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Three Authentic Curriculum-integration Approaches to Bird Adaptations that Incorporate Technology and Thinking Skills

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Abstract

Integration of subject areas with technology and thinking skills is a way to help teachers cope with today's overloaded curriculum and to help students see the connectedness of different curriculum areas. This study compares three authentic approaches to teaching a science unit on bird adaptations for habitat that integrate thinking skills and technology skills: a problem-based learning approach utilizing the CoRT Breadth thinking skills (de Bono, 2000); a thematic approach integrating several subject areas using *Talents Unlimited* thinking skills (Schlichter & Palmer, 1993); and a process skill-focused approach using object boxes (Rule, Barrera, & Stewart, 2004). Three third grade classes of students (N=60) of mixed ability and Spanish/English proficiency from a western rural community participated in this pretest- intervention-posttest study. Posttest scores showed all classes gained in knowledge of bird facts and adaptations, descriptive vocabulary, curiosity, technology self-efficacy, and knowledge of computer applications. Problem-based learning students showed the most curiosity (measured by questions generated for a topic-related image); thematic unit students excelled in computer application knowledge; while object box students showed largest gains in science knowledge, vocabulary, and computer self-efficacy. Integration of thinking skills allowed teachers to structure and scaffold learning in all three approaches. All three authentic approaches exhibited strengths along with challenges and are recommended. [67 references, 12 tables]

Introduction

Increasingly, teachers are asked to teach additional concepts, focus on thinking skills rather than memorization, and incorporate technology into their lessons. A strategy for accomplishing these pressing demands is to integrate several domains into one unit of study. Additionally, many teachers must address the needs of English language learners.

In the present investigation, third grade teachers at a school serving a significant number of students who were limited English proficient were asked by their school district to use word-processing, spreadsheet and database applications in their classroom instruction. These teachers collaborated with the authors, who were involved in a university technology outreach program with the school district, to produce technology-integrated science units related to bird adaptations for habitat.

The three teachers organized their units in different ways, allowing a comparison of three different approaches to teaching third graders about bird adaptations for habitat. Each unit was based on a separate approach to curriculum integration (problem-based, thematic, and object box) and each incorporated a different system of thinking skills: CoRT (Cognitive Research Trust) Breadth thinking skills (de Bono, 2000), *Talents Unlimited* thinking skills (Schlichter & Palmer, 1993), and science process skills (observation, classification, inference-making, communication, and other age-appropriate "habits of mind" as described in the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993).

This article describes results of this study exploring the three curriculum integration approaches, comparing student vocabulary acquisition under the different conditions, and the highlighting their strengths and challenges for others seeking models to integrate science with thinking skills and technology.

Review of Existing Research

Authentic Learning

Authentic learning occurs in a student–centered environment with activities that mimic or involve real-world situations that are extensions of the learner's world (Maina, 2004). Rule (2006) identified four criteria: real-world problems that engage learners in the work of professionals; inquiry activities that allow learners to practice thinking skills and metacognition (thinking about one's thinking); discourse among a community of learners; and empowerment of students to choose aspects of the investigation.

Renzulli, Gentry, and Reis (2004) have suggested that learners make an emotional commitment in addition to a cognitive attraction to open-ended real world problems, and that the results of the investigation change the actions, attitudes, or beliefs of an audience beyond the classroom. Donovan, Bransford, and Pellegrino (1999) proposed that teachers scaffold activities to build on previous learning and skills to guide learners and provide suitable resources to support exploration. Callison and Lamb's seven indicators for authentic learning (2004) included the aforementioned student-centered learning, the role of students as scientific apprentices engaged in inquiry, gathering of original data, and team collaboration, along with accessing of multiple resources beyond the school, lifelong learning beyond the assignment, and authentic assessment of process, product, and performance.

Montessori (1964) believed that student choice was an essential part of self-mastery leading to life-long learning. This same idea appears in the recommended mathematics pedagogy strategy of problem posing (Knuth, 2002; National Council of Teachers of Mathematics, 2000), where students choose their own problems and therefore feel ownership and interest in them. Hence, authentic learning appears best to occur in a learner-centered environment where students can be actively involved in lessons and have some choice in what or how they learn.

The *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) propose that students in grades three to five conduct authentic investigations in which they learn to understand their surroundings by conducting their own simple investigations working in small groups. They should observe carefully, focusing on similarities and differences in their findings, record data clearly in logs and journals, communicate their results through charts, graphs, and written explanations, and present results to others. Class discussions of findings provide the beginnings of scientific argument and debate, forming an authentic learning experience that approximates the actions of real scientists. The National Science Education Standards (National Research Council, 1996, p. 31) state, “Inquiry into authentic questions generated from student experiences is the central strategy for teaching science.” Authentic experiences must, therefore, involve students in choosing aspects of the investigation.

Incorporation of Thinking Skills

Authentic learning is supported through integrated instruction as students deliberately reflect upon and review their thinking processes (metacognition). These real-life skills appear to prepare students to become part of the workforce. For example, Moy (1999), in reviewing previous research on important workplace competencies, concluded that generic thinking skills such as collecting, analyzing, and organizing information are essential for successful workplace performance.

Thinking skill instruction can benefit students. All students, both higher and lower achieving, need and are able to improve their thinking skills through inquiry activities that incorporate appropriate cognitive exercises (Zohar & Dori, 2003). Students may not know which skills they need to function successfully in society; therefore the teacher must plan activities that will provide students with knowledge and skills. The thinking of experts differs from that of novices in that experts exhibit multiple sets of useful thinking strategies, and a mature ability to recognize patterns combined with a rich body of content knowledge (Bransford et al., 1999). Therefore, direct teaching of a system of thinking skills applied to a content area can benefit students in obtaining deeper content knowledge and mental analysis skills.

Two generic systems of thinking skills that have been used successfully with elementary students are the CoRT Breadth thinking skills (Baum, 1990; de Bono, 2000; Cotton, 1991) and the *Talents Unlimited* thinking skills (Baum, 1990; Cotton, 1991; Crump, Schlichter, & Palk 1988; Schlichter & Palmer, 1993).

CoRT Thinking Skills. Edward de Bono realized in 1970 that most people pay little attention to thinking, yet there are differences between the efficacies of different approaches to thinking. He designed the CoRT thinking skill systems for school children to help them improve their thinking. This system is used extensively in the United States, the United Kingdom, Ireland, Canada, Australia, New Zealand, Israel, Malta, and most recently, Venezuela (de Bono, 2008). These thinking skill lessons come in six sets of ten skills each, with the ‘Breadth” set being the most basic.

The Cognitive Research Trust (CoRT) Program’s set of ten “Breadth” thinking skills include PMI (determining the Pluses, Minuses, and Interesting aspects of an idea), CAF (Consider All Factors); APC (Alternatives, Possibilities, Choices); AGO (Aims, Goals, Objectives); FIP (First Important Priorities), C & S (Consequence and Sequel); OPV (Other People’s Views); Planning, Decisions, and Rules.

Talents Unlimited Thinking Skills. The Talents Unlimited model addresses students’ critical and creative thinking skills within the context of the classroom curriculum (Schlichter & Palmer, 2002). This program of thinking skills was designed to help teachers recognize and nurture children's multiple talents (Schlichter, 1996). The system of thinking skills is based on research anchored in the work of Calvin Taylor who identified high level talents in which all people excel to varying extents. Taylor based the thinking skills on the needs of employers. Each of these talents can be used to gain knowledge in any content area.

The Talents Unlimited set of thinking skills includes Productive Thinking, Planning, Forecasting, Decision Making, and Communication, which are applied to the Academic Talent - the curriculum context. Students are taught to think metacognitively about their mental process in applying these thinking skills to the integrated content. This model was used in a study of elementary students by Newman (2006), who found that students engaged in these thinking skills completed their products and produced higher quality products than a control group.

