

# **JUST PLAYING A GAME? EDUCATIONAL SIMULATION SOFTWARE AND COGNITIVE OUTCOMES**

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## **ABSTRACT**

The study investigated if young students internalized content and concepts embedded in a science computer microworld simulation as opposed to treating it as merely a game to be played. The article reports changes in the Grade Two students' cognitive outcomes and processes after learning with the software integrated within a thematic curriculum in a classroom over a period of six weeks. Results indicate improvement in various thinking skills and strategies, from basic recall to the higher level skills such as classification and inference, as well as in the children's usage of scientific language. Transfer occurred but was not significant thereby emphasizing the importance of providing numerous practices instead of relying on the software to teach higher order cognitive skills. Daily usage and a flexible paired working environment with the computer were pedagogical variables in the cognitive outcomes.

## **INTRODUCTION**

There have been numerous studies of the interrelationship between interactive multimedia and learning in journals, conference proceedings, and literature reviews. Many reported positive cognitive outcomes [see reviews: 1, 2]. Even so, Jones and Paolucci argued that research is minimal when concerned with learning

outcomes in terms of pretest measurements [3]. Narrowing the review focus, there is little research related to student learning outcomes of incorporating educational science microworld simulations in early childhood education (generally perceived as the first three to four years of formal schooling) [4, 5]. Watson concluded that concerns remain about the extent to which simulations teach problem-solving skills and if students can discern between the fun of the game and the skill they are supposed to be learning [6]. Rieber and others have emphasized the importance of the connection between serious play and educational games and simulations [7-10]. This is not contended, particularly in early childhood education. Nevertheless, particularly given the gaps in the literature, it is legitimate to query if young children just superficially play a computer simulation or whether they become producers of knowledge as they analyze data and information and develop testable propositions [11].

By traditional evaluation standards, the most satisfying data are those generated in laboratory or controlled clinical settings using well-specified and implemented treatments and readily measured outcomes. However, because utilization of interactive multimedia in classrooms is not clinical, exploration of in-situ implementations is necessary [12]. According to Selwyn, what is still missing from the literature are studies of what happens in real contexts over time [13]. Thus, in keeping with current literature [12-16], our investigation was not concerned with ascertaining whether learning with a particular piece of software produced better test scores than learning without the software. Rather, the research examined students' cognitive outcomes of the incorporation of interactive multimedia science software as part of an integrated curriculum in the authentic environment of a Grade Two classroom over a period of six weeks.

The research aim was to 1) ascertain if there was internalization of various cognitive skills relevant to the curriculum and the interactive software used, 2) establish if transfer to other contexts occurred, and 3) ascertain if appropriate scientific methods, terminology, and discourse were used. The article therefore does not concentrate on any one thinking skill or process; each will be placed within the literature during the analysis section.

## METHODOLOGY

### Context

In 1993, Edunetics, a multimedia production company, was contracted to help redesign the segregated discipline-focused K-5 curriculum for the Plano Independent School District, Texas, in-service its teachers in the area of computer technology, and develop educational computer software that would serve as the backbone of the new thematically integrated curriculum. Thirty-five K-5 teachers were released part-time to work cooperatively with the pedagogical and content experts in Edunetics. Together they developed a student-centered multidisciplinary

integrated curriculum influenced by constructivist learning theory, arguing that their traditional teacher-centered curriculum made learning fragmented and lacking in relevance and conceptual connections because of its confinement within disciplines [17]. The integrated curriculum contains six overarching concepts that are translated at each grade level into different developmentally appropriate organizing ideas, or thematic units. "The overarching concepts create the opportunity to spiral the curriculum through the grade levels while the organizing ideas provide horizontal curricular coherence" [17]. Objectives stress student construction of their knowledge, higher order thinking skills, group work, learning choices, real-world applications, promotion of life-long learning behaviors, and self-reflective assessment [17].

In Grade Two, one of the six overarching concepts is "Communication"; it emphasizes gathering, interpreting, and communicating evidence to solve mysteries and problems, particularly those that inform our understanding of the past. "Evidence in our World" is the organizing idea and is divided into six thematic sub-units, each of approximately one week's duration: 1) Introduction: What is evidence?; 2) What does evidence tell us about the past?; 3) Evidence helps solve mysteries; 4) Evidence helps solve problems; 5) the Culminating (summarizing) activity: Find the missing piece; and 6) Review. Among other activities, a computer-based learning environment is used as the linking thread through the six weeks of the unit. Our research investigated the incorporation of *Message in a Fossil* (MIF), one of the CD-ROMs developed for the K-5 curriculum.

*Message in a Fossil* is a microworld simulation. For Papert, a microworld is software with which children play and discover concepts and cause-effect relationships through exploration and experimentation [18]. Building on this general definition, Rieber adds that a microworld is also characterized as a complete small version of some domain that is found in the world (for example, a zoo that places its animals in replicas of their natural environments can be a microworld for learning about world habitats) or artificially constructed (LOGO and SimCity are probably the most well known examples) [7]. A simulation attempts to faithfully mimic an imaginary or real environment and content (in this study, that of palaeontology) that cannot be experienced directly, for such reasons as cost, danger, accessibility, or time. Thus a microworld simulation allows the learner to reshape the microworld simulation to explore and manipulate increasingly more complex processes and concepts [7, 19].

