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Mobile Dichotomous Key Application as a Scaffolding Tool in the Museum Setting

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ABSTRACT

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This study explored the use of a dichotomous key as a scaffolding tool in the museum setting. The dichotomous key was designed as a scaffolding tool to help students make more detailed observations as they identified various species of birds on display. The dichotomous key was delivered to groups of fifth and seventh graders in two ways: on a mobile platform and by museum educators. Data was collected in the forms of pre- and post-testing and observations to compare the two methods. Findings suggest the Mobile Dichotomous Key (MDK), developed by educators at the Bean Life Science Museum at Brigham Young University, was equally as effective as a teacher (museum educator) in assisting students in a learning activity designed to improve or develop scientific observation skills. While both groups' outcomes were the same, data from observations made during the learning activity showed that there were significant differences in the experience for the students. Students using the MDK were more engaged, could work at their own pace, and were more likely to work with their peers than students working in groups led by a museum educator. In contrast, students in the educator-led group were able to receive immediate feedback during the learning activity, as museum educators were able to make assessments and answer questions or expand the learning experience. A feedback mechanism is suggested for a future version of the Mobile Dichotomous Key app.

Keywords: Mobile tool, museum, scaffolding

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TABLE OF CONTENTS

LIST OF TABLES

Introduction

The primary responsibility of a teacher is to help students learn. To be effective, teachers often use a variety of approaches and methods to accomplish this task. One way a teacher can facilitate the learning process is to use a technique called scaffolding. Like a scaffold used to hold up a building during construction, some type of assistance or framework is provided to help students complete learning tasks they are not capable of completing on their own. Assistance can come from a variety of sources (e.g., a person, a textbook, a computer program) but the idea is to provide the student with only the help they need to accomplish the task. The amount and type of assistance varies based on the needs of individual students with the expectation that when the "scaffolding" or help is removed, the student will be able to perform the task on his or her own (Hogan & Pressley, 1997b).

Providing scaffolding in the traditional classroom can be difficult for teachers because children often have different capacities for learning. This makes it challenging for the teacher to assess individual students' needs and provide the necessary assistance (Hogan & Pressley, 1997b). One-on-one tutoring or mentoring is a better option than traditional classroom instruction because it is easier to vary the amount of assistance based on each individual child's understanding and ability. It is also a more effective method of teaching (Bloom, 1984). However, providing a tutor for each child is expensive and impractical. This is where different forms of technology might be used to assist the teacher in providing students with a scaffold for individual learning tasks.

Informal learning environments, such as museums, create another challenge for scaffolding because learning experiences are often not structured or controlled by the teacher. Students are self-directed, choosing which exhibits to visit and deciding how long to spend at each exhibit. This makes it difficult for a tutor or mentor to assist the learner in the completion of a learning task targeted at a specific learning outcome. In addition, the number of students a teacher or mentor can interact with in the museum setting is limited because exhibit and gallery space is often much smaller than the average classroom.

Scaffolding by a teacher or educator can happen in the museum setting if groups are small enough. Yet this type of scaffolding can be problematic since mentors are usually few in number and children are easily distracted in the museum setting by the various items on display. Recognizing this problem, museum educators at the Bean Life Science Museum at Brigham Young University have experimented with ways to incorporate technology to simulate the one-on-one learning experience. Along with traditional ways of transmitting information in a museum setting, such as exhibit labels, live animal shows, and tours that only present factual or conceptual knowledge and do not necessarily engage the learner, the education team at the Bean Life Science Museum have incorporated a scaffolding tool called the Mobile Dichotomous Key (MDK) that is formatted to work on Apple's iOS devices (iPad, iPhone, or iPod touch).

The MDK scaffolding tool is designed to serve individuals or small groups in a more effective way than a teacher or mentor could in the museum setting because of its mobility and accessibility. It is also designed to take the visitor beyond the typical museum experience and encourage interaction in a way that will facilitate students in developing scientific observation skills. Dichotomous keys have been used to identify species for some time, yet rarely have they been used as a learning tool in the museum setting. The key is designed to ask the user questions about a specimen they are observing eventually helping them identify the scientific name of the specimen. The questions are intended to encourage each student to make more detailed observations and provide a framework for the user to practice this skill.

Research Purpose

This study provides a unique look at a Mobile Dichotomous Key as a scaffolding tool in development of systematic observational skills in the museum setting. Comparisons were made between two scaffolding interventions given in the context of a museum setting and the specific scaffolding providers (mobile device vs. teacher). The purpose of this study was to evaluate the effectiveness of the MDK as a scaffolding tool in comparison to a teacher and to determine ways to improve upon it.

Research Question

The following research question guided this study:

> In the museum setting involving groups of elementary-aged learners, can a dichotomous key implemented on a mobile platform improve individual learners' a) knowledge of scientific terms b) observation skills and c) ability to make inferences to the same degree as groups of students in the same setting receiving guidance from a teacher?

The dependent variables for this study were the students' ability to make observations, their ability to use scientific terms to describe the birds being observed, and their ability to make inferences from their observations. The independent variable was the context for which the scaffolding tool was used (i.e., individual vs. group scaffolding).

Literature Review

This literature review covers the following topics: (a) informal learning, (b) museums as informal learning environments, (c) mobile learning in the museum, (d) scientific learning in the museum, (e) observation as a critical science skill, (f) scaffolding tools as support for skills developed in observation, and (g) identification tools to scaffold science learning.

Informal Learning

Informal learning is usually defined in contrast with formal learning, which most often has an objective and may or may not be of the learner's choosing. Informal learning as compared to formal learning is (a) voluntary vs. compulsory, (b) unstructured vs. structured, (c) unevaluated vs. evaluated, (d) open-ended vs. close-ended, (e) learner-led vs. teacher-led, (f) out-of-school context vs. classroom context, and (g) social vs. solitary (Hofstein & Rosenfeld, 1996). Yet often when authors and researchers try and define informal learning versus formal learning, they admit that they are intertwined with each other (Marsick, 2009). Because of this, there isn't a clear definition of informal learning in the literature (Hofstein & Rosenfeld, 1996) but rather descriptions and examples of its characteristics.

The following characteristics are symptomatic of informal learning: It is (a) contextualized, (b) conscious and intentional, and (c) incidental and implicit. Because the learner is free to choose learning, the motivation for learning is based on beliefs, values, unique interests, personal histories and social implications (Marsick, 2009). Informal learning accesses the individual's prior knowledge, is learner-centered and active, and usually occurs in a social setting. Because of the social aspect of informal learning, Anderson, Lucas and Ginns (2003) claim that it can be embedded within the human constructivist learning theory. The challenge is to focus learners on specific objectives while still allowing them to choose in informal settings, such as museums.

Museums as Institutions for Learning

Museums are educational establishments that facilitate informal or free choice learning. In addition, museums enable visitors to learn using mobile devices that can enhance their experience as they visit exhibits of their choice and at their own pace. The informal setting of museums allows for social interactions, which can also influence the learning process.

Informal learning environment. Museums are institutions that accommodate informal or free choice learning. The learner's own unique interests and background motivate this type of learning because the learner is allowed to choose what they learn about and for how long (Falk & Dierking, 2002). Museums are also non-evaluative, non-competitive, and non-structured. The unique learning atmosphere of museums allows for various types of social interactions that facilitate learning (Falk, Koran, & Dierking, 1986). Many different types of groups come to museums expecting to have an enjoyable learning experience. Because of the highly social atmosphere that museums provide for learners, the type of social group will greatly affect the learning experience. For example, a family learning experience in the museum setting will be much different than the learning experience of two people visiting the museum on a date. Visitors will not only learn together about the content presented in the exhibits, but they will learn many ancillary, unintended non-exhibit related things (Falk, et al., 1986). Studies have shown that the amount of time spent at an exhibit can be a predictor of learning (Falk, 1983) and because of this, museum educators strive to make the museum learning experience highly interactive and engaging. Traditional museum labels have been shown to be less effective than other, interactive types of learning activities in the museum setting (Falk, et al., 1986). Swinny (1976) claims the following:

> If the museum attempts to transmit a large quantity of information through lengthy labels, the label itself gradually becomes the exhibit and the object becomes an illustration for the label. Failure threatens an exhibition with long labels simply because a museum is not the right device for the transmission of the written word. A museum is not a book. (pp. 4)

Museums such as the Exploratorium in San Francisco seek to teach science through the use of interactive exhibits that demonstrate science concepts. These types of exhibits do not display collection objects, but focus on teaching science through interaction (McManus, 1992). Another study from Falk et al. (1986) concluded that museum visitors learn more from docents than from exhibit labels.