Science Process Skills. Science process skills for inquiry such as observation, classification, inference-making, measurement, communication, formulating hypotheses, planning experiments, and drawing conclusions also form a system of higher order thinking skills because they go beyond memorization and recall of information, allowing students to apply, analyze, synthesize and evaluate information and arguments (Zohar & Dori, 2003). Science process skills involve metacognition, for eample, when students distinguish between observations (which are based on information obtained through the five senses) and inferences (which go beyond observations to summarize, categorize, predict, or explain).

There are similarities between science process skills and other thinking skill systems. For example, both the Talents Unlimited thinking skill model and science process skills contain the skill of communication. Similarly, predicting effects is part of all three systems: the science process skills of hypothesizing and making predicting inferences; the CoRT skill of Consequence and Sequel; and the Talents Unlimited skill of forecasting effects of a situation.

Integrated Curriculum Units

Curriculum taught in an integrated way helps learners connect ideas to form a cohesive knowledge structure in the mind. As more connections are made between ideas, the complexity of the mind and the student's learning increases (Brooks & Brooks, 1993; Sunal, Sunal, & Haas, 1996; Sunal et al., 2000). Students taught through interdisciplinary or integrated curriculum units perform on standardized tests of achievement as well as or better than students taught through conventional subject-compartmentalized programs (Arhar, 1997; National Association for Core Curriculum, 2000; Vars, 1996, 1997).

There are many different possible approaches to curriculum integration units. In this study, we considered three: a problem-based learning approach that focused on the problem of enhancing a bird habitat, a content-and-skills-based thematic unit focused on bird adaptations, and an approach using sets of manipulative materials (object boxes) for learning science concepts of bird adaptations, based on Montessori Education ideas.

Problem-based learning. Savery (2006, p.12) described problem-based learning as "an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem." Problem-based learning has several unique characteristics (Barrows, 1985; Stepien & Gallagher, 1993). It relies on a real-world problem to drive the curriculum, allowing students to develop skills as they investigate its various aspects. Ill-structured inquiries are chosen so that as information is gathered, the problem evolves. The teacher acts as a coach who facilitates the problem-solving process, allowing the students to arrive at their own unique solution. The final assessment is the solution to the problem, in this case, the bird habitat, which is a performance-based assessment.

Problem-based learning has been shown more effective than traditional lecture-discussion methods for both typical and gifted students (Hmelo-Silver, 2004; Mergendoller, Maxwell, Bellisimo, 2006) and useful in helping students develop empathy for peers with special needs (Belland, Ertmer, & Simons, 2006). Integration of CoRT thinking skills is an effective way to provide some structure to a loosely defined problem and support learners engaged in problem-solving science inquiry (Rule & Barrera, 2006).

Thematic Units. "Thematic" units have been interpreted with many meanings in the literature, but generally are based on "relevant topics selected by the children and teacher, which allow the teacher to integrate subject matter into meaningful activities (Vartuli & Rohs, 2006, p. 235). "By focusing student learning on the connections among traditional subject matter categories using major unifying themes, students can grasp relationships, see more of the big picture, and learn to make sense of the world" (Ignatz, 2005, p. 39). Authentic literature and literacy activities play a strong role in thematic units (Meinbach, Rothlein, & Fredericks, 1995). The thematic unit employed in this study was a "content and skills integrated unit" (Sunal, et al., 2000, p. 41) that combined science content on bird adaptations with authentic literature (non-fiction trade books on birds), Talents Unlimited thinking skills, mathematics, technology skills, and social studies.

Object Boxes. Montessori (1964) first used object boxes (a set of objects and corresponding cards housed in a box) for successfully teaching reading/writing skills. Montessori noted (1966, p. 82), "In order to develop his mind, a child must have objects which he can hear and see. Since he must develop himself through his movements, through the work of his hands, he has need of objects for his work that can provide motivation for his activity."

Several types of science object boxes have been shown effective in teaching science vocabulary and science concepts to elementary students Descriptive adjective object boxes contain cards that show four or more descriptive adjectives that correspond to one object in the box; students make observations of the objects to match them with their corresponding cards (Rule, 1999; Rule, Barrera, & Stewart, 2004). In an object box focused on words with multiple meanings, students find objects that represent everyday and scientific meanings of a word, and then place definitions next to them to complete the layout of materials (Rule & Barrera, 2003; Rule, Graham, Kowalski,

& Harris, 2006). In working with object boxes for exploring form and function analogies (Rule, Baldwin, & Schell, 2008; Rule & Barrera, 1999; Rule & Furletti, 2004; Rule & Rust, 2001), a student reads about the form and function of an animal body part or human system part and finds a manufactured item with a similar form and function. Science process skills are the natural accompaniment to an object box-based unit because they are an integral part of completing the activities.

Standards Related to Bird Adaptations for Habitat Units for Third Graders

Standards for science learning, defined by national organizations, delineate concepts, skills, and dispositions important for students to acquire. The National Research Council, author of the National Science Education Standards (1996), suggests, in their unifying concepts and processes standard, educators use, among other themes, the theme of form and function. The topic of bird adaptations for different habitats fits with this theme and was therefore chosen as the focus for the integrated science units for third grade students. The Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) state that in grades three through five, students should explore how organisms satisfy their needs in the environments in which they are found. A science unit centered on bird adaptations for habitat assists students in achieving this goal. "Bird adaptations for habitats" was also part of the third grade state science curriculum for students in the school at which the study took pace.

Technology Integration

Two types of barriers exist for teachers to integrate technology into instruction: external barriers such as having equipment and the skills to operate it, and internal barriers such insufficient pedagogical models for integrating technology into other subject areas (Ertmer, 1999). A national survey ten years ago (Jostens, 1997) indicated that computer technology had produced a large impact on classrooms, but mostly with regard to students accessing information through the Internet and improved student motivation, rather than on instructional use. In a meta-analysis of the value and use of educational technologies in K-12 instruction, Valdez and others (2001) found a strong connection between appropriate teacher use of technology and increased student achievement. Earle (2002, p. 10) finds, "We must weave technology into the fabric of learning." Appropriate models of technology integration are needed to help teachers envision the role of technology in instruction. This article provides three such models.

Vocabulary Development

Extensive vocabulary is positively related to overall scholastic achievement of students (Dobb, 2004). For example, science texts contain a proliferation of introduced vocabulary, often more new words than are introduced in texts for learning foreign languages (Groves, 1995; Yager, 1983), making the comprehension of these texts challenging to many students. However, vocabulary and language use during hands-on science activities naturally follows the use of science process skills in observing, classifying, making inferences and communicating ideas and can provide opportunities for English learners to practice and acquire new language (Dobb, 2004). Descriptive words in particular are needed to communicate science observations and make comparisons. Because observations through the senses are the primary way humans acquire information about the world, and because words are needed for mental processing of ideas (Vygotsky, 1989) descriptive vocabulary skills form a foundation for science learning. In this article, we examine the increase in students' descriptive vocabulary after participation in the different lesson approaches.

Purpose of the Investigation

The purpose of this investigation was to determine the relative strengths and challenges found in implementing three different authentic learning models on bird adaptations to their habitats with integrated thinking skills and computer technology use to provide effective models for teachers. Therefore, we compared the pretest-posttest performances of students in each instructional condition with regard to science fact and concept acquisition, vocabulary development, computer technology skill improvement and growth of curiosity, an important disposition in science learning (Tolman, 2002; Martin, Sexton, Wagner, & Gerlovich, 1997). We also noted teacher observations recorded in journals during the study and comments made by teachers in a discussion of the study after its completion.