*Message in a Fossil* is based on constructivist learning theory. In MIF, the student is a palaeontologist who excavates in virtual grided dig-sites by choosing appropriate tools (such as a hammer, brush, or pick) to discover plant and animal fossils hidden in the ground. More than 200 fossils can be excavated including dinosaur bones, sea-urchins, fish skeletons, shark teeth, and fern leaves. The student predicts what they might be and identifies them by comparing and contrasting them with the pictures in the fossil database, that also includes information on the

environment of the organism. The student infers the prehistoric habitat based on the fossils they excavated and then tests the hypothesis by constructing a museum diorama that reconstructs the habitat as it looked in ancient times. During their work the students can type into a notebook and tape-record information about their progress and understandings. They can watch videos that show how fossils form, observe how a team of paleontologists work at a dig site, and learn about the different functions of paleontologists at the dig site. Also available are a brief virtual tour of MIF and other scaffolding forms of help (such as Mr. E. Solver asking students if they might wish to visit the museum or database after the student has made some incorrect choices). It incorporates three levels of difficulty, beginner, advanced, and expert, and the complexity of the required cognitive tasks increases with each level. In this interactive environment, the student emulates a scientist and utilizes the scientific method and thinking skills.

For approximately forty-five minutes each day, the class worked in different stations where each small group activity integrated the 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 twenty minutes during reading, with some using it twice a day as their station activity. 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.

## Participants

The research was conducted in a Grade Two class in Plano, Texas, during the last quarter of the school year. From the twenty seven-year-old students, the teacher was asked to select three, same-sex 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 two male students, one high achiever, and one low achiever. As revealed in the pre-interview, the teacher had also paired the students according to the strength of their friendship [20] as she had not used pairs before when working with MIF and was concerned that the students not be disadvantaged by having to get to know each other as they worked together at the computer. Brush sees 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, it was thought that, for the scope of this investigation, mixed gender pairs would have provided one too many variables [22-24].

## Data Collection Instruments

Global data were obtained from pre and post, written and interview questionnaires with the students and teacher. There is some concern that data collection instruments “do not reliably measure the outcomes being sought. The measures that are reported are usually from traditional multiple-choice tests. New measures need to be developed which would assess the higher-level skills and other effects often affected by technology” [15]. Thus, the written questionnaires for the students contained a variety of question types, some of which had labeled colored pictures attached [see Appendix 1]; they were administered to the whole class by the teacher who read out each question at a suitable answering pace for the children [21]. Besides the written questionnaires, we believed 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. They were asked, first, to sort fossils from stones; second, to explain how the fossil they were given to examine was formed; and, third, to classify duplicate picture cards by grouping them into categories, labeling the groups, and providing reasons for their classification.

In-depth data were obtained by narrowing the research focus to a small sample of six students. Each student in the three pairs was individually administered a pre and post open-ended structured interview. Each pair was 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.

Pre and post audiotaped interviews were conducted with the teacher. These took the form of flexible open-ended structured questions. Data were also obtained from the teacher’s anecdotal and assessment records.

## RESEARCH FINDINGS

Two of the goals of the search were to ascertain if students utilized various thinking skills emphasized in MIF and the curriculum generally and if transfer, a higher order problem-solving and life-long learning skill, occurred. Findings pertaining to these goals is presented in Table 1. It contains data from both the pre and post written questionnaire and the pre and post hands-on questionnaire that aimed to provide information concerning changes in the children’s knowledge about fossils and their ability to classify, infer, use scientific reasoning, and transfer skills to solve problems that were, and were not, directly dealt with in MIF. These changes are identified for the whole class with a gender and selected pairs

Table 1. Changes in Students' Cognitive Skills: Number of Students Answering Correctly and Total Number of Correct Responses as a Percentage Improvement

Question Task	Cognitive Skill	Males	Females	Total	Pairs			N = 6
		pre/ post	pre/ post	pre/ post	high (F)/ high (F) pre/post	high (M)/ low (M) pre/post	low (M)/ low (M) pre/post	Total pre/ post
Selected Questions from Pre and Post <b>Written</b> Questionnaire								
Q1 Fossil identification	Identification	N = 11 6/9	N = 7 5/6	N = 18 11/15	1/1 1/1	1/1 1/1	0/1 0/1	4/6
Q2 Identification of occupation (palaeontologist)	Identification Recall	N = 11 6/11	N = 7 3/5	N = 18 9/16	1/1 1/1	0/1 0/1	0/1 0/1	2/6
Q3 Identification of fossil's habitat (sea, landfill, forest, or factory)	Inference from evidence Transference	N = 11 6/6	N = 7 5/6	N = 18 11/12	1/1 1/1	0/1 0/1	1/0 1/1	4/5
Q4 Identification of how habitat looked in ancient times	Inference from evidence Transference	N = 11 10/8	N = 7 6/5	N = 18 16/13	1/0 1/1	1/0 1/1	1/1 1/1	6/4
Q5 Identification of the fossil that doesn't belong	Classification Inference from evidence	N = 11 8/9	N = 7 3/5	N = 18 11/14	1/1 0/1	1/1 1/1	0/1 1/1	4/6
Q6 Solving a mystery (Where does lost package belong?)	Transference Inference from evidence	N = 11 3/4	N = 7 4/5	N = 18 7/9	1/1 1/1	1/1 0/0	0/0 1/1	4/4
Selected Questions from Pre and Post <b>Hands-On</b> Questionnaire								
Q7 Identification of fossils from rocks	Identification Classification (comparison-contrast)	N = 9 5/9	N = 7 5/7	N = 16 10/16	1/1 1/1	1/1 0/1	1/1 0/1	4/6
Q8 Explanation of how fossils are formed	Logical sequencing (cause-effect)	N = 8 2/3	N = 7 2/6	N = 15 4/9	0/1 0/1	1/1 1/0	0/1 0/-	2/4
Total Number of Correct Answers as a Percentage Improvement								
Males pre/post 46/59 22%	Females pre/post 33/45 27%	Total No. pre/post 79/104 24%		Low Students pre/post 11/19 42%		High Students pre/post 19/22 14%		

breakdown. Two students were absent during the post test so the table reports the results of eighteen students.