Mobile learning in the museum environment. Since prior knowledge is key to determining how well a visitor learns at a particular exhibit, museums will often create some kind of orientation device, such as a video, to introduce the museum in general or for specific exhibits (Falk, et al., 1986). With the advance of portable technology, mp3 players and cell phones are being used by museums for various educational purposes including visitor guides (Trionova, 2003). Museums use these mobile learning devices for many purposes—namely, as an electronic map using GPS to show the visitor exactly where they are in relation to different areas in the museum, or as a virtual docent using various audio and visual methods to give facts and information to the user (Boehner, Gay, & Larkin, 2005). A popular element for mobile learning devices in the museum setting is the "push" feature. This feature "pushes" relevant content to the device depending on the location of the user with the aid of infrared signal transmitters of GPS technology (Li-Der, Ching-Chou, Ming-Yu, & Chun-Yen, 2004). Similarly, these devices can have a "pull" feature, allowing the user to access more in-depth content if desired.

One advantage to a mobile learning tool is that the technology and assistance provided by the device can be used in a variety of different environments. This makes it possible to take the learning activity out of the classroom and into a more authentic location, such as a museum (Hwang, Chu, Shih, Huang, & Tsai, 2010). Hwang et al. (2010) indicates that with the progress of wireless technology, educational issues have shifted from web-based learning, to mobile learning, to context-aware ubiquitous learning where the device can detect where the student is and can "push" information or learning opportunities in a personalized way.

The kinds of mobile learning activities that users can access in a museum vary just as traditional activities do. Participatory exhibits that engage the user by guiding them through a task or quest (problem-based) provide a more interactive and engaging learning experience than the traditional information expressed in a museum label or audio track (Sung, Hou, Liu, & Chang, 2010). These kinds of exhibits also attract more attention and are more popular with museum visitors (Koran, Koran, & Longino, 1986).

Although interactive exhibits, especially those that integrate technology, attract more visitors, museum educators must consider the "novelty factor" of the museum setting (Hofstein & Rosenfeld, 1996). When the technology is new to students, it can sometimes become a distraction in the classroom if it is seen as a novelty rather than a resource (Davies, Sprague, & New, 2008). Both Davies et al. (2008) and Hofstein and Rosenfeld (1996) claim that the novelty factor fades with familiarity.

Relationship between social and scientific learning in the museum. Museums are not only environments for informal and mobile learning but they provide an atmosphere for social interaction and shared investigation. This kind of exploration in the museum setting can promote the understanding of scientific processes, which can lead to enhanced scientific learning

(McManus, 1992). The assistance of a parent in helping a child make a connection between new information learned at an exhibit and prior knowledge and experience is an example of how social interaction in this setting can promote scientific learning (Dierking & Falk, 1994).

Scaffolding in the Museum Setting

Social learning can also facilitate scaffolding for learners in the museum setting. The scaffolding learning theory is based on the analogy of a building under construction, which is supported by a structural framework (scaffold). Once the building is completed and the scaffold is removed, it is expected that the building will stand on its own. Similarly, when the "scaffold" is removed in the learning process, the student should be able to perform the task on his or her own. The Zone of Proximal Development conceived by Russian constructivist, Lev Vygotsky, is the zone identified as being between the point where a student can learn using their own abilities and where they can learn better with some kind of support (Hogan & Pressley, 1997b).

In general, there are three main learning goals of scaffolding. First, scaffolds can serve to assist in the acquisition of specific knowledge or skills. Second, they can help build learning habits in students so that in the future they are less likely to need a scaffold. And third, scaffolds can be used to motivate and produce effective outcomes in student learning (Hogan & Pressley, 1997b).

Saye and Brush (2002) distinguish between two types of scaffolding: soft and hard. Soft scaffolding is support from a teacher with verbal communication and hard scaffolding is with a paper or computer-based aid. Hard scaffolding can and should be supplemented with soft scaffolding because a teacher or mentor is better equipped to assess and alter the type and amount of assistance required.

There are different types of verbal scaffolds that teachers use daily in the classroom:

offering explanations, verifying and clarifying student understanding, modeling behavior, and inviting student participation (Roehler & Cantlon, 1997). Teachers can also serve as verbal scaffolds by pointing out learning strategies and identifying elements of a larger system (Gaskins et al., 1997). Teachers can also supply information, or clues to help students accomplish a specific task. Verbal scaffolds are ideal in certain learning environments because teachers can gradually remove assistance based on the teacher's assessment of student understanding (Roehler & Cantlon, 1997).

The drawback to verbal scaffolding is that this type of assistance usually occurs in groups rather than with individuals, the exception being a tutoring situation. Large class sizes present challenges for verbal scaffolds with one teacher providing assistance to a number of diverse learners with diverse communication styles. Time and curriculum constraints also prevent a deep learning experience with verbal scaffolding. Additionally this type of scaffold does not allow for student ownership and it is hard for a teacher to make assessments of thinking processes, instead it forces the teacher to make assessments based on products. This kind scaffold is also demanding on the teacher's time and energy (Hogan & Pressley, 1997a).

Instruction on Scientific Observation

Scaffolding can enhance both science content learning and science process understanding in any setting. In recent years, the focus of science teaching has shifted from scientific process skills to content and conceptual knowledge (Johnston, 2009). Many educators recognize this shift as problematic, emphasizing the importance of not just learning science but learning how to do science. Because of this, there has been a push to incorporate more scientific process skills into science curriculum (Davies, et al., 2008). One skill that is crucial as a first step in the scientific process is observation.

Importance of Scientific Observation. Observation is an essential part of the scientific process. It is used in generating questions, hypotheses, experimentation, data collection, and analysis, and in recognizing patterns and drawing meaningful conclusions (Oguz-Unver & Yurumezoglu, 2009). Observation also helps in the recall of important details and in problem solving (Grambo, 1994). According to Johnston (2009), younger children use observation to classify objects, make predictions and form hypotheses; older children also use observation to interpret scientific patterns and processes. Observation can be incidental and unsystematic but when observation is used in a scientific way it is active, systematic, and goal-oriented (Kohlhauf, Rutke, & Neuhaus, 2011).

Science education researchers emphasize the importance of incorporating learning activities that promote the development of scientific observational skills in young children (Johnston, 2009). They also emphasize that observation is more than "just seeing" and should include as many of the five senses as possible as well as data obtained from electronic instruments (Yurumezoglu, 2006). Tomkins and Tunnicliffe (2001) claimed that observational skills in children were influenced by the child's previous knowledge and experiences. Later, Tunnicliffe and Litson (2002) concluded that situational interest about the object being observed influences the level of competency in scientific observation. Kohlhauf et al. (2011) studied the influence of previous knowledge, domain-specific-knowledge, and language skills on the ability of scientific observation competency. Their study showed a statistically significant difference with previous knowledge as a predictor for good observation but was unable to find that language skills or domain-specific interest played a significant role. This research suggests that it would be helpful for educators to find learning tools aimed at improving observation skills that incorporated as many of the five senses as possible, included authentic and situational experiences, and accessed the student's prior knowledge.

Tools used to scaffold observation skill development. Because science education researchers and practitioners are becoming more aware of the importance of observation to the scientific process and consequently the importance of helping children develop this skill, they are seeking effective methods to incorporate the development of this skill into science-based learning (Tunnicliffe & Litson, 2002). Educators are striving to promote systematic, scientific observation skills in children by incorporating observational aids or scaffolds in science education (Smith & Reiser, 2005).

Verbal scaffolds. Teachers can and should use verbal assistance to act as soft scaffolds in the development of systematic, scientific observation as a part of the scientific process. They can provide opportunities and assignments that focus on this skill, use guiding questions, and discuss observations with students (Oguz-Unver & Yurumezoglu, 2009). Hard scaffolding tools have also been used for this purpose, including handouts or "observation sheets," which encourage the learner to ask certain questions related to objects. Oguz-Unver and Yurumezoglu (2009) used observation sheets as a "reflective and interpretive discussion tool for students" (pp. 118). They also had the learner draw and verbally describe what they saw to scaffold the students' observations (Oguz-Unver & Yurumezoglu, 2009).