The current study adds to the existing research on problem-based learning, thematic unit instruction, and object box-based instruction by comparing these three authentic methods of science instruction that had integrated thinking skills and technology use. Most research to date has focused on comparing authentic methods to more traditional lecture and discussion methods rather than comparing two or more authentic approaches.

Method

Participants

Three third grade classes of students of mixed ability and Spanish/English proficiency and their teachers from the same elementary school in a rural farming/ranching community in the western United States participated in the study. Teachers and classes were randomly assigned to one of three approaches. All three teachers were experienced educators (all had over eight years of teaching experience) with similar intermediate levels of computer competency, having volunteered for two years to be part of a technology study group with the authors and having passed the state test of computer competency for teachers. Prior to this study, these teachers typically taught science through reading and worksheet exercises rather than hands-on activities. Teachers met weekly with the authors to discuss their approaches and to ensure correct implementation.

Demographics of the student population are shown in Table 1. Sixty students participated in demographically similar classes, Class A (n=21), Class B (n= 22), and Class C (n=17). Each class had representation from students who were from migrant families, qualified for special education services, and had limited English proficiency. The large majority of students were identified as "low income", defined as participating in Title 1 and/or free lunch programs.

Table 1.
Demographics of the Sample Population

Class	Gender		Race/ Ethnicity		LEP	Migrant	Low Income	Special Education
	Female	Male	White	Hispanic				
A	11	10	12	9	5	5	15	3
B	10	12	16	6	4	2	19	2
C	8	9	9	8	3	3	9	2
Total	29	31	37	23	12	10	34	7

Instructional Conditions Focused on Authentic Learning

The three conditions for learning (problem-based learning of enhancing a bird habitat at the school, the thematic unit on bird adaptations, and the object box-based instruction on bird adaptations) are summarized in Table 2. All three approaches can be classed as authentic learning experiences, as they were student centered, involved students in the work scientists do, practiced inquiry and thinking skills, required collection of original data, involved students in discussions as a community of learners, allowed choice, engendered emotional commitment of students, and affected an audience beyond the classroom. The three classroom teachers collaborated with the authors to define the activities for each approach and to ensure that each approach taught bird adaptations for habitat science concepts.

Problem-based Learning Unit. Students working on the problem of enhancing bird habitat gathered information about the experiences of members of the community with local birds, tabulating and graphing it. They found print information in books and on the Internet about birds' adaptations /needs and carefully planned a habitat for their bird of choice. The CoRT thinking skills helped scaffold their learning by providing a structure for approaching the various parts of the problem. For example, AGO (Aims, Goals, and Objectives) was used to generate possible goals for the bird habitat and FIP (First Important Priorities) was used to help students determine the best goals. Students worked in teams at the classroom computers. Their emotional commitment of making the best habitat at the school for hummingbirds (the final project choice) was evidenced by their willingness to bring materials from home, their care in decorating the hanging flower baskets, their careful consideration of the rules for other school children using the habitat area, and their interest in having a record of observations of birds visiting the habitat. The class presented a slide show of photographs of the habitat to the school, their list of rules for visiting their enhanced hummingbird habitat, and invited other classes to enter information in their record book of bird observations.

Table 2
Major Components of the Three Curriculum Integration Approaches

Class and Approach:	A. Problem-based	B. Thematic	C. Object Box
Major Product	A bird habitat at school planned and created by students.	A class book of detailed information about local birds and their habitats.	Papier-mâché sculptures of new birds invented to ideally fit a chosen habitat.
Major Activities	Step-by-step choice, planning, and implementation of a bird habitat at school.	Integration of science with reading, language arts, mathematics, and social studies through study of local bird populations and habitats.	Investigation of bird adaptations and habitats, focusing on science process skills through activities with collections of objects and cards.
Technology Skill Integration	Create a database of birds identified as beneficial.	Create a database of characteristics and behaviors of locally observed birds.	Create a database of bird adaptations.
	Create a survey. Make a spreadsheet of survey results.	Create a spreadsheet of bird counts at different local habitats.	Create a spreadsheet for making graphs of data from box activities.
	Use software to create an ecology web of interconnections among organisms in a specific habitat.	Create a map of local bird habitats on a digitally-scanned base map.	Create a database of descriptive vocabulary for each of the boxes. Add extra vocabulary words to the database.
Thinking Skills System Emphasized	CoRT Breadth Thinking Skills	Talents Unlimited Thinking Skills:	Science Process Skills

Thematic Unit. Students using a thematic approach conducted bird counts, made observations of local birds, and mapped local bird habitats, compiling and summarizing their work in a class book. The Talents Unlimited thinking skills helped students approach different aspects of their work (e.g. choosing birds, planning the class book, and writing about emotional responses to birds) in a step-by-step structured manner that allowed the teacher to scaffold learning. Students worked as teams at the classroom computers and the class discussed ideas, making decisions about the nature of the final class product related to this unit. Each student chose a local bird on which to focus and created several unique pages of information, poetry, and artwork for the class book, using library books, Internet resources, and information pamphlets from a local birds of prey nature preserve. Several of the talent activities focused on emotional reactions to birds, during which students revealed their commitment to appreciating birds and preserving bird habitats. A slideshow of the maps of local bird counts and digital images of pages of the classroom book were presented to the school during an assembly and the book was loaned to other classes for use as a model class product.

Object Box Condition. Students in the object-box condition used analogy to relate bird adaptations to human tools, used process skills of observation, classification, and inference-making to study bird nesting materials and nest types from different habitats, identified bird foods, explained a variety of bird dangers, and noticed the correlation of placement of bird eyes for peripheral or binocular vision with the bird's status as predator or prey. Process skills were explicitly taught during the unit and applied to the activities. Students used library texts and Internet resources to find out more information about birds. They created databases of bird adaptations and bird related vocabulary, graphing results for different birds. The culminating projects of individually creating a model of an ideal bird adapted to a chosen habitat as a papier-mâché bird in a diorama were presented to other school children as a display in the school cafeteria.

Experimental Procedure

This study was a pretest-intervention-posttest design study in which three different authentic curriculum integration approaches were compared to determine relative strengths and challenges. Student performance in bird habitat content knowledge, curiosity, descriptive vocabulary acquisition, technology self-efficacy, and technology knowledge were measured using a multi-faceted instrument, described in the next section.

The pretest allowed teachers to assess student understandings of birds and bird adaptations for habitat to better design the unit instruction. For example, the pretest showed that students knew very little about bird vision, foods, territories, camouflage, and defense; teachers decided to incorporate these ideas into lessons and discussions. The teacher for the problem-based unit asked students to consider bird foods, homes, and defense mechanisms when discussing different birds. The teacher for the thematic unit found trade books about birds that addressed these topics and read them to her class. The teacher for the object box approach suggested object boxes that focused on bird nesting materials and sites (territories, camouflage, and defense) along with bird foods so that students would become familiar with these concepts. Teachers also examined student questions about the bird photographs to gain insights into student interests. They incorporated these ideas into the lessons, using this foundation to build bridges to new understandings (Duckworth, 1995).

Instrumentation

Assessment questions for all parts of the pretest/posttest are shown in Table 3. Pretests and posttests were administered to students approximately seven weeks apart with the intervention using the three approaches being conducted in between. Two similar versions of the pretest/posttest were produced, differing only in the pictures and objects to which students responded. Every other student on each class roll was given version A as a pretest and version B as a posttest. The remaining students were given the opposite versions. The teachers read all test questions to the students several times to minimize differences in performance caused by reading skill levels.

Question 1: Students' Knowledge of Bird Adaptations. This question was open-ended and criterion-referenced to the main objective of the unit, bird adaptations for survival in habitat.