At the end of the six week unit, there was an overall improvement of 24 percent in the number of correct responses between the pre and post tests (Table 1). The number of students who improved was generally small in most items. The exceptions were for Questions 2, 7, and 8. The results were probably influenced by the fact that, in comparison with the other questions, Question 2 required a lower level cognitive skill, recall, and that Questions 7 and 8 involved hands-on concrete manipulation. Question 4 was an anomaly in that there was a decrease from the pre to post tests in the number of students giving a correct answer; this is discussed below. Female students improved slightly more than the male students, 27 percent versus 22 percent, respectively. Of the six students singled out for more in-depth research, the three teacher-identified low achievers showed a substantial improvement (42%) compared with the three teacher-identified high achievers (14%). Two children were absent during the post hands-on questionnaire and another child left before Question 8 could be administered. Hence their pre test results were not included in the calculations for Questions 7 and 8 resulting in smaller numbers for the class participants for these items (see Table 1).

From Table 1, it is apparent that the focus of the questionnaires was to ascertain the children's ability in a variety of thinking skills utilized in scientific inquiry. Questions 1 and 2 demanded the lower level cognitive skills of identification and recall and, while Question 7 also required the children to be able to identify, it was based on the higher order thinking skill of classification requiring comparison and contrast. Inferring from evidence was required in Questions 3 and 4. Question 5 required an ability to classify based on inference skills. An ability to apply logical sequencing was tapped in Question 8. Questions 3, 4, and 6 sought to ascertain the children's ability to transfer their understandings.

## DISCUSSION

### Identification

In terms of the integrated unit (organizing idea), identification was defined as the process that leads to labeling or establishing the identity of an object. When the teacher walked around the room holding up a large shell fossil in the post written questionnaire and asked the students to identify what she was holding, 83 percent gave a correct answer (Q1, Table 1). In comparison, all the children (100%) could classify the two different fossils and the three different rocks in the post hands-on questionnaire activity (Q7, Table 1). Their identification was based on observable criteria, that is, if it "had markings" or "a picture or print on it" then it was a fossil (Post hands-on questionnaire). One of the teacher-identified low achieving boys in our paired students used more complex cognitive reasoning: he sorted the rocks and said "the rest were fossils. The first rock was just concrete; the second rock



was like one that I have at home and I don't have any fossils at home; and the third rock was old but not like palaeontologists get." The post test result would seem to support the strategy of using concrete physical aids with student explanatory comments for data collection with, at least, younger children.

Question 2 (Table 1) required students to identify or recall the occupation of the scientist who studies fossils from a multiple choice list of five occupations, three of which were very close (geologist, archaeologist, palaeontologist) and two were obvious distracters (teacher and astronaut). Sixteen students (80%) correctly identified "palaeontologist" in the post questionnaire compared with nine (50%) in the pre test. The two students who answered incorrectly in the post test could have been influenced by the visit of an archaeologist to their classroom a few days before the post questionnaire. Given that the designation, "palaeontologist," was constantly used in context in MIF and in the classroom during the six week unit, it seems that the difference between the two occupations was not habituated for these two children but was for the other children who had given either the wrong or correct answer in the pre test.

### Logical Sequencing

Logical sequencing involves the ability to arrange a set of terms or objects in a successive order according to rational coherent criteria applicable to those terms or objects. For instance, it would involve arranging a set of events according to the time they occurred or reconstructing the linear process or chain of events involved in the construction of an artifact or, in this case, a fossil (Q8, Table 1).

Each student was handed a fossil during the hands-on questionnaire and asked to explain how the fossil was formed. There was an improvement from pre to post test: 27 percent gave a correct answer in the pre test while 60 percent answered the question correctly in the post test (Q8, Table 1). Instead of having a number of photos, each portraying a stage in the cause-effect progression of fossil formation, that they could arrange in a logical sequence, our participants only had a fossil to hold and examine. Therefore Question 8 demanded mental envisaging of the logical steps of fossil formation. The students who obtained the correct answer in the post test could have recalled a video clip in MIF discussing fossil formation as 39 percent of all students indicated in a post questionnaire item that they had watched this video. This video is part of the extension database and not necessary for creating dioramas or becoming more expert in the field of fossil identification and classification. As the stages in fossil formation occur over time in a particular order, the pre and post test results reflect the literature which argues that temporal ordering skills develop between the ages of six to twelve [25]. Nine children could mentally manage logical sequencing without concrete props to manipulate and were thus beginning to consolidate control of their temporal ordering skills. Future research could ascertain if picture cards of the stages of fossil formation



that could be used by the students to illustrate the formation sequence would produce better results.