Verbal scaffolding tools that promote the development of systematic observational skills are not exclusive to the classroom. For example, students attending Weill Cornell Medical College increased their observational skills by observing paintings at an art museum (Bards, Gillers, & Herman, 2001). This assignment was generated because observation skills are important to a doctor in diagnosing problems and reading patients' emotional status. The study included pre- and post-tests in which the students observed and described the same painting. In between the tests, students were put in pairs and instructed to study and discuss other paintings in the museum. Analysis of the results indicated that the observations in the post-test improved because the descriptions were more detailed, more interpretive and included more comparisons. Because students made observations in pairs while discussing things they noticed, they acted as verbal scaffolds for one another.

Computer-based scaffolds. Smith and Reiser (2005) studied a computer-based scaffolding tool used to help students systematically and methodically organize their observations so that they could reach valid scientific conclusions. This study included a library of videos of animal behavior in the wild. Students were to watch animals and make observations and inferences. The software provided a structure for the student to organize and analyze their observations, questions, and inferences. However, for the scaffold to work properly, teachers were needed to instruct and model how the software functioned and what was expected of the learner. The study concluded that this kind of computer-based scaffolding software did indeed help in the development of scientific observational skills and actually took the learner from "looking at" to "explaining why."

Identification scaffolds. The identification of living things is key to understanding and accurately describing biodiversity and ecological relationships (Randler & Zehender, 2006). Additionally, the classification and identification of living things gives children an opportunity to use and develop their observational skills because they are systematically answering questions and making comparisons, which can lead to other important parts of the scientific process. Scaffolding tools, such as field guides (Randler & Zehender, 2006), decision-trees (Hwang, et al., 2010), and dichotomous keys (Ohkawa, 2000), have been used to assist scientists in the identification of living things.

Field guides are comprehensive books with organized, thick descriptions of all species in a given area (e.g., North America) and include color images, morphological features, distribution information, and written descriptions of behaviors. Randler and Bogner (2002) conducted a study comparing traditional teaching methods with a hands-on, task-oriented approach using field guides to identify bird species. They found that the hands-on approach with taxidermy specimens and field guides improved identification skills when compared with a control (lecture) group.

In addition to field guides as identification tools, a decision tree is like a mind map, organizing the characteristics of the focal objects. Students work within this framework, making decisions at each node based on the features of the object they are trying to identify. A study conducted by Hwang et al. (2010) looked at the influence of the decision tree in a context-aware ubiquitous learning environment on participation, motivation, and interaction and found that the tool had a positive impact.

Another identification tool commonly used in the life sciences is a dichotomous key. Dichotomous keys consist of a series of questions each with two possible alternatives that ultimately lead the inquirer to the identification of the specimen based on the pathway they follow. Because images are a major part and focus of field guides, students don't often read the descriptions and information in field guides. When comparing dichotomous keys to the use of traditional field guides, Randler and Zehender (2006) indicated that, "this key trains students to look critically at verbally explicated differences and to scrutinize the models in detail" (pp. 60). They conducted a study comparing the use of field guides and dichotomous keys with sixth graders. The students used both tools to identify six European reptile species. They found significant differences in the improvement of identification skills for both groups after using the identification scaffolds but no significant difference between the groups.

Summary

As the literature for this study illustrates, informal learning is an important way to foster sociality and ensure a more authentic educational environment. Museums are one example of educational establishments that facilitate this informal, free choice learning. As non-evaluative, non-competitive, and non-structured environments, museums allow students to learn at their own pace and engage with the material and other students. Because of this informal nature, museum educators strive to create exhibits that are highly interactive in order to engage their visitors.

One way to generate interest is to use mobile technology. Portable technology allows the museum "classroom" to move with the visitor. Some of the ways educators apply this technology is through electronic maps of the museum, as well as audio and visual presentations to relay information and facts about various exhibits. As the literature shows, informal, mobile learning experiences that create a task or quest have been found to be an effective way to engage the learner (Sung, et al., 2010), and enable the user to have an educational experience.

However, museums are not only important for informal learning, but have significant potential for instruction in scientific learning. Recently, the focus on scientific teaching has shifted away from process skills to content and conceptual knowledge. Many educators foresee problems with this approach because it focuses on knowing science rather than doing science. Museums offer an informal opportunity to educate visitors in the scientific process. Through various educational tools and scaffolds, museums can facilitate the attainment of various skills integral to the scientific process.

One of the most important skills in science learning is observation. Education researchers emphasize the importance of developing observational skills in students, and studies have shown that learning tools aimed at improving these skills would be valuable assets in the attainment of scientific understanding. Teachers often use different methods to scaffold the learning of their students. This strategy can also be applied in the museum environment, and is particularly relevant in the attainment of observational skills in scientific learning. Identification tools, such as decision-trees, field guides, and dichotomous keys scaffold scientific observation by directing visitors' attention on specific characteristics of museum objects.

As the literature has indicated, mobile learning in the museum environment provides an important opportunity for informal, engaged learning. This is particularly significant in the attainment of scientific knowledge and skills. Museums can use mobile technology to scaffold science learning by teaching observational skills through identification. In this way, students can interact and engage with the material. This provides important implications for future instruction in science learning outside of the traditional classroom setting.

Method

To test the research question, both quantitative and qualitative methods were used. An equivalent form pre- and post-test was given to all participants in order to gather quantitative data related to their observations before and after the treatment. Qualitative observations were also made during the learning activity with the different treatments.

Participants

Participants came from two different age groups: fifth grade students from Timpanogos Elementary School and seventh grade students from Centennial Middle School. Both schools are located in the Provo, Utah School District. Timpanogos Elementary School is a Title I school and receives additional funding from the state of Utah because of the low socioeconomic background of the majority of its students. Centennial Middle School is located on the northeast side of Provo in a more affluent part of town. These grades were chosen (fifth and seventh) because classification of biological species is part of their state science core curriculum. Additionally, both groups of students had classroom sets of iPads, which were used in the study.

Procedures

Students from each age group, both fifth and seventh grades, were divided into two subgroups (four total groups). Each subgroup of fifth graders had approximately 45 students and each subgroup of seventh graders had approximately 30 students (see Table 1). Because of logistical issues, only the fifth graders were randomly assigned to treatment groups since all 90 students were in the museum at the same time. The seventh grade students came to participate in the study one class at a time so they could not be randomly assigned to treatment and control groups. However, the seventh graders all had the same science teacher whereas the fifth graders did not. Subgroups within the same age range received one of two treatments. Each subgroup from both age groups participated in the activity separately to eliminate any interaction between the students using different interventions. The data was collected on two separate days, one day for each age group from the two schools. By using multiple educators to lead the students during the learning activity with the educator-led treatment, the real museum experience was simulated.

Treatments

Data were collected before, during, and after each of the following learning activities, or "treatments" as summarized in Table 1. Each treatment took about 20 minutes.

Table 1

Summary of Treatments and Participants

Grade	Treatment	n	Date & Time	Group Size
5th Grade	Educator	43	April 17th at 11:00 AM	7-10 students per group
	MDK	46	April 17th at 12:00 PM	Individuals
7th Graders	Educator	32	April 23rd at 12:00 PM	7-10 students per group
	MDK	28	April 23rd at 1:30 PM	Individuals

Treatment A (MDK). Students receiving treatment A were given the Mobile Dichotomous Key (MDK) to scaffold their learning experience. The integration of the dichotomous key with a mobile device enables the use of features that will make the key easier to use than the paper option. Instead of following a "path" through the key (e.g., if you selected this go to #8), the application will take the user directly to the next question, allowing the user to stay focused on the specimen. The "pop-up" ruler can be used to measure parts of objects and the built in glossary with hyper-links allows the learner to look up terms they may not know. After a brief explanation of how to use the Mobile Dichotomous Key (MDK), each student was given an iPad and instructed to find and identify as many marked birds as they could in the allotted time (i.e., 20 minutes). The MDK allowed students to individually answer the questions about the birds at their own pace. It also allowed them to backtrack if they realized they had made an identification error. It provided some additional information about the birds, as well as explanations about scientific terms used when classifying them. As a scaffolding tool, the MDK is intended to organize and focus students' attention on various aspects of the bird they are trying to identify while making detailed observations.