Question 2: A Measure of Curiosity. A standard measure of curiosity is to present students with an image and request them to ask as many questions as possible. This method is used on the “Thinking Creatively with Words Verbal Test” by Torrance (1992). We presented students with photographs

Table 3
Questions on the Pretest/Posttest

Science Content, Curiosity, and Vocabulary Questions	
1.	Tell everything you know about how birds' bodies and ways of living help them survive in the places they choose as their homes.
2.	Ask as many questions as you can about the picture [Version A: photograph of sandpipers and other shore birds with long beaks wading in water and dipping their beaks, with some vegetation shown; Version B: a photograph of two adult egrets with two hatchlings in the nest]. Write all the questions here.
3.	Use as many words as you can to describe each object. [A set of three of the following objects were given, Set 1: flat glass marble, piece of Styrofoam, toy plastic lobster; Set 2: metal car key, spherical ornament, toy plastic frog.]
Self-Efficacy Technology Questions	
1.	I use Microsoft Works Database (circle the best answer): a) never b) with a lot of help c) with a little help d) all by myself
2.	I use Microsoft Excel Spreadsheet (circle the best answer): a) never b) with a lot of help c) with a little help d) all by myself
3.	I use Microsoft Word (circle the best answer): a) never b) with a lot of help c) with a little help d) all by myself
4.	I use Jostens Concept-Mapping (circle the best answer): a) never b) with a lot of help c) with a little help d) all by myself
5.	I use PowerPoint Presentation Software (circle the best answer): a) never b) with a lot of help c) with a little help d) all by myself
Technology Knowledge Questions	
6.	Below is a chart of birds found in different places. Which computer program would you use for comparing the total number of birds in each place? [Tally chart provided.] a) Microsoft Works Database b) Microsoft Excel Spreadsheet c) Microsoft Word d) Jostens Concept-Mapping e) PowerPoint Presentation Software f) I don't know.
7.	Below is a chart of information on different birds. Which computer program would you use to keep a collection of bird notes? [Chart provided showing physical characteristics of birds.] a) Microsoft Works Database b) Microsoft Excel Spreadsheet c) Microsoft Word d) Jostens Concept-Mapping e) PowerPoint Presentation Software f) I don't know.
8.	If your teacher asked you to write a story, what program would you use? a) Microsoft Works Database b) Microsoft Excel Spreadsheet c) Microsoft Word d) Jostens Concept-Mapping e) PowerPoint Presentation Software f) I don't know.
9.	If you want to draw circles, use clipart, and label with big titles, what program would you use? a) Microsoft Works Database b) Microsoft Excel Spreadsheet c) Microsoft Word d) Jostens Concept-Mapping e) PowerPoint Presentation Software f) I don't know.
10.	Which program will help you make a web to connect ideas? a) Microsoft Works Database b) Microsoft Excel Spreadsheet c) Microsoft Word d) Jostens Concept-Mapping e) PowerPoint Presentation Software f) I don't know.

of birds in the natural environment to stimulate their questions.

Question 3: Vocabulary Development. Students were asked to write descriptive words for three given small objects of widely varying physical characteristics to assess students' descriptive vocabularies. These objects were: set1) a pearly, green Styrofoam s-shaped pellet, an ovoid red glass flattened marble containing air bubbles, and a colorful plastic toy lobster; set 2) a square-ended silvery metal car key, a green plastic toy frog, and a multi-colored hollow spherical ornament. This

Technology Self-efficacy The technology portion of the pretest/ posttest instrument asked students to rate their skill levels on different computer procedures Self-efficacy (an individual's beliefs about competency in some area), a measure first developed by Bandura (1986), when applied to computer technology, has been found to influence individuals' expectations of the outcomes of using computers, their emotional affect and anxiety regarding computer exercises, and their actual computer use (Compeau & Higgins, 1995).

Knowledge of Computer Applications Questions. The second set of technology-related questions asked students to determine the appropriate computer application for various tasks, a criterion-referenced assessment. This bird adaptation unit was the first experience students had with using computers at school for anything other than drill and practice games for reading and mathematics or simple word processing of paragraphs. Although several computer applications might be used to accomplish several of the described tasks, students used each software application only for its main purpose. For example, students could have made a table in Word to collect bird counts, but these were instead collected in an Excel spreadsheet because that software was designed for data manipulation. Therefore, the typical use of each software application was being sought as a correct response on the test instrument. same assessment was used with third graders at two Southwestern Idaho schools in another study (Rule, Barrera, & Stewart 2004).

Limitations of the Study

An important limit to the generalizability of the study is that only three classrooms were investigated for just one unit of instruction for a seven-week period. Although the teachers had similar levels of teaching experience, science knowledge, and technology skills, it is difficult to discern the effect of individual teachers' styles and personalities on student performance. Similarly, although the three classes of students drew from the same population, there were differences owing to student individuality. Finally, the results of this study apply specifically to the treatments as they were applied and not to the individual components in other combinations or settings.

Results

Problem-Based Learning Approach

The teacher and students of Class A engaged in problem-based learning with all activities contributing to their objective of creating an enhanced habitat at the school for a bird of choice. The CoRT Breadth thinking skills guided this project as detailed in Table 4.

Students used the CoRT Breadth Thinking Skills to help them determine the best bird habitat to enhance for the school. The following teacher's notes show how the students used the PMI Skill of rating ideas of different possible habitats as "Plus," "Minus," or "Interesting," to determine the best one for their school:

> April 22nd. The class ran out of time to complete the lesson

yesterday. So today we did a P.M. I. on the different kinds of habitats to figure out which habitat would be the best one for our school. The first habitat we rated was the wetlands. The plus side was we would be able to have the ducks, geese, and so on. The minus part was the absence of a lake or river nearby our school. Interesting part was the observation of ducks but only flying by. The next habitats we discussed were the rain forest, high mountain areas, desert, and arctic areas. For each habitat we discussed Plus, Minus, and Interesting points. The class finally realized that the best habitat would be a rural, farming, country area similar to our school, and that the birds found in this particular habitat would be the best for us.

Students created a spreadsheet of survey data and a database of birds that they viewed as beneficial to humans in their area. They also used computer software to make a web of the interconnections between hummingbirds and other organisms in the habitat to help in solving the problem.

The teacher's major challenge was planning for this open-ended problem and resisting shortcutting student decisions. Because she did not know the final outcome of the problem, it was difficult for her to envision the necessary lesson activities several days hence. Lehman, George, Buchanan, and Rush (2006) in analyzing results from a four-year professional development program for teachers implementing problem-based learning, noted that teachers improved in allowing students to determine the activities as the years elapsed. Ertmer and Simons (2006) discussed three major challenges teachers face when initiating problem-based learning: creating a culture of collaboration and independence, adjusting to changing roles, and scaffolding student learning. Rule and Barrera (2006) show in detail how the CoRT Breadth thinking skills structures helped the teacher organize and provide a framework for student inquiry and how the examination of other people's views (OPV), consideration of all factors (CAF) and projections of consequences and sequels (C&S) in particular, helped build a collaborative atmosphere. Interjection of the thinking skills at the appropriate points helped the teacher scaffold student learning.

Thematic Approach

The thematic approach taken by the teacher and students of Class B involved an integration of different subject areas through the theme of bird adaptations and habitats. See details in Table 5. Students researched local birds through books and the Internet, and then each student wrote a report about a specific bird, which was incorporated into the class book, among other items, thereby combining reading and language arts. Students created a table of contents and glossary of terms for the book, along with compiling an extensive list of bird-related compound words. They matched pictures of birds showing body parts highlighted in red with terms and descriptions to develop vocabulary. Later, students wrote poems about birds and illustrated them with sketches and other artwork (art incorporation).