### **Scientific and Logical Classification**

Classification requires the ability to cluster or codify objects according to relevant criteria. For instance, sorting or arranging animals, plants, and rocks in a series of specialized groups according to similarities in structure (vertebrates and non-vertebrates) or habitat (land, water, and air) or origin (sedimentary, igneous, and metamorphic). Classifications can become further specialized, for instance, animals or plants that are categorized according to a land habitat could be further divided into belonging to coastal, forest, mountain, and desert habitats. The research was interested in the children's ability to apply scientific classificatory principles as these were addressed in MIF within the integrated unit. When the data was being coded, it also made sense to ascertain the children's ability to classify logically, whether or not it was a scientific categorization. Illogical groupings are those that indicate an inability to group or classify coherently. For instance, "chicken" is an illogical classification because the group has only one member; so, too, is "all part of nature" since all the examples are part of nature (examples from Post hands-on questionnaire).

The children were asked to sort different items into meaningful groups (Hands-on questionnaire). The items were small duplicate cards, each of which depicted a picture of a plant (e.g., flower) or animal (e.g., shark, bear, cat). All the plants and animals were familiar to the children. 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 the scientific classifications. In the pre-test the students mostly used descriptive, general knowledge type classifications, such as "water things" and "fast runners." In the post grouping test, many students used more scientific classification terminology. It was generally either by places where animals live or according to the biological classification of organisms (Table 2). Many of their terms were used in MIF, for instance, "forest habitat" and "amphibian." In the post test, all students used the criteria used in the software, with six using more software criteria in the post test compared with the pre test; three students used fewer categories in the post test. Nevertheless, these three and the other students utilized appropriate scientific categorization; for example, "animals with camouflage" (Table 2).

There was improvement in the students' ability to sort the items into logical categories (Table 2). All students gave some logical groupings on the pre test. Out of eighteen students, nine provided significantly more logical groups out of their total number of groups in the post test compared to what they had in the pre test. Seven students had the same number of logical categories in the pre and post test

Table 2. Changes in Students' Logical and Scientific Schemata

Classification Terminology of Students Selected on Teacher-Identified Ability		
Student by Ability	Pre-Test Terminology	Post-Test Terminology
High ability	can fly; slimy animals; fast runners; grow outside	reptiles; mammals; amphibians; insects; plants; feathered
High ability	aqua group; snake group; mammal group; winged group; plant	reptiles; have fur; winged; aqua; plants; mammals
Average ability	bird; all smooth, slick kind of skin; chicken; shades of green; have fur that keeps them dry	plants; wild animals; house pets; animals with camouflage
Average ability	all hairy; part of nature; all dangerous; live on a farm	cold blooded family; plant family; flying family; farm family; hair family
Low ability	water things; pretty things; things that have fur	plants; wild life; home pets; farm animals; sea creatures
Low ability	nice to people; not nice to people; snake and frog; snake and shark; tree and flower	plants; birds; cats family; same skin

while two gave fewer logical groups in the post test; however the classifications they did use were more scientifically appropriate (Table 2).

The examples in Table 2 demonstrate the dramatic pre- to post-test change that occurred at an individual level. It would seem that MIF and the other integrated activities effectively supported the cognitive growth of all ability levels, rather than singling out the talented or low achiever. The computer and non-computer activities helped most students order concepts into a more logical and scientific classificatory schema. There was internalization of what constitutes logical and scientific criteria and how to appropriately categorize that criteria.

## Inference

Inference is defined as a process of reasoning in which a conclusion is obtained from certain facts or premises. In the case of MIF, students infer the ancient habitat from the fossils they find and the information they read about them that is presented when they correctly identify their fossil by matching it with its replica in the fossil museum database.

Three questions (Q3, Q4, and Q5, Table 1) required inference based on data. Question 3 asked the children where the large shell fossil, that the teacher held up

as she walked around the classroom, was formed. They had to put a check beside the best answer: "in the sea," "in the forest," "in the landfill," or "in the factory" (see Appendix 1). Question 5 required the students to infer which fossil did not belong with the others based on classifying or sorting which fossils belonged in the same habitat from the one that did not; the question contained labeled color pictures (see Appendix 1). More than half the children were correct in both the pre test (61% for both Q3 and Q5) and post test (67% and 78%, respectively); however, the percentage improvement for Question 3 was equivalent to one child. Question 4 provided three labelled color pictures of fossils (a "fossil of a fish," a "sea urchin fossil," and a "shell fossil") and asked: "Imagine that you found these fossils in the ground. What can you tell from these fossils about how the place looked in ancient times?" They were given a choice of three habitats: "The place was covered by the sea," "The place was land with high mountains," and "The place was land with a large forest." In this question the number of children who had the correct answer dropped from pre test to post test (89% to 72%, respectively).

A major goal in the microworld simulation is building the diorama which is equivalent to what was asked in these questions. In order to construct the diorama in MIF, the students had to infer the environment from the collected suite of fossils based on their analysis of appropriate living conditions acquired from MIF's database. In effect, the students had to understand what was an appropriate habitat for the fossils when the fossil had been alive. We therefore expected a greater improvement in Questions 3 and 5, and, of course, any improvement in Question 4 (Table 1).

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 how the fossils were converted into real "living" plants and animals when they placed them in the diorama. They could see that the fish fossil did not live in the forest and were able to change their diorama. Maybe better results could have been obtained from having the questions as part of the hands-on 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.