Treatment B (mentor/teacher). Treatment B provided students with the dichotomous key delivered by a live museum educator. Students were put into small groups of seven to ten individuals with a museum educator as their guide. The museum educator used a paper dichotomous key (see Appendix A) to ask the group questions about marked birds on display. The educator asked the same questions that the MDK used to direct students in their efforts to identify birds. The educator knew the correct answer for each bird and discussed options to help the group come to the correct answer. Like the MDK, the teacher used scientific terms and pointed out things about the birds being observed. To check for constancy among educators, each wore a microphone and was audio recorded. Transcriptions were made from the recordings and analyzed for consistency.

Control for Extraneous Variables

Even though it was impossible to control all potential confounding variables that may have affected the outcome, attempts were made to keep things as consistent as possible. The variables held constant between the subgroups were the museum setting, the dichotomous key tool, time allotted for the learning activity, the specimens used in the learning activity, the grade level, and the school. Some variables we could not control included the background knowledge of each child, the specific information given to each group by their teachers prior to coming to the museum, socio-economic background, and family situation, to mention a few. While these variables could not be controlled, because the study looked at the improvement of a skill as determined by pre- and post-tests, things such as prior knowledge, family situation, or the socio-economic background did not seem to be a factor of concern.

Data Collection

Data was collected on a Tuesday with the fifth graders from Timpanogos Elementary School and on the following Monday with the seventh graders from Centennial Middle School. Data was collected at the Bean Life Science museum in the form of pre- and post-tests and qualitative observations.

Pre- and post-test. Each group was taken to a classroom when they first arrived at the museum. Before the learning experience, each student in the subgroup was given a pre-test (see Appendix B). Four designated bird specimens were placed on tables around the room and students were assigned a table with a bird. They were given two minutes to write down as many observations as possible. They were then told to move on to the second question, “Based on your observations, what can you tell me about this bird?” The intent of the second question was to see if students could make legitimate inferences based on their observations.

After the tests were collected, students were given instruction about their particular learning experience including how to use the iPads (for those student in the MDK group). They were given 20 minutes to complete the learning experience based on the two different treatments. Following the learning activity, students returned to the classroom for the post-test. They were assigned a different table with a different bird than the one they were assigned to in the pre-test. The birds used in the pre- and post-test were similar to the birds in the learning activity but not the same specimens. Pre- and post-tests were marked so a comparison could be made for individual student’s test scores.

Observations. Prior to the pilot test and data collection, a meeting was held with the three investigators assigned to make observations during the learning activity. After a discussion about the important things to make note of, a checklist was made. After the pilot test, the three observers met again to review and fine tune their observations. Although no inter-reliability score could be determined with observational data, the measures described above were used to ensure consistency among observers. During each of the four learning activities, three investigators made detailed, descriptive field notes: observing specific behaviors, interactions, and scripting comments made by the students. Observations were noted about the way the students engaged in the learning activity, how they interacted with one another and the educator, and the ways they engaged with the MDK. Investigators followed up initial descriptive observations with reflective notes, offering up new questions, thoughts, feelings, and inferences about what was observed. These observations were transcribed later for the purpose of coding and analysis, and as a way to easily add reflective notes after the learning event.

Data Analysis

Pre- and post-test. Pre- and post-tests were transcribed and the data entered into scoring sheets with hidden codes for the purpose of blind grading. Three educators with biology backgrounds independently scored a portion of each test, determining the level of detail for each observation and the validity of each inference. Prior to grading the tests, the graders discussed the rubric and came up with standards for these particular sub-scores. The graders did numerous spot checks during the grading procedure to ensure they were making similar judgments. Both sub-scores that were graded (level of detail and valid inferences) were used to determine inter-rater reliability using the intra-class coefficient test. The average measure intra-class correlation for the level of detail was .979. The average measure intra-class correlation for valid inferences was .966. Averages for the sub-scores from all three graders were used to compile the final overall score. The rubric was organized so as to provide three sub scores, one for knowledge of scientific terms, level of observation detail, and ability to make inferences based on their observations, as well as a total score for each test (see Appendix C). Table 2 shows how the rubric and scoring sheet in Appendix C is structured. Appendix D is a student sample test illustrating how the sub-scores and total scores were aggregated.

Table 2

Components of Total Observation Score on the Pre- and Post-tests

Sub-Score	Point Value	Determined by
Number of Observations	1	Transcription & counting
Level of Detail	1, 2, 3 (1 is low level of detail and 3 is high)	Average score between graders
Number of Glossary Terms used in Observations	1	Transcription & counting
Number of Inferences	1	Transcription & counting
Number of Glossary Terms used in Observations	1	Transcription & counting
Valid Inferences	1	Average score between graders

Because the same group of students was taking the same pre- and post-test, a repeated measures test was used to determine statistically significant differences within and between groups. This test looked to see if students improved significantly from pre-test to post-test within groups as a whole. It also looked to see if there were any differences between groups as a result of the different treatments.

Observations. Observation field notes were analyzed with an open coding iterative process. Two investigators separately identified phenomena for every sentence and assigned labels, names and categories (Strauss & Corbin, 1998). These were counted and compared between groups. Reflective notes were also considered and analyzed. To establish reliability in coding, two researchers conducted the coding process. Results were reported with the pre- and post-test data in the following section. Peer review and a detailed audit trail were used to establish credibility of the interpretations.

Triangulation. Attempts were made to triangulate the data so researchers could be confident in the results. It must be noted that observers were aware of which treatment group they were observing which could have created some bias in their observations. By using three observers during each learning activity, findings from the observations were confirmed. By using three graders, with a blind grading procedure and performing inter-rater reliability tests, researchers were more confident in the accuracy of the pre- and post-test scores.

Results

The results from the data in this section are shown in two ways. Using the pre- and post-tests as well as the observation data, a comparison between treatment groups for all participants combined is followed by a comparison of the results between the fifth and seventh graders.

Achievement Comparison by Treatments

The following results compare pre- and post-tests together with observations made during the learning activity for all fifth and seventh graders combined.

Total observation score. Total scores for both the pre- and post-tests are comprised of the following sub-scores: number of observations, level of detail in observations, number of glossary terms used in their observations, number of inferences, number of glossary terms in inferences, and legitimate inferences based on observations. A 2 X 2 repeated measures ANOVA was used to examine the effects of the scaffolding treatments (i.e., teacher-led group versus iPad group) and time (i.e., Pre-test and Post-test) on test scores (see Table 3).

The main effects (i.e., total observation score) from pre- to post-tests were significant, $F(1,147) = 4.6$, $p = .033$, indicating that overall, students observation skills improved in both treatment groups. There was no statistical significance in the interaction between groups, $F(1,147) = 1.79$, $p = .184$, both groups changed from the pre- to the post-test in a similar fashion. An analysis of between group factors found that there was no difference in terms of how each group performed, $F(1, 147) = 0.43$, $p = .836$. However, students in the educator-led group went from a mean score of 27.2 on the pre-test to 27.8 on the post-test, a difference of 0.6. Students in the MDK group improved from a mean score 25.8 on the pre-test to 28.4 on the post-test, a difference of 2.6. This slight difference in improvements between groups (0.6 improvement with the educators and 2.6 improvement with the MDK) was apparently not statistically significant but worth noting.

Table 3

Means for the Total Observation Score on all Pre- and Post-tests

Treatment	n	Mean Pre-Test	Mean Post-Test	Standard Deviation Pre-Test	Standard Deviation Post-Test	Difference
Educator	75	27.2	27.8	12.1	11.2	+0.6
MDK	74	25.8	28.4	10.5	10.6	+2.6
Total	149	26.5	28.1	11.3	10.9	+1.6

Level of detail. Results for the level of detail used on all pre- and post-tests are reported in Table 4. The main effects were statistically significant, $F(1,147) = 6.02$, p = .015. This means that regardless of treatment group, students overall, were more detailed in their observations on the post-test than on the pre-test. The interaction effect, $F(1,147) = 3.09$, p = .081, and between factors, $F(1,147) = 0.48$, p = .490, had no statistical significance, meaning there was no difference between treatment groups in the amount of change or in the level of change observed. Again, the difference in scores (0.3 for the educator-led group and 1.7 for the MDK group) is not statistically significant but is worth noting.