Table 4

CoRT Thinking Skill System Guides the Problem-based Learning Unit for Class A

CoRT Thinking Skill	Activity	Example Responses
PMI: Plus, Minus, Interesting	Brainstorm all of the birds known to live in our area. Ask parents and neighbors to suggest additional birds. Do a PMI on the idea of creating a bird habitat at school for most frequently cited birds.	Crow: Plus- Probably could attract crows- crows eat almost anything; crows are tame; crows are large and easy to see; some people have talking crows for pets – they are intelligent. Minus: Crows are noisy; nearby farmers may object to providing a habitat for crows since they eat crops; some people think crows symbolize evil. Interesting: maybe if we study crows closely, we will get to like them. Hummingbird: Plus: beautiful; interesting to watch; some are rare or endangered – it would be good to help them; most people like them. Minus: They are shy – we might not see many of them; feeders with sugar water can give hummingbirds diseases; Interesting: We might discover something new others did not know about hummingbirds. Maybe it won't matter that we seldom see them if our habitat provides a beauty spot.
CAF: Consider All Factors	Consider all the factors involved in choosing the type of birds for whom a habitat will be built.	Will our class be interested in watching these birds? Will these birds actually come and use the habitat? Will nearby farmers or residents object to us attracting these birds? Will the birds create a mess for the custodian? Will the birds distract other classes from their work? Are these the kinds of birds we want to encourage and support in our area? Can we realistically meet their needs at our school?
APC: Alternatives, Possibilities, Choices	Generate all the possible choices for a bird habitat.	Symmetrical plantings of flowers or bushes the birds like Enhancement of an existing natural area with additional plantings, bird bath. Series of birdhouses. Series of bird feeders. Create a nature walk through a natural area that we "clean up" and enhance.
AGO: Aims, Goals, Objectives	Determine all possible goals of the bird habitat.	Provide shelter, food to a specific bird Educate students at the school about birds Provide a model that families may duplicate at home Beautify the school grounds Provide a place for quiet contemplation Provide a place for bird observation Provide data for research on birds
FIP: First Important Priority	Prioritize the three most important goals listed above.	1. Educate students at the school about birds 2. Provide shelter, food to a specific bird 3. Beautify the school grounds
Decisions	Decide the type of birds for whom the habitat will be designed and the type of habitat.	Our class chose hummingbirds because they are beautiful and no one would object to us helping them. We want to plant beautiful flowers that the hummingbirds would like rather than have feeders. The plantings will beautify our school.

Table 4 Continued

CoRT Thinking Skill	Activity	Example Responses
CAF: Consider All Factors	Consider all factors involved in building the habitat.	We need money to buy materials or need donated materials We will have to research the needs of the birds Our habitat must look nice Our habitat must be easily maintained We must consider safety during construction We must consider how much time it will take – we have other schoolwork to do.
C&S: Consequence and Sequel	Think of the immediate, short term, medium term, and long term effects of the bird habitat project.	Immediate effects: Pride in our work, satisfaction that we did it ourselves, praise from teachers and parents, joy of watching the birds, other classes enjoy our habitat Short term effects (1-5 years) Next year's class adds to and improves the habitat, or, it becomes weathered, forgotten and an eyesore. Medium term effects: (5-25 years) Our school has extensive habitats for birds and other wildlife, or, nothing – it is forgotten, or some of the kids who worked on it become ornithologists. Long term effects (> 25 years) Our school has a big student-built greenhouse with birds all flying around in it.
OPV: Other People's Views	Consider the point of view of others toward the proposed bird habitat.	The Principal's view: Will this beautify our school? Is it a valuable learning experience for students? The class's view: Will it be worth all of the hard work? Will enjoy waiting and watching for hummingbirds Other class's views: Might be jealous that they didn't get to make one. Might enjoy looking at our habitat. The custodian's view: Might worry that he will have to maintain it or clean it up. Nearby farmers' views: Not concerned about hummingbirds eating their crops Nearby residents' views: Probably would like it- probably like hummingbirds Parents' views: Proud of kids' accomplishments; concerned that they will have to contribute when they don't have time to help.
Planning	Plan the design and construction of the bird habitat.	We will research favorite flowers of hummingbirds. We will have hanging "baskets" of flowers. We will make the "baskets" from recycled milk jugs that we cut into basket shapes. We will use acrylic paints to decorate the baskets. Parents will donate potting soil and plants for our baskets. We will also plant flowers that hummingbirds like along the front sidewalk of the school outside our classroom window. Our class will be divided into 5 groups – each group will make a basket. We will hang the baskets outside our classroom window on hooks. We will keep a journal of observations about our habitat.
Rules	Create a set of rules for people who visit the habitat.	Please be quiet. Stay on the sidewalk. Don't pick or touch the flowers. Report any problems to our teacher. Don't disturb the hummingbirds. Please tell our teacher if you do see a hummingbird. Please enter your observations and comments in our hummingbird habitat journal.

Table 5

Integration of Talents Unlimited Thinking Skills into a Thematic Unit for Class B.

Talents Unlimited Thinking Skill	Bird Adaptation to Habitat Concepts Guiding Questions	Activity
Productive Thinking: Key words: many, different, unusual, add details.	What birds are local to our area?	List all the birds that students can name (*many* birds). Think of birds from *different* categories (water birds, song birds, large birds, brightly colored birds). Think of *unusual* birds. Choose from this list the birds that live in our area. What do you know about these birds (*add details*)?
	What characteristics do these birds have? How are different bird species and genders distinguished?	List all of the observations you might make about a bird (*many* observations). Can you combine some of these ideas into *different* categories? What other observations might fit into those categories? Examples: Category of physical appearance: color, beak type, feather ornaments; Other categories: where birds sit, food, unusual behavior, typical behavior, sounds made. What *unusual* observations might you make? Examples: time bird stays in one place, bird silhouettes. Can you tell more *details* of a particular observation?
Planning	What different habitats are in our area? What birds live in the different habitats? Why do birds with specific characteristics prefer certain habitats?	What: Planning the Data Collection Materials and Equipment: Data collection booklet, bird guide Steps(in order): 1. Have students help determine different local habitats. 2. Write a letter to parents explaining assignment. 3. Make the data collection forms with local birds on them (woodpecker, owl, swallow, hummingbird, robin, crow, magpie, sparrow, pheasant, Canada goose, hawk, quail, finch, mallard, grouse). 4. Make a field guide to local common birds for student to use. 5. Collect bird count data over 2-week period. 6. Create a database of local bird characteristics. 7. Put bird count data into spreadsheet. Analyze data. 8. Present findings to class. Improvements to the Plan: The list of birds was determined and added.
Communication Talents #4, #2	How do humans interact with birds?	Students tell personal experiences about bird observations. Students list as many emotional adjectives as possible to describe their perceived feelings of birds. Examples: hungry, tired, hopeful, happy, cheerful, proud, protective of babies, patient.
Forecasting Causes and Effects	How do humans affect bird habitats?	Examine environments to find dominant birds and forecast causes why these dominant birds prefer the identified environment. Forecast the effect on bird of changes in the environment such as pesticides, electrical wiring, clear-cutting, farming, noise, or new construction.
Decision Making	How can we inform others of our investigation?	What: Decide how the bird book should be produced. Alternatives: single class book, individual books, personalized and modified class books. Criteria: Will we have something to show to other classes that is impressive? Will we have something to take home? Do we have enough materials? Would it involve working together? Weighing: Students rated each alternative according to each criterion. Decision: Students decided to make a large class book. Reasons: This alternative scored well with all the criteria.
Communication Talents #1, #3, #5, #6	How can we communicate our feelings about birds?	In preparation for writing poetry, students listed as many descriptive adjectives as possible related to the bird of their choice. Students made many comparisons in the form of a simile regarding their birds. Student then wrote bird poems and illustrated them with artwork.
Productive Thinking	How can we represent our findings on a map?	List as *many* possible map features as you can. Group these into *different* categories (water features, land features, human features). Think of *unusual* features (places of bird sightings). Choose the features we want on our map and draw them on the map, *adding details*.