We cannot provide any rational explanation as to why the three children who gave the correct answer in the pre test then obtained the wrong answer on the post test (Table 1), particularly when Question 4 had "sea" in the multiple choice stem and the three labelled pictures contained either the word "sea," "fish," or "shell." Maybe they did not identify these linguistic clues; they may have guessed in the pre test, or, perhaps, because it was two of the high ability paired students (1 female and 1 male; see Table 1) who gave the incorrect post test answer, they may have thought that the answer had to be less obvious than it was.

## Transfer

Applying acquired knowledge or skills obtained in one context to new instances or problems is a matter of transfer [26, 27]. Achieving new understanding in unfamiliar contexts is critical to scientific educational situations and, indeed, for life long learning [25]. There were a number of questionnaire items that 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.

One question on the pre and post written questionnaire required students to apply knowledge of a scientific concept, decay and longevity. They were asked to identify which of six items (an apple, wooden door, shark tooth, bread, a sea shell, and a book), presented as labeled pictures, they could still dig and find in the ground if the items had been buried for a long time. Of the six items, two were correct. Out of a possible thirty-six correct answers (2 answers by 18 children), thirty-five correct answers and one incorrect answer were recorded in the post test. This was a substantial improvement on the pre test results with twenty-six correct answers and thirty-seven incorrect answers recorded. Although activities about what would decay and what could become fossilized were not included in the microworld simulation or listed as an integrated activity in the curriculum unit documentation, the students obviously had internalized the concepts of decay and preservation over time which are key concepts in the process of fossil formation.

The three questions on inference (Q3, Q4 and Q5, Table 1) also demanded transference which was poorly achieved, particularly in Question 4. Cormier [28] and Evans [29] noted that attention is selectively focused on both the information presented and the retrieval of prior knowledge, rules, or schema. Thus, the probability of retrieving such information is a joint function of the way in which the material was originally encoded and the cues available at the time of retrieval. Additional support for this conclusion is provided by the fact that all the students produced a significant number of dioramas at expert level. This suggests that there was an improvement in their ability to make inferences but within the environment of the simulation only; their transference to the unfamiliar situation was not as proficient.

The logical and scientific classification hands-on activity with the picture cards could also be considered one of transference. In MIF the user does not engage in grouping activities but does engage in matching or classifying activities. In other words, the student matches or classifies organisms (fossils) according to the environment in which they lived. Strictly speaking, this is not a grouping exercise. In addition, the picture cards were not of fossils but pictures of plants and animals currently found in the children's life experiences, both real and through the media. The fact that the students showed improvement in grouping from pre test to post test may indicate that MIF helped them transfer their understanding of classification (based on the concepts of similarities and differences) to the hands-on grouping exercise.

One of the off-computer activities in the integrated curriculum was the visit by an archaeologist to describe his work. The following comments demonstrate the ability of some students to transfer knowledge about fossils to the field of archaeology. The teacher believed that the children's replies to his questions indicated that they:

transferred knowledge about dating fossils over to how the archaeologist would know how old a pot was because the children said that the layer of rock that you found the fossil in was how you know how old the fossil is. He also asked: 'If you found a pile of bones, what would it tell you about the people? What if you just found frog leg bones?' And they said: 'The people who lived then were just probably eating the legs and throwing away the bones.' They really understood that everything in the grid belonged in the diorama and that everything in the archaeologist's grid belonged to the people who had lived there (Teacher post interview).

She argued that using the grid on a daily basis in MIF made it much more realistic for them than just her usual once-off practice of making a grid outside in the playground. More importantly, it helped them make the connections between what was found in the grid at any one site and what the habitat would have been like where that site now exists.

The purpose of Question 6 (Table 1) was to test transference based on hypothesizing. The teacher read aloud this written question presented as a scenario: "Imagine that as you were walking down the street, you found a package on the ground that included lots of money. As a good citizen, you want to find the person who lost it and return the money. But you don't know where to look. Fortunately, the following items were also in the package." Under this was a set of labeled pictures depicting a pair of coveralls, a wrench, a dirty pen, a piece of paper, and some screws. They were next asked: "Where is the best place for you to look for the owner of the package?" and they had to choose from a list (in the school, in the garage, in the nearby grocery store, or in the kitchen of the restaurant). Although half the children obtained the correct answer in the post test, there was only a small improvement of two children from the pre to post test.

It would seem that the activities based on hypothesizing habitats in MIF did not help nine students internalize strategies about how to use evidence to solve a problem presented in a different context. Nor does there seem to have been transference of using evidence to solve mystery problems which were included in the non-MIF integrated activities. These non-computer activities were whole class or small group activities where the children had to discover evidence and use it to solve the mystery, for example, who had left the mystery parcel in the room. Another activity involved reading a dinosaur mystery story based on finding fossils of a dinosaur that would have been native to Texas. Palaeontologists come from over the world to work at the dig site. Unfortunately a bone is broken. The

story then requires the students to hypothesize who broke the fossilized bone based on evidence.

The way Question 6 (Table 1) was presented to the students differed in a number of major ways to their other experiences. First, it was abstract without the hands-on in-class activities or the vivid representation of the simulation. Second, highlighting the importance of context for problem solving transfer [26, 30], our participants had little or no prior experience of working with this type of question structure before. (The teachers in the Plano Independent School District had commented on the “newness of this item,” believing that it would be difficult for Grade Two children; Teacher pre interview). Third, in comparison with the non-test activities, the students were given limited time by the teacher who administered the questionnaires in which to deduce the answer. Salomon and Perkins argued that all problems must initially be approached mindfully if relevant knowledge and skills are to be used to solve that problem [27]. The test item only allowed a small amount of time for reflectivity, a necessary ingredient for correct transference results according to Harmon’s review of the literature [31]. Fourth, the students had to answer the questionnaire individually but the in-class activities were whole class or small group.