Table 4

Means for the Level of Observation Detail on all Pre- and Post-tests

Treatment	n	Mean Pre-Test	Mean Post-Test	Standard Deviation Pre-Test	Standard Deviation Post-Test	Difference
Educator	75	14.3	14.6	6.7	6.1	+0.3
MDK	74	13.0	14.7	5.4	5.5	+1.7
Total	149	13.7	14.6	6.1	5.7	+0.9

Inferences. The results of the valid inferences sub score are reported in table 5. There was no statistical significance on the main effects from the pre-test to the post-test, $F(1,147) = .81$, p = .370. The interaction effects, $F(1,147) = 1.55$, p = .220, and between factor effects, $F(1,147) = 0.035$, p = .850 were also not significant. Students' ability to make valid, scientific inferences did not seem to improve regardless of the treatment group.

Table 5

Means for Valid Inferences on the Pre- and Post-Tests

Treatment	n	Mean Pre-Test	Mean Post-Test	Difference
Educator	75	1.6	1.6	0
MDK	74	1.6	1.5	-0.1
Total	149	1.6	1.5	-0.1

Student engagement. During the learning activity, both treatment groups, the educator-led group and the MDK group, identified birds on display using a dichotomous key (i.e., one paper one electronic). Students in the educator-led treatment group worked in small groups using a paper version of a dichotomous key while students in the MDK group worked on their own using an electronic version of a dichotomous key. Students being led by museum educators identified 15.9 birds on average during the learning activity with a standard deviation of 2.4, while students in the MDK group were able to identify 13.6 birds on average with a standard deviation of 4.9. An independent samples t-test was used to determine if there was a difference between treatment groups in variances and means. The results reveal a statistically significant difference between the average number of birds identified in the iPad group (13.6) and the average number of birds identified by the educator-led group (15.9). An analysis of the standard deviation for these results seems to suggest that educator-led groups worked more consistently through the identification process. Students in the MDK groups tended to work at a varied pace depending on the individual student. Some students identified only three specimens while others identified as many as 26 specimens (i.e., 5 more than the fastest educator led group).

Table 6

Statistics for the Number of Birds Identified During Learning Activity

Treatment	n	Mean	Range	Minimum	Maximum	Std. Deviation
Educator	75	15.9	10	10	20	2.4
MDK	74	13.6	23	3	26	4.9
Total	149	14.8	23	3	26	4.0

Note. Statistical significance between groups was found for number of observation made. $t(105) = 3.57$, $p = .001$

Percentage of "off-task" behavior during learning activity. During each treatment group, three investigators made observations of how well student stayed on task. Percentages were determined by dividing the number of observations classified as "off-task" by the total number of observations made for each treatment group. More than half (57%) of the observations in the educator-led group were classified as "off-task" compared to the small percentage (3%) of off-task observations in the MDK group. Examples of observations labeled as "off-task" include students talking to each other about unrelated topics, getting a drink from the drinking fountain, looking at displays other than the one containing the bird they were trying to identify, or sitting down on the floor and not participating at all in the learning activity.

Emotional responses observed during the learning activity. Observation notes made during the learning activities for both treatment groups were coded for emotional responses. Emotional responses were defined as anything that demonstrated that the student actually cared about the task. If the observation showed that the student was either satisfied or frustrated while completing the learning activity, this observation was counted. We did not include boredom, because this emotion is hard to decipher. Examples of observations that were classified as emotional responses include fist pumps, head nods, or exclamations such as "yes" or "ah man." These responses were considered an indication of student engagement in the learning experience. It was noted that students using the MDK had an average of eight emotional responses (e.g., either satisfaction, excitement, or frustration) during the treatment while no emotional responses were observed at all in the educator-led group.

Social learning. Social learning was observed in the MDK group, meaning that students naturally paired up and collaborated about their learning experience. This happened an average of five times with fifth graders and an average of seven times with seventh graders. Students in the educator-led group, although already in groups, didn't necessarily work together or discuss answers. Only one observer noticed two instances of social learning and in both cases, students were sharing answers rather than collaborating.

Comparison of scaffolding feedback. Clarification or expansion of learning was observed an average of eight times with the fifth graders in the educator-led group. This was also observed nine times with the seventh graders in the educator-led group. The MDK scaffolding tool does not have a feature to provide feedback during the learning activity other than displaying the bird the student identified and allowing the student to decide if their identification was correct. There was no expansion of learning observed although the MDK tool does have an option to learn more by pressing a button for "more info."

Achievement Comparison by Grade Level

Because total scores for several students dropped from the pre-test to the post-test, a negative case analysis was conducted. Table 6 shows the percentages of students who scored lower on the post-test than on the pre-test. In every category more seventh graders scored lower on the post-test than the fifth graders. Because of this, results were analyzed by grade to see what specific differences existed between fifth and seventh graders.

Table 7

Percentage of Students Who Scored Lower on the Post-test than on the Pre-test by Category

	Treatment	n	No. Obs.	Level of Detail	Glossary Terms	Total
5th Grade	Educator	43	16%	35%	19%	9%
	MDK	46	4%	20%	13%	15%
7th Grade	Educator	32	22%	53%	41%	25%
	MDK	28	29%	57%	39%	29%

Total observation score by grade. The total observation score for fifth graders, regardless of treatment, improved significantly from the pre- to post-test $F(1,87) = 23.09$, p = .000 while the total score for seventh graders, regardless of treatment, did not $F(1,58) = 1.73$, p = .193. In fact, mean scores for seventh graders dropped slightly for both treatment groups (see Table 7). Although not statistically significant (likely due to the small n), $F(1,87) = 2.54$, p = .115, there was a notable difference in total observations scores between treatment groups with the fifth graders. The MDK group for fifth graders improved on average by 5 points while the educator-led group improved on average by 2.5 points.

Table 8

Means for the Total Observation Score on the Pre- and Post-tests

	Treatment	n	Mean Pre-Test	Mean Post-Test	Difference
5th Grade	Educator	43	20.2	22.7	+2.5
	MDK	46	19.8	24.8	+5.0
	Total	89	20.0	23.8	+3.8
7th Grade	Educator	32	36.5	34.6	-2.0
	MDK	28	35.8	34.3	-1.5
	Total	60	36.2	34.5	-1.9

Glossary terms by grade. Table 8 shows that fifth graders improved significantly more than the seventh graders, regardless of treatment group, in the use of glossary terms. The main effects for fifth graders were statistically significant, $F(1,87) = 46.2$, p = .000. This reveals that overall, regardless of treatment group, fifth graders used more glossary terms on their post-test observations than they did on their pre-test observations. The interaction effects between treatment groups were not significant for fifth graders, $F(1,87) = .33$, $p = .57$; both treatment groups improved in a similar fashion. Between factors for fifth graders was not significant, $F(1,87) = 0.15$, $p = .9$, meaning that there was no difference between treatment groups.

The main effects for seventh graders were not statistically significant, $F(1,58) = 2.45$, $p = .123$, meaning that there was no improvement in the use of glossary terms between the post-test and pre-test observations. There was also no difference between treatment groups for seventh graders. Neither the interaction effects nor the between factors were significant. $F(1,58) = .24$, $p = .63$, $F(1,58) = .16$, $p = .69$, respectively.

Table 9

Means for Use of Glossary Terms on the Pre- and Post-tests

	Treatment	n	Mean Pre-Test	Mean Post-Test	Difference
5th Grade	Educator	43	1.0	2.3	+1.3
	MDK	46	0.9	2.4	+1.5
	Total	89	0.9	2.4	+1.4
7th Grade	Educator	32	2.8	3.3	+0.5
	MDK	28	2.8	3.7	+0.9
	Total	60	2.8	3.5	+0.7

Number of observations by grade. The number of observations went up slightly for both treatment groups of fifth graders and went down significantly $F(1,58) = 7.98$, $p = .006$, for both groups of seventh graders (see Table 9). The number of observations made by seventh graders, regardless of treatment groups, was significantly less on the post-tests.

Table 10

Means for the Number of Observations on the Pre- and Post-test

	Treatment	n	Mean Pre-Test	Mean Post-Test	Difference
5th Grade	Educator	43	5.4	5.6	+0.2
	MDK	46	5.7	6.2	+0.5
	Total	89	5.6	5.9	+0.4
7th Grade	Educator	32	9.2	8.3	-0.9
	MDK	28	8.8	7.8	-1.1
	Total	60	9.0	8.1	-1.0

Note. For fifth graders: The main effects were not statistically significant, $F(1,87) = 2.37$, $p = .13$. The interaction effects were not significant, $F(1,87) = .53$, $p = .47$. Between factors was not significant, $F(1,87) = 0.81$, $p = .37$. For seventh graders: The main effects were statistically significant, $F(1,58) = 7.98$, $p = .006$. The interaction effects were not significant, $F(1,58) = .06$, $p = .81$. Between factors was not significant, $F(1,58) = .73$, $p = .4$

Discussion

This discussion addresses the implications of the results previously presented, first by summarizing the results, second, reflecting on achievement by treatment group and by grade, and third, considering implications. Limitations of this study and recommendations for future research are also considered.