As an integration of mathematics, students went to different local sites (backyard, park with trees, river area, farm field, and school) on their own as homework and with classmates during school time to make a tally chart of the number of birds sighted during ten-minute intervals. These observations were combined on a spreadsheet. Students sorted data, then investigated graphs and spreadsheet functions such as sums. Here is an excerpt from the teacher's journal about the first day of data collection:

> We discussed the directions for using the journals and collecting data. Then we found the schoolyard environment and went outside to practice collecting data. We actually went into the fields around the schoolyard and began looking for birds. It was amazing how excited the children became. We noticed that some of the birds were far enough away that we had trouble identifying the birds. Some of the children guessed. (I suggested they use binoculars if they have them at home). Our time was limited so I had a little trouble bringing them back to the classroom. That is good! We are READY!

Social science mapping skills were incorporated by students marking sightings on a map and coloring in areas of different bird habitats. Many of the thematic activities were organized around *Talents Unlimited* thinking skills as shown in Table 5.

Students learned content about bird body form and function as they investigated local birds and their environments. They practiced skills in data gathering, organizing, processing and communicating as they conducted their investigations and prepared pages for their bird book. The *Talents Unlimited* thinking skills helped the teacher structure many activities in such a way that students had ownership of the work through generating ideas, making decisions, and planning activities.

The challenge for the teacher using the thematic approach was to find meaningful ways to integrate several subjects. Integration of mathematics is often difficult, but in this case, the data collection, spreadsheet use and graphing supported the theme while exercising inquiry and mathematics skills. Another challenge was to help students produce a product that had meaning beyond their own classroom. This requirement was satisfied by making a class book that was shared as an example with other classes and presenting their process through an electronic slide show to the school during an assembly.

Object Box Approach

This hands-on approach taken by teacher and students of Class C centered on activities with several carefully planned sets of materials. Each "object box" consisted of a group of items and corresponding cards for matching or sorting. Details of the contents of object boxes used in this study are shown in Table 6.

The object boxes focused on birds’ adaptations to their environments. Students explored nesting materials, environmental dangers, foods, eye position (e.g. binocular), and beak and foot types. They made a database of bird adaptations and a database of descriptive vocabulary gleaned from the object box cards. Students made a bar graph of the number of familiar birds the class named that could be classified as predators or prey by eye position. They also made bar graphs of numbers of familiar birds with different foot types. Students engaged in the object box activities practiced science process skills of making observations, classifying things, making inferences, and communicating ideas through descriptive vocabulary and graphs.

Table 6
Object Boxes Related to Bird Adaptation or Habitat Concepts and Integrated Science Process Skills used in Unit for Class C.

Concept Category and Process Skills	*Objects in Box*	*Activity*
Observations of physical properties of materials. Inferences about shelter and availability of materials.	Nesting materials Photographs of nests and their environments.	Match nest materials with photos of nests. Discuss the properties of the materials that make them good nesting materials for birds. Discuss the environment where each nesting material is found.
Classification of different types of bird dangers. Inferences of problems posed by different objects or situations.	Toy models of humans, cars, animals, planes, wires, pesticides, house (encroachment)	Match each object (buildings, car, plane, pesticides, fox, dog, cat, snake, hawk, hunter, electric wire, balloon, chewing gum, six-pack plastic holder, oil slick, snowflake, icicle) with a bird danger term (encroachment, collision, pollution/ poisoning, sport, predation, choking, electrocution, drowning, freezing to death) Tell how each object threatens birds
Observations of bird bones.	Bird bones Diagrams of bird skeletons	Match the bone to a plan view drawing of a bird skeleton
Observations and inferences related to bird characteristics	Non–realistic birds characters and statues	Identify the characteristics that have been exaggerated or simplified in each bird figure.
Observation, classification, and inference making related to food sources.	Plastic models of different bird food items	Match photo of bird to typical food type
Observations and inferences related to anatomical adaptations.	Drawings of bird beak types; human tools	Match to a human tool that does the same job.
	Drawings of bird foot types; tools and footwear	Match to human tool or footwear that accomplishes same task
	Drawings of bird eye position types; bird statues.	Sort birds by eye positions as predator (binocular) or prey (near 360 degree peripheral vision)

Students in this condition engaged in several self-motivated investigations via reference books and the Internet of additional birds that shared the characteristics highlighted by object box activities. At several points, animated discussions between groups of students occurred in the classroom with children excitedly making claims and countering the claims of others with evidence from books and Internet sites. For example, students wondered whether robins, which hunt and eat worms but have eyes on the sides of the head for peripheral vision, should be classed as predators or not. An excerpt from the teacher's journal shows another part of this discussion:

> April 27th. We spent 30 minutes in class opening the predator/prey box. We made a chart on the wall and listed the items from the box... Students defined predator and prey.... Each team added birds to the wall chart. One team got in an argument about a flamingo being a predator so now they want to prove their point... They have spent three days browsing information to prove their theory...
>
> April 28th. Today some students found that a flamingo is not a predator... I have been getting positive feedback from other teachers, aides, and even the school counselor how excited my students are about what they are doing....
>
> April 29th. I now have another team of students who have added themselves to the great debate because they found a picture that actually shows the kingfisher diving for fish and they want to add the kingfishers to the predator list....
>
> May 5th. We had Cinco de Mayo celebration so we read and discussed a book about hummingbirds. The students were shocked to find that hummingbirds spear insects with their beaks... Questions were generated. "Are hummingbirds predators?" "Should we look closer at definitions of predator and prey?" "How does the eye position influence this definition?" "Should we start other classifications of omnivores, herbivores, carnivores, insectivores on the chart?"

Therefore, although the object box activities introduced topics and guided students' work with the materials, students used these as springboards to apply newly learned concepts to birds with which they were familiar and birds they were reading about. Finally, the culminating activity of creating a papier-mâché model of an imaginary bird ideally suited to a chosen habitat required students to synthesize and apply the knowledge they had gained from the object boxes.

A major challenge for the teacher of the object box group was preparation of and management of materials. The authors helped in providing many of the object boxes. Over a period of several years, a large collection of resources can be built. Teachers using concrete objects need to prepare students to respectfully handle them that many classes can enjoy the work put into their production. Involving students in adding to the collection helps develop students' appreciation for the materials.

Pretest - Posttest Results and Discussion

Question 1: Students' Knowledge of Bird Adaptations

Students in all three classes scored similarly on the pretest, writing an average of about 10 or 11 bird facts and 2 or 3 statements of bird adaptations (See Table 7). Examples of the most commonly written bird facts included 1) birds have wings, feathers, beaks, heads, eyes, claws and legs; and 2) birds fly, eat worms, build nests, lay eggs, and live in trees. The most frequent responses of bird adaptation statements (occurring eight or more times) are shown in Table 8.

Table 7
Mean Pretest and Posttest Results for Question 1

Class	Approach	Number of Simple Bird Facts Written			Number of Bird Adaptations for Survival Written		
		Pretest	Posttest	Gain	Pretest	Posttest	Gain
A	Problem-Based	11.5 (5.2)	15.4 (7.7)	3.9 (7.9)	2.1 (2.4)	5.4 (3.5)	3.3 (3.3)
B	Thematic	11.3 (6.2)	16.6 (7.8)	5.3 (9.0)	3.0 (2.4)	5.4 (4.0)	2.3 (4.7)
C	Object Box	9.7 (4.8)	18.0 (8.8)	8.3 (10.5)	1.7 (1.9)	8.3 (5.1)	6.6 (5.5)

Note: Standard deviations are shown in parentheses
.