If we interpret these factors and test results from a Vygotskian perspective the explanation would go something like this: These factors were likely to have affected their results and, hence, the test scores may not be a true reflection of their transference abilities within their Zone of Proximal Development [32]. Vygotskian theory contends that children learn in a socio-cultural environment and that their cognitive abilities should be judged on what they can do when provided with scaffolding by a more knowledgeable other, who could be the teacher or a peer or a computer simulation [32, 33].

On the other hand, if we interpret them from a cognitive perspective, the explanation argues that “an essential condition of problem solving (transference) as a learning outcome is the absence of guidance by the teacher; students must be able to effectively solve problems in unfamiliar contexts on their own” [25, p. 473]. This example is yet another instance of the significant effects that practice, content, and context have on problem solving involving transfer [26]. Given the research, the fact that there was only a difference of two students in the pre and post scores indicates that practice in novel situations, including individualized test environments, needs to occur if transfer is to succeed and the strategies to do so become habitualized.

### **Internalization of Content and Use of the Scientific Method and Language**

This section discusses data pertaining to the third goal of the article that sought to ascertain if appropriate scientific methods, terminology, and discourse were used. Data were obtained from documents (an assessable writing activity and the

teacher's anecdotal records), the teacher's post interview, and the pairs' audio-taped conversations while using MIF. The purpose was to ascertain if the students internalized content and concepts embedded in the computer simulation as opposed to treating it as merely a game to be played to obtain a certificate of expertise.

A change in the discourse by middle school children who were involved in a structural engineering class project was recently reported [34]. Our study reflects the growth in professional language reported in this study by Roth. There were numerous examples of using appropriate language in correct contexts from the paired students' conversations and post interviews. For instance, when placing a fossil into their diorama, one girl told her partner: "That won't fit the habitat." Appropriate coordinate terminology was common and is reflected in the following two comments while the children were digging for fossils: "It is in C3" and "Go to A1 now!" During his post interview, when asked what he thought he might have learned from MIF, one of the teacher-identified high achieving boys commented: "We learn what prehistoric things might look like." During the post questionnaire one child commented on why he enjoyed MIF: "I liked doing what palaeontologists do. I like to investigate and to build [a museum diorama]."

On a class level, 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 and relevant "professional" language. As the teacher pointed out, the topic was of "very high interest to them" so the quantity that the children wrote was no real surprise. The children's writing did not reflect the traditional focus on listing the names of dinosaurs and their characteristics, although these aspects were included. They wrote more descriptively and scientifically, even the lower achieving students. Though sometimes misspelled, the children correctly used "evidence," "problem solving," "palaeontologist," "diorama," "habitat," and "interdependence" (a "buzz word for them"). Their writing included the following points and concepts: using a digging grid; what digging tools were appropriate for particular tasks; measuring and labeling fossils; building a diorama; "fossils are evidence that dinosaurs lived"; "if you want to find out about them you can look at fossil remains"; and "dinosaurs lived a long time ago and some lived in the ocean and some on the land." Their writing overall contained information that embodied concepts presented in MIF and the other integrated activities.

From the pairs' audiotaped conversations, there were some instances that overtly demonstrated a lack of understanding of scientific processes. On the other hand there were a number of verbalized examples from all pairs that reveal the students' cognitive processes in attempting to solve their scientific problem. Table 3 is such an example from the high and low achieving pair of students. It follows other studies [34, 35] that employ discourse analysis to examine the quality of student discussion. This example (Table 3) from the pair's audiotaped conversation demonstrates internalization of aspects of the scientific method: observing, hypothesizing, testing (or gathering evidence), drawing conclusions, and



Table 3. Analysis of Student Discussion Identifying Usage of Science Skills

	Verbatim Discourse	Identification of Science Skills
Student 1:	It should be this one!	Disbelief; no problem solving yet.
Student 2:	Let's look at the fossils again.	Rechecking the evidence.
Student 1:	Okay. We've got three fish fossils, some shell fossils [pauses] that means the sea, so . . .	Observation of evidence; inference.
Student 2:	We've got a dinosaur—a pterodactyl. It must eat the fish. It has to live by the sea.	Observation; formulates hypothesis; draws conclusion.
Student 1:	Yeah; the beach habitat. But that's wrong. This is a hard one. [they are silent]	Draws same conclusion; reaffirms hypothesis and conclusion are incorrect.
Student 2:	Go to the information about the dinosaur? [asks as a question thus inviting peer input to the solution]	Gathering evidence from relevant sources.
Student 1:	It's got sort of wings . . . [contributes to the solution but doesn't answer peer's question]	Gathering evidence from re-examining the dinosaur.
Student 2:	[clicks to go to database]	Strategy to obtain evidence.
Student 1:	It says that it might have dived off to catch fish.	Gathering information.
Student 2:	[mumble] something high? Cliff? Maybe mountain?	Posing questions.
Student 1:	[at same time as student 2] The mountain diorama—go there—choose that one!	Testing hypothesis.
Student 2:	He's [the pterodactyl's] nodding yes!	Confirmed hypothesis.
Student 1:	We're right. [They give each other a high five]	Confirmed hypothesis.

confirming or not confirming the hypothesis. It also demonstrates the students' determination to work out the problem.

