comparison with the commonplace usage of computer software as an extension, minor group activity, a once-a-week experience, or as a management device to reward good behaviour and early work completion (Jonassen, 1996; Maddux, Johnson, & Willis, 1997). It represented a critical understanding of the software that is being used and how that software can be integral to learning and not an activity that is seen as taking valuable time from "real" teaching. From the teacher's own assessment of the class's affective and social learning outcomes and that of our data, it would appear that extended time need not diminish student enthusiasm, engagement, and enjoyment in their learning or their willingness and ability to collaborate and cooperate; and, in terms of the cognitive outcomes, it would appear to promise greater internalisation of various thinking skills, the discourse used in the microworld simulation, and the discipline being studied.

The teacher's enthusiasm for incorporating computer technology in the classroom was unabated at the end of the six week unit: "I think it's the most wonderful thing that has happened" (teacher post interview). From the data (teacher pre and post interviews; research observations), it is obvious that her attitude was not merely a loyalty to being involved in the restructuring of the Plano K-5 curriculum. Her attitudes were based on the children's affective, social, and cognitive learning outcomes.

Integrated Curriculum and *MIF*

Another contributing factor that affected the classroom learning climate was the integrated curriculum and the place of *MIF* within it. The teacher believed that software would produce meaningful learning outcomes if used as a stand-alone, but its real value was enhanced through appropriate curriculum integration of the simulation and the other classroom activities. Indeed, one of the girls in the research pair explained that one reason she enjoyed *MIF* was "because it fits in with our integrated [sic]." The following example clarifies the close connections. The teacher used a rotating small-group integrated activity, digging out the chocolate chips in a chocolate chip cookie, to tease out the connections with digging in *MIF*: "What conclusions can you draw from digging chocolate chips up? What tools did you have to use? How can you compare that to *MIF*? How is it the same? How is it different?" (teacher post interview) These are the sorts of reflective strategies necessary in a cognitive apprenticeship approach to teaching (Norman, 1993).

The teacher elaborated further: "Even though evidence was our Organizing Idea, it was almost like *MIF* was the Organizing Idea. It was the heart of everything. And it really has to be because it's the one constant throughout the unit. Everything else changed daily." The teacher believed that, because of the integration, the children could go "deeper and deeper [thus] allowing them to make bigger connections within and between the activities." Our data and analysis generally support her contention.

CONCLUSION AND CHALLENGES

Effective technological innovation is a complex and difficult process. Obviously, the context investigated had two characteristics that other schools may not have: there was systemic incorporation of computer technology into the school district's curriculum in which the teachers had ownership roles and the software was producer-teacher tailored for the curriculum. Nevertheless, the study reveals various factors that resulted in improvements in the affective, social, and cognitive outcomes for the students and for the teacher that have implications for computer integration generally.

The major elements include:

(a) allocating significant time to each student to learn with the software. From our study, the continuous length of time (daily for six weeks) supported the internalisation of content, concepts, processes, and skills. This very practical action signals the teacher's confidence in the worth of the computer as a cognitive and social learning tool. Indeed, there was a reciprocal enthusiasm between the teacher and students for learning with the computer that was apparent in the classroom atmosphere and confirmed by the research.

(b) using partners when learning at the computer. This meant accepting a certain level of noise through ignoring headphone usage as they prevent collaborative conversation—another practical signalling device that confirms joint ownership of learning tasks. The research found that partners helped with internalization of cognitive skills and processes. Additionally, and in conjunction with the length of time, it permitted students to enhance their social skills. Further research is needed with respect to various types of partnering—including the one utilized in this study, that of student-decided flexibility in selecting a partner—on student cognitive, affective, and social outcomes as well as on the teacher's pedagogical practices.

(c) the teacher using a cognitive apprenticeship approach that encouraged student-initiated problem solving and decision making. Even though in this case the teacher's pedagogy reflected and reinforced the same approach that was used in the microworld simulation, it is plausible to assume that the pedagogy could be adopted by the teacher regardless of the software's instructional pedagogy. Further research would be useful in this area.

(d) not just ensuring that the software is appropriate and, therefore, integral to the curriculum unit being taught, but also ensuring that the students are aware of that integration. The study revealed that, within a cognitive apprenticeship approach, the teacher encouraged reflectivity on how the computer and non-computer activities were integrated. It also highlighted that the teacher has to understand thoroughly the pedagogy and goals of the software so that it and the non-computer activities address the unit's theme and goals. However, the poor results on transference point to the need to include more experiences with differing non-computer activities so that students have meaningful practice beyond that provided in the software to solve problems requiring transference.

(e) a microword computer simulation can produce meaningful social and cognitive outcomes if incorporated effectively. Based on the research findings, the overall impression of the computer-integrated classroom was enthusiastically engaged students who were motivated to construct their own knowledge and learn how to learn collaboratively within an environment supported by the cognitive apprenticeship approach of *MIF* and the teacher. Their engagement was supported by the realization that they were experiencing affective, social, and cognitive successes.

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