All classes exhibited growth on the posttest in numbers of bird facts and bird adaptation statements. Students mentioned adaptations associated with the most stereotyped characteristics of birds on the pretest: wings, eggs, babies, beaks, nests, feathers, and claws. On the posttest, students in all three classes widened their understandings of birds, learning new concepts such as binocular and peripheral vision, camouflage, territories, human influences, predators, food sources, and defense.

Class C, the object box group, scored highest on posttest question 1 and made the largest gains. The object boxes were particularly effective in highlighting bird adaptations, most likely because of the concrete materials and the way the teacher used spreadsheet and database lists to motivate students to add to the information. Students continually sought additional birds who were predators or who had certain foot or beak types, thereby practicing and applying the information. Cohen’s effect size, *d*,(1988) using pooled standard deviations (Rosnow & Rosenthal, 1996) for the gain scores for number of bird facts written by students in the object box group compared to the problem-based learning group was d = 0.47, a medium effect size. The effect size for the object box group compared to the thematic group was smaller, with d =0.31. Effect size for the number of bird adaptation statements made of the object box group compared to the problem-based learning group was d = 0.73, and the object box group compared to the thematic group was d = 0.84, both large effect sizes.

Table 8

Most Frequent Student Responses and Number of Students Making Each Response to Question 1 on the Pretest and Posttest

Bird Adaptation Statement	Pretest				Posttest			
	Class			Total	Class			Total
	A	B	C		A	B	C	
Birds have wings to fly from danger/ enemies, or to fly south	12	23	7	42	23	26	15	64
Birds lay eggs and feed, protect, and care for the babies.	4	11	7	22	2	6	0	8
Birds have beaks to peck, grab, tear, and eat food.	8	5	5	18	17	10	39	66
Birds build nests to keep babies up high from danger, to hide eggs, or keep cool.	2	10	2	14	0	10	0	10
Birds have feathers to help them keep warm or waterproof.	5	7	0	12	11	3	10	24
Birds have feet/claws to protect, grab food or twigs, or swim.	6	4	0	10	18	14	35	67
Birds have good vision, binocular vision to see prey, peripheral vision to see enemies.	0	0	0	0	11	3	20	34
Birds can camouflage themselves.	0	0	0	0	15	2	9	26
Birds choose good trees or other places for homes and defend their territories.	0	0	0	0	0	11	0	11
Birds live near people who feed them	0	0	0	0	1	2	8	11
Some birds are predators.	0	0	0	0	3	6	0	9
Birds know how to eat many things.	0	0	0	0	5	3	0	8
Birds can circle and dive at predators to defend themselves.	0	0	0	0	0	8	0	8

Question 2: Ask as Many Questions as You Can

Table 9 describes the results across classrooms in generating new questions given a bird photograph prompt. On the pretest, students in Class B (thematic) and Class C (object box) asked about six or seven questions each, whereas students in Class A (PBL) asked an average of about four questions. However, on the posttest, students in Class A made large gains to reach the levels of peers in other classes. An ANOVA was conducted to compare the pretest and posttest scores (both versions combined) of each approach. There were no significant differences between pretest and posttest scores of students in Classes B and C, but students in Class A significantly improved in their ability to ask questions about the bird scenes (*alpha* =.05, F_{crit} = 4.1, F = 9.7, df = 1/38, p = 0.004). Cohen's effect size for gain scores of the Problem-based learning group compared to the thematic group was d = 0.56, and compared to the object box group was d = 0.77 . These are medium to large effect sizes, indicating the positive impact of the problem-based learning condition on curiosity.

Table 10 shows the fifteen most common topic areas for questions. The final category, "Other" includes a large variety of topics about which only a few individual students asked questions. These areas include: birdsong, ownership, patterns, speed, family, camouflage, shadow, legal issues, time of day, breathing, beauty and appearance, lifespan, eyes, habitat, tongues, bones, cobwebs, snakes, and predators.

Table 9
Mean Pretest, Posttest, and Gain Scores for Question 2.

Class	Approach	Pretest Scores: Version A	Pretest Scores: Version B	Pretest Scores: Both	Posttest Scores: Version A	Posttest Scores: Version B	Posttest Scores: Both	Gain Scores: Posttest minus Pretest for Each Student
		Number of Questions Written						
A	PBL	4.3 (3.5)	3.8 (1.0)	4.1 (2.6)	7.3 (4.1)	6.9 (2.8)	7.1 (3.5)	3.1 (3.3)
B	Thematic	7.5 (6.7)	7.2 (3.3)	7.3 (5.0)	8.6 (3.9)	7.3 (3.7)	7.9 (3.8)	0.6 (5.4)
C	Object Box	6.7 (4.1)	6.0 (2.4)	6.4 (3.3)	6.3 (3.4)	6.9 (2.9)	6.6 (3.1)	0.2 (4.2)

Note: Standard deviations are shown in parentheses.

Table 10
Most Frequent Student Question Topics and Number of Students Making that Response to Question 2 on the Pretest and Posttest

General Topic Area	Example Question	Pretest Class A	Pretest Class B	Pretest Class C	Pretest Total	Posttest Class A	Posttest Class B	Posttest Class C	Posttest Total
Activity	What are they doing?	7	22	13	42	20	8	9	37
Beaks	Why do they have long and pointy beaks?	9	16	10	35	12	13	6	31
Bird Species	What kind of birds are they?	12	15	7	34	15	19	11	45
Food	What is the one at the bottom eating?	8	6	7	21	11	13	9	33
Size	How big are they?	1	9	10	20	2	14	5	21
Water	Is that a lake?	2	10	7	19	9	5	5	19
Color	What color are they?	1	9	8	18	9	11	8	28
Location	Where are they?	6	3	9	18	7	11	11	29
Babies	Are the birds feeding the babies?	5	7	5	17	4	5	4	13
Vegetation	What kind of trees are those?	5	10	1	16	5	5	6	16
Count	How many birds are there?	2	7	4	13	5	1	3	9
Dangers	Can they bite and hurt you badly?	0	4	7	11	5	1	3	9
Nest	What do they make the nest with?	2	4	5	11	5	6	4	15
Background	What is in the picture?	2	5	2	9	5	0	0	5
Legs	Why do they have long legs?	3	5	1	9	7	9	5	21
Gender	Which is the mother?	5	3	1	9	3	4	3	10
Feathers	Why do they have feathers?	1	4	3	8	2	8	0	10
Flight	Can they fly?	1	5	2	8	7	4	0	11
Other	A large variety of questions.	5	22	16	43	30	26	14	70

There were qualitative differences between the questions asked by students in Class A, the Problem-based group who used the CoRT thinking skills, and the other two classes. Students of Class A asked more unusual or elaborate questions about the typical topics, and asked more questions that fell into the "Other" category. For example, a student asked, "Are they flamingoes, or woodpeckers, or hummingbirds?" rather than a more typical question, "What kind of birds are they?" Another example is the question, "Why do most birds make their houses in big, big trees?" rather than the more frequent question, "Why is there a tree?" Examples of students from Class A's questions about unusual topics include, "Who drew the picture?" "Do they breathe under water?" "Is it illegal to kill them?" "Why is it so dark?" and "Why does the bird look invisible?"

It seems likely that problem-based learning combined with the CoRT Breadth Thinking Skills during which students carefully examined and generated ideas, aided students in developing their verbal curiosity skills. Practice in the CoRT thinking skills of Consider All Factors (CAF) and Other Points of View (OPV) helped students to think of questions that covered different aspects of the pictures. Another CoRT thinking skill of Consequence and Sequel (C&S) comes through in the following questions from students in Class A: "Would you still go to jail if you had a hunting license and killed one of the birds?" "Why do the parents leave the baby birds when they go to get food?" and "Why do some birds have curved beaks when others have straight ones?"