Summary of Results

The results showed a significant difference in the scores from the pre-test to the post-test regardless of treatment, when combining both grades. Because there was no significant difference between treatment groups and all students did improve significantly, the MDK tool was as successful as the educator-led scaffolding in improving observation skills. In other aspects, the MDK was actually better than the teacher-led scaffolding: allowing students to work at their own pace, engaging them in the learning process, and encouraging collaboration.

Reflection on Findings

Student achievement is considered in the following section in two ways: First, by discussing the results for all students by treatment groups and second, by reflecting on the difference in outcomes between fifth and seventh graders.

Achievement by treatment. All pre- and post-test scores, including the total observation score and the sub-scores, did not have a significant difference between treatment groups. Perhaps the results would have shown a significant difference between treatment groups if the sample size had been larger. However, because many individuals did improve considerably, the lack of statistical significance is more likely due to the large variance among scores. Many individuals did show large gains.

Glossary terms. Although there wasn't a significant difference between treatment groups in the use of scientific terms on the post-test versus the pre-test, students using the MDK in both grades did use slightly more terms on their post-tests than students in the educator-led group. There are some reasons why the MDK is superior in scaffolding new vocabulary for students in the museum context. The built-in and easily accessible glossary provides consistency and accuracy with definitions and usage. The scientific terms presented with the MDK used to identify species puts the new word to use immediately in context. While the educators in this study were instructed to use the same definitions as the MDK, in a real museum setting, teachers leading a group may or may not teach scientific terms and they may or may not give accurate definitions.

Observation skills. Students using the MDK did as well or slightly better on the total observation score with an average increase of 2.6 points from the pre-test to the post-test as compared with students in the educator-led groups with an average increase of 0.6 points. Based on these results both methods helped students improve observation skills. If the goal of either treatment of scaffolding tool, MDK or educator, is to improve the observation skills of learners in the museum setting, the MDK works just as well as a group led by a teacher or museum docent.

Inferences. The almost non-existent, and certainly not statistically significant, difference between the pre- and post-tests in regard to the use of valid inferences provides evidence that the dichotomous key scaffolding tool used on a mobile device or with an educator does not help students make acceptable, scientific inferences. This was not surprising since the tool was not designed to improve the students' ability to make valid, scientific inferences. The dichotomous key scaffolding tool simply asks questions that focus the learner's observations and doesn't help them make the next logical step in the scientific method, which is to make hypotheses and or inferences based on observations. Another explanation could be that students were already able to make inferences before the treatment so there wasn't room to show improvement. Another instructional intervention may be needed to target this specific learning outcome.

Achievement by grade level. While there were no differences found in achievement between treatment groups, a number of different findings suggest that the scaffolding tools were more appropriate and more effective on a whole for fifth graders than for seventh graders. In respect to learning and use of scientific terms, regardless of treatment, this learning activity in the museum context was more effective for fifth grade students than seventh. Additionally, fifth graders' total observation score in the MDK group increased by five points and the educator-led group increased by 2.5 points while the total scores in both treatment groups for seventh graders actually decreased. The negative case analysis also confirms that the learning activity was more fitting for fifth graders. More seventh graders scored lower on the post-test than the pre-test in every category when compared with fifth graders.

There are a number of possible explanations for why this learning activity is more suitable for fifth graders than seventh graders. Perhaps this type of activity or content was new for fifth graders whereas seventh graders may have already been exposed to dichotomous keys or similar learning activities. New material could be more motivating for students while material previously studied could result in boredom or apathy. It could also mean that this activity or subject matter was more interesting and more engaging for fifth graders in general. Or it could mean that seventh graders had already developed their observation skills to a level that would not show much improvement using this particular scaffolding tool.

The fact that seventh graders scores were in the mid-thirties and didn't improve much while the fifth graders scores were in the low twenties and did improve suggest that this intervention was more appropriate for the fifth grade. The increased sociability of seventh graders could account for the lack of improvement as well because they were perhaps more interested in interacting and impressing their peers than they were in performing on the tests or participating in the learning activity. It should also be noted that the seventh graders were shuttled back and forth from their school for each treatment, one group in the morning and one in the afternoon. The fifth graders were all on campus at the same time, and participated in the study after viewing a musical presentation at another campus location. The time of day and transportation methods could have affected the energy level of the students participating in the study.

Implications

Although the data from the pre- and post-tests for all students indicate that the MDK was as effective as the educator-led group in improving observation skills, there are some advantages that the MDK has over the educator-led group. Conversely, there are some advantages that the educator-led group has over the MDK. The following discussion summarizes these advantages and disadvantages.

Working pace. There was a significantly larger range in the number of birds identified by students in the MDK groups than in the educator-led groups during the learning activity. This suggests that students in the MDK groups could work at their own pace during the learning activity while students in the educator-led group were forced to work at the pace of the group. Being able to work at one’s own pace enables student engagement because the material isn’t being presented too quickly or too slowly. It could be argued that students working slowly through the learning task weren’t learning as much and perhaps weren’t being challenged. However, in this learning task, with the goal of improving observation skills, working slowly could mean that the student was being more thoughtful and careful in their observations.

Student engagement. It was observed that students using the MDK scaffolding tool were more engaged and motivated than students in small groups led by an educator. A significantly larger number of instances were observed of students demonstrating off-task behavior in the educator-led group than in the MDK group. This finding is likely related to the work pace of the students during the learning activity. Because students in the educator-led group were not able to work alone, but instead had to rely on the teacher as their scaffold, they could not work through the dichotomous key at their own pace. Perhaps this caused them to become bored or distracted since they had to wait for the group to reach the identification together. It could also mean that the educator wasn’t engaging or the students were not interested in this type of learning, which caused them to tune out. The transcripts from the educators did not show any inconsistencies between groups within this treatment.

It would seem a reasonable assumption that off task behavior would correlate with lower performance but in this case it doesn't. There was not much difference in this finding between fifth and seventh graders either. One possible explanation for this could be that even though the students were not as engaged in the educator-led group as they were in the MDK group, they still participated and completed the assignment. They still used the scaffolding tool to complete the task but their motivation was from the educator and the expectation that they were to fill out their handout as the group identified the bird together; whereas the motivation from the MDK group appeared to be intrinsic.

Emotional responses. Emotional responses, (i. e., satisfaction or frustration), were observed during the learning activity in the MDK groups and not at all in the educator-led groups. These emotional responses showed that students were invested and cared about the outcome of the task. One possible reason that the MDK prompted these kinds of emotional responses is because the activity involving use of the MDK could be viewed as a game. Students appeared to be intrinsically motivated by games or challenges. In this case, students seemed excited or disappointed as they confirmed their identifications. The lack of emotional responses in the educator-led group may be due to the fact that students were forced to move at the pace of the group and did not necessarily need to engage fully to get the answer at the end of each bird identification.

Social learning. The pattern of emotional responses observed in the MDK group suggest that the students actually cared about the activity to the point that they naturally wanted to pair up and share their successes and failures with each other. This type of scaffolding situation helps students internalize information because they have natural opportunities to communicate their thoughts with their peers who are also working on a similar task (Roehler & Cantlon, 1997).

Scaffolding feedback. Students using the MDK did not receive feedback during the learning activity except when they were expected to make their own decision by matching a picture to determine if they had correctly identified a specimen. Feedback from the educator to the students was observed in the educator-led group. This is a key advantage over the MDK because a teacher can make instant assessments and adjustments in what and how they respond to certain questions and situations while the MDK cannot.

Limitations

Two limitations to the study are the novelty factor and the tiredness effect. It could be argued that the motivation observed in the MDK group was due to the novelty of the technology. However, only one time in both the fifth and seventh grade groups was it observed that a student was not working within the "IdentifyMe" app. Both the fifth and seventh graders at their respective schools have a classroom set of iPads, which they use regularly so the students were already familiar with these devices. Familiarity with the specific technology can decrease the impact of novelty on learning activities (Davies, et al., 2008).