The teacher believed that the internalization of the scientific method and usage of scientific language was because of MIF (Teacher post interview). Three examples will suffice to demonstrate this contention. One example occurred when the teacher compared this year's results with an earlier year that included a visit to a museum to look at fossils:

It's just not the same, reading about and looking at fossils and doing it. And they really did it. They felt like they were palaeontologists and that's what made the big difference because they had so much ownership of it. With respect to the scientific method, when they had to apply it in other situations, they felt like they were scientists doing it, rather than just something we have to learn because we are in school. You know, because they used the following statements: 'We are going to collect data;' 'We are going to look for evidence;' 'We are going to make observations' (Teacher post Interview based on anecdotal records).

The second example occurred during the last week of the unit. Two teacher-identified middle ability girls decided to make a fossil book, which they completed in their own time during recess periods:

They had finished a small group station and were looking at the fossils; they felt that rather than just look at the fossils they would 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 probably 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 third example can be found in the differences from pre to post tests in Table 2. Most of the children demonstrated their internalization of the scientific terminology in MIF as they were able to use it appropriately when labeling their classification schema in the picture cards sorting activity in the post test interview questionnaire.

The teacher also argued that, "in comparison with previous years, working with partners made an incredible difference . . . It kept them focused [and thus] 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).

### **ADDITIONAL PARTNER AND GENDER CONSIDERATIONS**

All students mostly worked 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 advice, between partners and neighbors as well as up and down the computer row. The anecdotal records confirm socio-constructivist pedagogy that supports computer collaborative learning with peers [36].

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 further discussion. On the days when the research was not being conducted, the six students usually chose the same partner or worked individually (student interviews and researcher observations). There was only a slightly larger percentage improvement in results from pre to post tests for the paired students (27%) compared with those for the whole class (24%) or for the rest of the class (22%, that is, the percentage improvement in the results for the class minus those of the 6-paired students). However, when we examine some individual items in Table 2, we find the following sorts of dramatic differences: for instance, 83 percent or five of the paired students obtained the correct answer in the post test on Question 3, which required identification of the habitat based on inference, compared with 54 percent, or seven, of the remaining thirteen students. Again in Question 8, a hands-on activity that required the students to explain how the fossil was formed, 80 percent of the paired students obtained the correct answer on the post test while 36 percent of the rest of the class ( $N = 14$  because one of the pairs was absent for the post test) were successful. It would appear that interactions between more permanent partners when working with MIF helped contribute to their understanding and ability to apply various thinking skills. The result confirms other research findings on the benefits of cooperative learning [for example, 37-40].

In terms of cooperation, student ability, and learning outcomes, our research reveals that on the questionnaire test items in Table 1, the teacher-identified low achievers demonstrated a significant improvement in their pre to post test 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, heterogeneous or homogeneous, the teacher-identified low achiever who was paired with the higher achiever (that is, a heterogeneous group) demonstrated a 33 percent improvement while the two teacher-identified paired low achievers (a homogeneous grouping) showed a higher improvement result of 46 percent. The high achiever paired with the low achiever demonstrated a slightly higher percentage improvement (14%) than the homogeneous grouping of the two teacher-identified high achievers (13%).

These results do not support findings of meta-analysis research [39, 41]. According to such research, low ability students learned significantly more in heterogeneous ability groups than in homogeneous ability groups; this was not so for our study. However, our study supported the meta-analysis results in terms of the general finding that for high ability children, group ability composition

produced no significance difference. In comparison, Brush's study revealed no differences in the learning outcomes of homogeneous and heterogeneous pairs when learning with computers [21]. Besides the small number of paired students, 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.

Although our study did not target gender as a specific focus of study, there are some findings that merit comment. Some researchers like Creese [42] and Scott, Cole, and Engel [43] have argued that computer assisted learning should help lessen girls' poor results in, and attitudes to, science. Our study appears to support that hope, at least with seven year old girls. The female students showed a slight increase in improved correct answers compared with those of the male students: 27 percent to 22 percent, respectively (Table 1). This may have been influenced by the girls positive swing to things scientific. Students were asked to tick which occupations they would "find the most interesting to be when they grew up." They could tick more than one of the eleven choices. Compared with the pre test, in the post test the girls doubled their choice of science-type occupations. It supports Levine's study that reported increased positive attitudes toward science by girls after using science software [44]. 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 the written questionnaire, more girls ticked more items listing books with science content in the post test compared with the pre test. 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 an impact on their occupation and reading choices.

### **CONTEXTUALIZING THE COGNITIVE LEARNING OUTCOMES**

The cognitive learning outcomes discussed did not occur in isolation but were affected by their contextualization within the classroom learning community. As reported elsewhere, the student's attitudes, the microworld simulation (MIF), an integrated multidisciplinary curriculum, and the teacher's pedagogy were significant contributing factors in the students' learning outcomes [45]. The students' unanimous perceptions were that "you learned a lot" working with MIF; the findings support the accuracy of their perceptions. The software provided the necessary intrinsic motivational ingredients for an effective simulation: challenge, curiosity, fantasy, and control [7, 46, 47]. The children were "actually in control;

they had so much ownership of it" and "felt like they were scientists doing it . . . it was very real life for them and because of this, it was not just a game" (Teacher post interview). 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 . . . it really makes a difference." It was not just the commitment though. A critical element for success is how technology is incorporated into instruction. The teacher developed a facilitator role scaffolding the children's learning but returning the problem back to them to solve with the guidance she provided [48]. The teacher's pedagogy and enthused commitment to integrating the microworld simulation with the other non-computer activities to support the curriculum unit goals were important factors in the classroom learning community and the students' cognitive learning outcomes.