Question 3: Vocabulary Development

Students were asked to write descriptive words for a given set of three small objects. Table 11 shows the mean pretest, posttest and gain scores for each class. On these results, the use of object boxes produced significant posttest gains on the number of words described by students in Class C compared to the other two classes (mean gain score for Class C=8.4, Class B and Class A were 2.4 and 2.8, respectively). On the pretest, students in each class scored similarly, giving about five words per object. On the posttest, all students exhibited growth in descriptive vocabulary. However, Class C, the object box class, nearly tripled the number of words written from pretest to posttest. Cohen’s effect size for the object box group compared to the problem-based learning group was d = 1.83, and compared to the thematic group was d =1.77. Both of these are very large effect sizes, indicating the positive impact of the object box condition on vocabulary acquisition. This growth can be attributed to the application of new vocabulary to manipulated items, use of process skills of observation, inference, classification, and communication, along with practice in identifying descriptive words through the database activities. These results are similar to those obtained by Rule, Barrera, and Stewart (2004) who used descriptive adjective object boxes to increase third graders' vocabulary.

Table 11

Mean Pretest, Posttest, and Gain Scores for Question 3

Clas s	Approach	Mean Number of Observations of Physical Properties Written						
		Pretest Scores			Posttest Scores			Gain Scores
		Set 1: Styrofoa m Lobster Marble	Set 2: Frog Key Ornament	Both Sets	Set 1: Styrofoa m Lobster Marble	Set 2: Frog Key Ornament	Both Sets	
A	PBL	5.6 (3.1)	4.1 (2.8)	4.8 (3.0)	7.0 (2.9)	7.4 (3.3)	7.2 (3.0)	2.4 (3.7)
B	Thematic	7.1 (3.1)	4.5 (2.6)	5.8 (3.1)	8.1 (3.2)	9.2 (2.9)	8.6 (3.0)	2.8 (3.5)
C	Object Box	5.4 (1.8)	3.7 (2.1)	4.5 (2.1)	12.5 (2.7)	13.5 (2.1)	13.0 (2.5)	8.4 (2.8)

Note: Standard Deviations Shown in Parentheses

Table 12
Pretest, Posttest, and Gain Scores for Technology Assessment

Class	Approach	Responses to Technology Questions					
		Set 1: Technology Self-Efficacy			Set 2: Knowledge of Computer Applications		
		Pretest Average Score	Posttest Average Score	Gain Score	Pretest Average Score	Posttest Average Score	Gain Score
A	PBL	1.8 (0.4)	1.9 (0.5)	0.2 (0.6)	28% (15)	36% (22)	8% (26)
B	Thematic	1.7 (0.6)	2.6 (0.5)	0.9 (0.5)	17% (13)	42% (19)	25% (19)
C	Object Box	1.4 (0.4)	2.6 (0.7)	1.2 (0.6)	9% (12)	26% (24)	17% (28)

Note: For technology self efficacy, the scoring was as follows: never = 1; with a lot of help = 2; with a little help = 3; all by myself = 4. For knowledge of computer applications, the percent of correct responses is shown.

Technology Assessments

Table 12 describes results on student self-efficacy and technology skill proficiency. Overall, students in Classes B and C showed similar gains in self-efficacy moving from a perception of feeling that they could use technology “with a lot of help” to a perception that they needed less help. Students Class A made the smallest gains in perceptions of self-efficacy. Effect size for gain scores of the object box group compared to the problem-based learning group were large with *d* = 1.67, but the effect size for comparing the object box group to the thematic group was smaller, but still medium-sized with *d* = 0.54. Object box group members added to their data bases several times during their investigation as they uncovered more information, thereby practicing skills each time. This may account for some of the differences.

This pattern of the problem-based learning group making smaller gains continued to student measures of computer proficiency in the use of software applications. Students in Class B, who used a thematic approach, made the largest gains in knowledge of computer applications followed by students using object boxes with students in the problem-based condition registering the smallest gains. The effect size of the gains in computer application knowledge of the thematic class compared to the object box class was d = 0.33 and comparing the thematic class to the problem-based learning class was d = 0.75, a large effect. All students in all classes completed the computer activities outlined in Table 1 for their condition. Students in Class B, through their thematic book-making activities that involved creation and printing of paragraphs, poems, digital images, charts, and maps, used applications for a larger variety of purposes, thereby giving students more familiarity with computer application use.

We recommend caution in interpreting the outcomes related to computer technology self efficacy and application knowledge, as these may be an artifact of the ways the models were carried out by the individual teachers rather than essential characteristics of the approaches themselves.

Conclusion

All three authentic learning approaches to integrating technology into a unit on bird adaptations for habitat were successful in teaching science concepts, increasing student vocabulary, and introducing databases and spreadsheets to students. All three teachers mentioned that students were highly motivated as evidenced by observations of on-task behavior and verbal expressions of student enthusiasm for the activities as compared with typical classroom work. The teachers were pleased with the results of their students' investigations and planned to share ideas for their subsequent implementation of these units.

Each approach presented challenges. The teacher conducting the problem-based learning investigation wrestled with the urge to “take over” rather than allow the solution to unfold as students methodically used the CoRT thinking skills to determine the problem’s solution. The suspense of not knowing and not being able to plan ahead for the outcome was difficult for her. The teacher engaged in the thematic unit sought ways to integrate different subject areas meaningfully with the theme. Integration of reading and language arts through non-fiction trade books accompanied by writing activities was familiar and comfortable, but integration of other subjects was not as easy. Use of technology to create a database of observations and subsequent graphs, along with plotting bird sightings on a digital map image assisted her in integrating mathematics and social studies concepts with this science unit. Finally, the teacher involved with the object boxes was challenged in making/assembling the materials and teaching students to care for them. The teamwork between the teachers and the authors generated ideas for object boxes, which the authors helped produce.

Each approach had strengths. Students who participated in the problem-based approach (Class A), made strides in content knowledge and vocabulary, but exhibited the greatest growth in curiosity relative to the other approaches. Tolman (2002) listed broadening interest in, and appreciation for, things around us as the first goal of elementary science education that supports changing the focus of science from science for scientists to science for all. Curiosity is an important emotional attitude that carries a mental state of readiness with it, leading to the development of additional curiosity, perseverance, positive approach to failure, open-mindedness, and cooperation with others (Martin, Sexton, Wagner, & Gerlovich, 1997). Curiosity or interest is what directs a student's attention, a necessary component in learning. Research by Wittrock (1986) shows that attention to learning tasks correlates more strongly with achievement than time on task. Therefore, a curriculum integration approach that enhances student curiosity promotes student learning of science. The more elaborate questions asked by students in this group also provide evidence of students' growth in language skills during the lessons.

Student scores in the thematic unit condition (Class B) showed gains in science knowledge, vocabulary, and in particular, knowledge of computer applications. Finally, Class C students in the object box condition, excelled in content knowledge of birds and their adaptations, developed their descriptive vocabularies, and made gains in self-efficacy of computer use. The results of this comparison show there are multiple ways to authentically involve students in exciting and effective integrated science units.

The integration of a system of thinking skills such as Talents Unlimited, CoRT Breadth, or science process skills helped the teachers organize the work and scaffold student learning in manageable steps. The thinking skill systems challenged students to think about their thinking and take new perspectives, resulting in gains in knowledge of bird facts and adaptations for all groups. The meaningful integration of database and spreadsheet use in the three conditions was appreciated by the teachers who had not, prior to this experience, used these tools in their classrooms. Teachers felt supported by the authors during this study and expressed that they were now ready to use these applications independently in future units they designed.

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