Another possible explanation for the large number of scores that decreased from the pre-test to the post-test in the negative case analysis is that there may have been a “tiredness effect”. By the time the students had taken the pre-test, participated in the learning activity and then were asked to take a post-test, their bodies and minds were perhaps ready for a rest. They may not have performed as well if the pre- and post-test were given the day before the treatment and the day after.

Recommendations

Based on the results and the limitations of this study, the following recommendations would advance the MDK scaffolding tool and improve the design of the study: a) incorporating a feedback feature in the MDK, b) developing more sophisticated content, and c) separating the pre- and post-tests so that they are given on different days.

Incorporating a feedback feature. Although the MDK provides consistency in content and students using the MDK were observed to be more on-task and engaged, they did not receive on-the-spot assessment and feedback, as was the case with the students in the educator-led group. This is a key aspect that is missing in the MDK.

The feedback aspect that the live educator option had over the MDK is a critical advantage. Although the MDK, as a hard scaffold, can provide individual and mobile scaffolding support for students engaged in learning activities in the museum setting, the lack of feedback prevents students from actually returning to their mistakes and analyzing where their thought processes failed. It could then be concluded that a live educator is the better scaffolding tool.

However, the downside to the educator as a scaffolding tool in this setting was the demand on his or her time and energy. This is especially important to consider since it has been demonstrated that students were more off-task in this treatment group and thus a teacher would need to exert even more energy than in the traditional classroom to keep the students engaged.

In order to facilitate feedback within the MDK and solve this scaffolding problem, museum educators at the Bean Life Science Museum have started to develop a feedback mechanism in newer versions of the “Identify Me” app. When a student begins working on an identification of a specimen in the museum, they would either scan a QR code or enter a number so that the MDK would be able to alert the learner when they answered a question incorrectly. The app would prompt the student to find and fix their mistake. While this new feature does not provide the human touch as a live educator can, it is an improvement from the version employed in this study.

Developing more sophisticated content. Findings from this study also indicate that this type of learning activity is more appropriate for fifth graders than seventh graders. Thus, investigators could develop content for the MDK that is more sophisticated, and hopefully more fitting for older students.

Separating pre- and post-tests. In addition to these improvements in the learning tool, the study could be improved by separating the pre-test, learning activity, and post-test onto separate days. This modification would hopefully minimize the potential effects of mental or physical fatigue.

Future Research

Future research would focus on the before mentioned recommendations along with a study of student engagement. Studies would concentrate on the effectiveness of integrating feedback into the MDK tool, developing specific content correlating with curriculum standards for multiple grades, and analyzing the effects of delaying the time between the pre-test, learning activity, and post-test.

In addition, future research could be focused on exploring the findings related to student engagement. Specifically, researchers could look at the working pace of students using the MDK and their emotional responses. This research could provide interesting results and have implications for future implementation of the MDK scaffolding tool in the museum setting.

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Appendix A

Paper Dichotomous Key

1. Black-necked Stilt

- Does this bird have a long bill (longer than its head) and long, stilt like legs? Yes
- Does this bird have a black tarsi? No
- Does it have a solid black nape and mantle? Yes

2. Virginia Rail

- Does this bird have a long bill (longer than its head) and long, stilt like legs? No
- Does this bird have webbed feet or lobed toes? No
- Does this bird have a short, curved downward-facing bill? No
- Does it measure less than six inches (from head to tail-feathers)? Yes

3. Blue-Winged Teal

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feed or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? No
- Does it have a white patch on its cheek? No
- Does it have a white patch on its lores? Yes

4. Green-Winged Teal

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feed or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? No
- Does it have a white patch on its cheek? No
- Does it have a white patch on its lores? No
- Does it have a black-feathered breast? No
- Does it have yellow feet? No

5. Cinnamon Teal

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feed or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? No
- Does it have a white patch on its cheek? No
- Does it have a white patch on its lores? No
- Does it have a black-feathered breast? No
- Does it have yellow feet? Yes

6. Northern Shoveler

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feed or lobed toes? Yes
- Does it have a solid white breast? Yes
- Does it have a long, white neck and predominately white wings? No
- Are there stripes on the nape? No
- Are there black or dark green feathers on the head? Yes
- Is there a white patch on the nape? No
- Does it have large, white patches on the lore area? No
- Does it have comb-like projections along the edge of the bill? Yes

7. Ruddy Duck

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feed or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? No
- Does it have a white patch on its cheek? Yes
- Does it have a long, black-feathered neck? No

8. American Coot

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? Yes
- Are there stripes on the nape? No
- Does it have only red heathers on its crown? No
- Are the lores a different color than the cheek? No
- Is there a mall white patch on the throat or just below the bill? No
- Does it have a bill that is flat like a duck's? No

9. Ring-necked Duck

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? Yes
- Are there stripes on the nape? No
- Does it have only red feathers on its crown? No
- Are the lores a different color than the cheek? No
- Is there a small white patch on the throat or just below the bill? Yes
- Does it have a bill that is flat like a duck's? Yes

10. Northern Pintail
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? Yes
    - Does it have a solid white breast? Yes
    - Does it have a long, white neck and predominately white wings? No
    - Are there stripes on the nape? Yes

11. Wood Duck
    - Does the bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? Yes
    - Does it have a solid white breast? No
    - Does it have more than one color on the bill (including top and bottom)? Yes
    - Are there stripes on the nape? Yes
    - Does this bird have black legs and feet? No

12. Redhead
    - Does the bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? Yes
    - Does it have a solid white breast? No
    - Does it have more than one color on the bill (including top and bottom)? Yes
    - Are there stripes on the nape? No
    - Does it have only red heathers on its crown? Yes

13. Canvasback
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feed or lobed toes? Yes
    - Does it have a solid white breast? No
    - Does it have more than one color on the bill (including top and bottom)? No
    - Does it have a white patch on its cheek? No
    - Does it have a white patch on its lores? No
    - Does it have a black-feathered breast? Yes
    - Does it have a bill that is flat like a duck's? Yes

14. Belted Kingfisher
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? No
    - Does it measure less than six inches (from head to tail-feathers)? No
    - Does it have a white ring at the base of its neck, and a prominent shaggy crest? Yes

15. Lesser Scaup

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? Yes
- Are there stripes on the nape? No
- Does it have only red feathers on its crown? No
- Are the lores a different color than the cheek? No
- Is there a small white patch on the throat or just below the bill? No
- Does it have a bill that is flat like a duck's? Yes

16. Pied-billed Grebe

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? Yes
- Are there stripes on the nape? No
- Does it have only red feathers on its crown? No
- Are the lores a different color than the cheek? No
- Is there a small white patch on the throat or just below the bill? Yes
- Does it have a bill that is flat like a duck's? No

17. Horned Grebe

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? No
- Does it have a white patch on its cheek? No
- Does it have a white patch on its lores? No
- Does it have a black-feathered breast? Yes
- Does it have a bill that is flat like a duck's? No

18. American Avocet

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does the bird have black tarsi? No
- Does it have a solid black nape and mantle? No

19. White-face Ibis

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does this bird have black tarsi? Yes
- Does it have a white nape and mantle? No
- Does it have yellow orbital rings? No
- Is the tarsus at least five inches long? No
- Are the belly and breast feathers all one color? Yes

20. Willet

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does this bird have black tarsi? Yes
- Does it have a white nape and mantle? No
- Does it have yellow orbital rings? No
- Is the tarsus at least four inches long? No
- Are the belly and breast feathers all one color? No

21. Trumpeter Swan

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? Yes
- Does it have a long, white neck and predominately white wings? Yes
- Does it have black-tipped primary feathers? No

22. Great Blue Heron

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does this bird have black tarsi? Yes
- Does it have a white nape and mantle? No
- Does it have yellow orbital rings? No
- Is the tarsus at least five inches long? Yes
- Are the belly and breast feathers all one color? No

23. American Bittern

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does this bird have black tarsi? Yes
- Does it have a white nape and mantle? No
- Does it have yellow orbital rings? Yes

24. Snowy Egret

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does this bird have black tarsi? Yes
- Does it have a white nape and mantle? Yes
- Does it have black feet? No

25. Ring-billed Gull

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? Yes
- Does it have a long, white neck and predominately white wings? No
- Are there stripes on the nape? No
- Does it have black or dark green feathers on the head? No