## CONCLUSION AND CHALLENGES

Four major implications can be drawn from the study.

The first is the commitment to incorporate interactive multimedia effectively into an integrated curriculum for a substantial time period; in this case it was daily for six weeks. Unfortunately much interactive multimedia is necessarily purchased sight-unseen from a software catalogue and not tailored to the curriculum as was the case in MIF. The teachers' task is to integrate it into their curriculum in coherent ways that ensure that the software is an integral element and not just an extension, minor group activity, a twice-a-week experience for a limited time, or a reward for good behavior and early work completion [16, 49]. Extended time would appear to promise greater internalization of cognitive skills. Schema building and problem-solving transfer cannot be left to chance. They do not arise spontaneously and their development cannot be assumed. As revealed in the study, the repeated daily experiences allowed students to internalize the professional language and certain scientific concepts and strategies.

Second, multiple experiences in these same cognitive areas need to occur more purposefully in the non-computer activities so that students are exposed to varied and new contexts in which to practice. The simulation, MIF, has embedded multiple exposures to various thinking skills and strategies. The study revealed overall improvement in various thinking skills and processes. However, the study also highlighted that transfer to different contexts was not substantial in a number of areas. Relying on a simulation to teach these high level skills is inadequate. Extension activities based on the thinking skills that are embedded in the interactive multimedia software need to be deliberately reinforced for habituation.

Third, partners certainly allowed verbalization, peer teaching, and risk-taking. Our study revealed that more permanent partners based on friendship generally had a positive effect on cognitive learning outcomes for both teacher-identified high and low achievers. The flexibility allowed the students to decide whether to work or not work with a partner or the same partner, and may have been a

significant factor in the enthused classroom climate and maintenance of engagement even though it may not have produced the same level of improvement in the cognitive learning outcomes as did the more permanent partnered students. As Abrami and Chambers [40] and Slavin [39] admonish, more research is necessary to understand the social and cognitive implications of pairing students for learning with computer software.

Fourth, our study's findings were such that further research is warranted. Our research was not focussed on the type of questionnaires that were administered. However, utilizing labeled pictures, the variety of question types (multiple choice, short answer, matching items, and choosing from a list then selecting one of those ticked as the most important), and individual hands-on activities combined with an interview, showed promise of obtaining valid data to the extent that further research would seem legitimate. Research is warranted in various classroom contexts. Such environments would include differing cultures and grades; comparative data on outcomes through focus on various teachers' pedagogies and philosophies; examination of the entire classroom learning community and its outcomes, and, especially, investigation of the long-term cognitive (and social) effects of learning with educational software every year for a particular cohort of students.

### **APPENDIX 1:** **Examples of Questions without Pictures and Questions with Labeled Pictures**

The following is the layout that was used for Question 3 (Table 1) except, in the original, the font size was larger. The teacher slowly walked around the room holding up a large fossil for students to see while loudly reading the question to the class. She observed to see if the children needed more time to look at the fossil and twice reread the question.

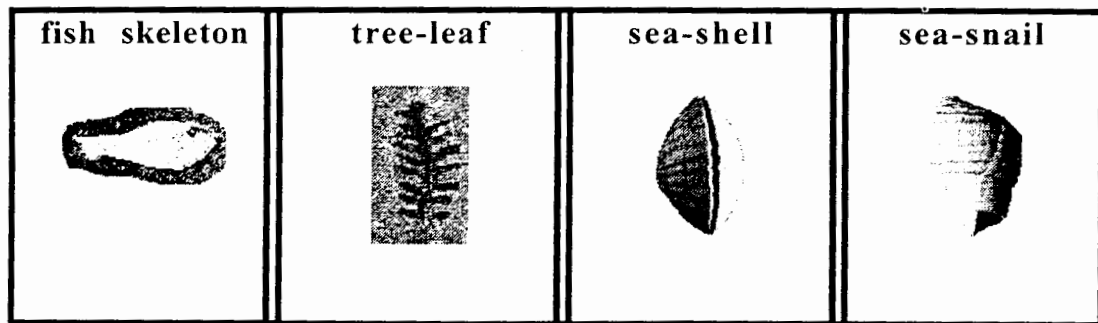
**Q.3** This fossil was given to the museum. The museum workers need your help so that they can tell visitors to the museum more about this fossil. Where could this fossil have been formed?

Put a check beside the best answer.

- ☐ in the forest
- ☐ in the sea
- ☐ in the factory
- ☐ in the landfill

The following is an example of a question that contained labeled pictures. It is Question 5 in Table 1. In the pre and post tests, the question contained colored pictures and was in a larger font size. The teacher read out the question and repeated it twice as she walked around the class.

- Q.5 Mr. E-Solver dug these fossils out of the ground and sent you drawings of his fossils. Unfortunately, he made a mistake and put in one fossil that does not belong there. Please help Mr. E-Solver. Put an X over the fossil that does not belong with the others.



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