26. Franklin's Gull

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? Yes
- Does it have a long, white neck and predominately white wings? No
- Are there stripes on the nape? No
- Does it have black or dark green feathers on the head? Yes
- Is there a white patch on the nape? No
- Does it have large, white patches on the lore area? No
- Does it have comb-like projections along the edge of the bill? No

27. Steller's Jay
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? No
    - Does it measure less than six inches (from head to tail_feathers)? No
    - Does it have a white ring at the base of its neck, and a prominent shaggy crest? No
    - Is the head covered in only black feathers? No
    - Does it have a prominent crest? Yes

28. Scrub Jay
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? No
    - Does it measure less than six inches (from head to tail_feathers)? No
    - Does it have a white ring at the base of its neck, and a prominent shaggy crest? No
    - Is the head covered in only black feathers? No
    - Does it have a prominent crest? Yes

29. American Crow
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? No
    - Does it measure less than six inches (from head to tail_feathers)? No
    - Does it have a white ring at the base of its neck, and a prominent shaggy crest? No
    - Is the head covered in only black feathers? Yes
    - Does it have a completely black body? Yes
    - Is the bill thick and more than 1 and ½ inches in length? No

30. Black-Billed Magpie
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? No
- Does this bird have a short, curved downward-facing bill? No
- Does it measure less than six inches (from head to tail_feathers)? No
- Does it have a white ring at the base of its neck, and a prominent shaggy crest? No
- Is the head covered in only black feathers? Yes
- Does it have a completely black body? No

31. Sandhill Crane
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does this bird have black tarsi? Yes
- Does it have a white nape and mantle? No
- Does it have yellow orbital rings? No
- Is the tarsus at least four inches long? Yes
- Are the belly and breast feathers all one color? Yes

32. Bufflehead
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? Yes
- Does it have a long, white neck and predominately white wings? No
- Are there stripes on the nape? No
- Does it have a black or dark green feathers on the head? Yes
- Is there a white patch on the nape? Yes

33. Great Egret
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? Yes
- Does this bird have black tarsi? Yes
- Does it have a white nape and mantle? Yes
- Does it have black feet? Yes

34. Common Goldeneye
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have solid white breast? Yes
- Does it have a long, white neck and predominately white wings? No
- Are there stripes on the nape? No
- Does it have black or dark green feathers on the head? Yes
- Is there a white patch on the nape? No
- Does it have large, white patches on the lore area? Yes

35. Oldsquaw

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? Yes
- Are there stripes on the nape? No
- Does it have only red feathers on its crown? No
- Are the lores a different coor than the cheek? Yes
- Does it have a predominately white crown? Yes

36. Harlequin Duck

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? Yes
- Are there stripes on the nape? Yes
- Does this bird have black legs and feet? Yes

37. Ring-necked Pheasant

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? No
- Does this bird have a short, curved downward-facing bill? Yes
- Is this bird longer than seven inches (from head to tail feathers)? Yes
- Are the bird's tail feathers easily a foot long? Yes

38. Snow Goose

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? Yes
- Does it have a long, white neck and predominately white wings? Yes
- Does it have black-tipped primary feathers? Yes

39. Canada Goose

- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? No
- Does it have a white patch on its cheek? Yes
- Does it have a long, black-feathered neck? Yes

40. Greater White-fronted Goose
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? Yes
- Does it have a solid white breast? No
- Does it have more than one color on the bill (including top and bottom)? Yes
- Are there stripes on the nape? No
- Does it have only red feathers on its own? No
- Are the lores a different color than the cheek? Yes
- Does it have a predominately white crown? No

41. Common Raven
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? No
- Does this bird have a short, curved downward-facing bill? No
- Does it measure less than six inches (from head to tail_feathers)? No
- Does it have a white ring at the base of its neck, and a prominent shaggy crest? No
- Is the head covered in only black feathers? Yes
- Does it have a completely black body? Yes
- Is the bill thick and more than 1 and ½ inches in length? Yes

42. Western Screech Owl
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? No
- Does this bird have a short, curved downward-facing bill? Yes
- Is this bird longer than seven inches (from head to tail feathers)? No
- Is the tarsus (feathered or un-feathered) clearly visible white perching? Yes
- Is the facial disc over 1 and ½ inches wide? Yes

43. Burrowing Owl
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? No
- Does this bird have a short, curved downward-facing bill? Yes
- Is this bird longer than seven inches (from head to tail feathers)? No
- Is the tarsus (feathered or un-feathered) clearly visible while perching? Yes)
- Is the facial disc over 1 and ½ inches wide? No
- Does it have tufts of feathers on its crown that look like horns? No

44. Barn Owl
- Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
- Does this bird have webbed feet or lobed toes? No
- Does this bird have a short, curved downward-facing bill? Yes
- Is this bird longer than seven inches (from head to tail feathers)? Yes
- Are this bird's tail feathers easily a foot long? No
- Does it have tufts of feathers on its crown that look like horns? No

- Does it have a white facial disc? Yes

45. Great Horned Owl
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? Yes
    - Is this bird longer than seven inches (from head to tail feathers)? Yes
    - Are this bird’s tail feathers easily a foot long? No
    - Does it have tufts of feathers on its crown that look like horns? Yes
    - Does it have a clear patch of white feathers on the throat? Yes

46. Short-eared Owl
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? Yes
    - Is this bird longer than seven inches (from head to tail feathers)? Yes
    - Are this bird’s tail feathers easily a foot long? No
    - Does it have tufts of feathers on its crown that look like horns? No
    - Does it have a white facial disc? No

47. Northern Saw-Whet Owl
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? Yes
    - Is this bird longer than seven inches (from head to tail feathers)? No
    - Is the tarsus (feathered or un-feathered) clearly visible while perching? No
    - Does it have a light, cream-colored bill? No

48. Northern Pygmy-Owl
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? Yes
    - Is this bird longer than seven inches (from head to tail feathers)? No
    - Is the tarsus (feathered or un-feathered) clearly visible while perching? No
    - Does it have a light, cream-colored bill? Yes
    - Does it have tufts of feathers on its crown that look like horns? No

49. Flammulated Owl
    - Does this bird have a long bill (longer than its head) and long, stilt-like legs? No
    - Does this bird have webbed feet or lobed toes? No
    - Does this bird have a short, curved downward-facing bill? Yes
    - Is this bird longer than seven inches (from head to tail feathers)? No
    - Is the tarsus (feathered or un-feathered) clearly visible while perching? No
    - Does it have a light, cream-colored bill? Yes

- Does it have <u>tufts</u> of feathers on its <u>crown</u> that look like <u>horns</u>? Yes

50. Long-eared Owl
    - Does this bird have a long <u>bill</u> (longer than its head) and long, stilt-like legs? No
    - Does this bird have <u>webbed feet</u> or <u>lobed</u> toes? No
    - Does this bird have a short, curved downward-facing <u>bill</u>? Yes
    - Is this bird longer than seven inches (from head to <u>tail feathers</u>)? Yes
    - Are this bird's <u>tail feathers</u> easily a foot long? No
    - Does it have <u>tufts</u> of feathers on its <u>crown</u> that look like <u>horns</u>? Yes
    - Does it have a clear patch of white feathers on the <u>throat</u>? No

Appendix B

Pre- and Post-test

Initials: ___________________________

Write down as many observations as you can about this bird. (2 minutes)

Based on your observations, what can you tell me about this bird?

Appendix C

Grading Sheet

Observations	Number of Observations	Level of Detail (1,2,3)	Glossary Terms	Inferences	No. of Inferences	Inferences based on observation	
							Total Score
Totals	0	0	0		0	0	0

Appendix D

Student Sample

Observations	No. of Observations	Level of Detail (1,2,3)	Glossary Terms	Inferences	No. of Inferences	Glossary Terms	Inferences based on observation	Total Score
two legs	1	2		It can probably fly	1		1	0
3 toes per leg	1	2		based on beak size it probably had a diet of insects and worms	1		1	0
top of head orange	1	3		it might have lots of colors so it may scare predators off	1		1	0
many colors	1	1						0
long tail feathers	1	2	1					0
med beak	1	2						0
red and light orange belly	1	3	1					5
feathers above	1	2						3
shiny wings	1	2						3
brown and blue wings	1	2						3
blue/pale beak	1	3						4
								0
Totals	11	24	2		3	0	3	**43**