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An exploratory study to understand elementary school students' conceptions of food chains

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An Exploratory Study to Understand Elementary School Students' Conceptions of Food Chains

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by Shelby Lynn Snowden

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Accepted by the faculty of the Department of Biology, James Madison University, in partial fulfillment of the requirements for the Honors College.

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Abstract

Research has shown that elementary school is a critical time to pique children's interest in science. However, many enrichment activities known to pique this interest in young children are not available to students of low socioeconomic status, English Language Learners, racial minorities, and students with disabilities. This has encouraged many higher education institutions to develop STEM outreach programs. Because of the cognitive gap between STEM professionals and young children and the logistics of implementing student-centered activities in heterogeneous classrooms, programs usually consist of activities that impress students with "sophisticated" science but are beyond the cognitive levels of most students and do not create lasting interest in science or facilitate learning. These activities can also be unattractive for teachers, as they do not have the resources to carry out expensive, complex lessons and are already rushed to cover material required by the Virginia Standards of Learning (SOLs). Development of a sustainable K-5 outreach model that piques interest while aligning with foundational standards requires an understanding of the extent to which a short-duration enrichment lesson can enhance conceptual understanding of topics. To assess a novel K-5 outreach model to make science enrichment accessible to *all* children, data were collected representing children's conceptions of food chains through visual representation. Although no statistically significant changes in understanding were seen, student scores increased overall after the lesson and misconceptions were uncovered that can be used to further develop the lesson. This study also gathered baseline data that can serve as a model for assessing other outreach lessons, ultimately leading to an outreach model that serves K-5 communities as well as the engagement missions of higher education institutions throughout the country.

Introduction

For more than two decades, there has been a societal push for increased STEM interest and literacy, but a decrease in the amount of time and funding schools have available to teach science (Fulp, 2002). While the job opportunities in STEM have and will continue to grow at a faster rate over the next ten years than other sectors, the minority and socioeconomic achievement gap in K-12 science performance continues to widen, limiting the potential for the diversity in United States STEM fields that is essential to being globally responsive, and therefore, competitive (NCES, 2016, Page, 2007, PCAST, 2012). On the 2015 National Assessment of Educational Progress (NAEP) Science Assessment, 51% of white fourth grade students scored at or above proficient, while 15% of black fourth grade students and 21% of hispanic fourth grade students scored at or above proficient. Furthermore, an increase in STEM interest and literacy is also necessary to create socioscientifically informed citizens. Those who are educated in science are able to fit their own worldview into the context of the natural world, gain a sense of responsibility for their actions, be sensitive to issues regarding the environment, respect differing opinions, and exercise moral reasoning (Zeidler, 2014). Collectively, these issues have led to a rise in the number of K-12 outreach programs from higher education institutions and other STEM and medical professionals (Laursen *et al.,* 2007).

One of the ways in which higher education strives to encourage STEM interest in K-12 students is through "scientist in the schools" programs, where a STEM professional comes into a school, does a demonstration for or activity with the students, and gives a brief description of his or her career. Outreach activities from higher education, STEM, and medical professionals are often targeted to older students - particularly high school students - as it is a good time to recruit students to colleges and careers and the students are cognitively ready for the higher level activities with which these professionals are familiar (Wilson and Chizeck, 2000). However, the elementary school years have been shown to be a critical period for piquing a child's interest in science (Maltese and Tai, 2010). Maltese and Tai (2010) found that 65% of 79 scientists and science graduate students interviewed gained an interest in science while they were in elementary school. Students' attitudes towards science tend to be rather fixed by the time they reach middle school (Lindahl, 2007). Furthermore, students who report interest in a STEM career by the eighth grade are much more likely to obtain a degree in a STEM-related field than their peers who do not express interest at that age (Tai *et al.,* 2006). However, students often have a very limited view of what a scientist is and what types of STEM careers are available to them (Cleaves, 2005). Having "scientist in the schools" programs in elementary school classrooms would increase the probability of sparking children's sustainable interest in science and expand students' conceptions about science and science careers, increasing the likelihood of them pursuing further science education and STEM careers.

While there is a lot of evidence to support sparking interest in science early, research and observations show that the majority of interest-piquing science activities are available only to select groups of students. Science enrichment opportunities are also typically targeted to high-achieving students of higher socioeconomic status (Weiss *et al.,* 2003, Wilson and Chizeck, 2000). Activities that have been shown to pique students' interest in science and create a desire to learn more about science are often available only to select groups of students, like those in gifted programs and STEM clubs. Students of low socioeconomic status, English Language Learners (ELL), racial minorities, and students with disabilities are generally underrepresented in science (Oliver and Hodges, 2014, Parsons, 2014). Students who do not have access to science education opportunities can feel discouraged by their lack of scientific understanding, even though it is most often due to lack of resources. In one study, a resource-limited district was given technology that allowed students to access previously unavailable educational opportunities and it was reported that the self-esteem of the students increased due to their new achievements in understanding (Oliver and Hodges, 2014). This is critical because a lack of confidence in science contributes to a student's choice not to further his or her science education (Cleaves, 2005). In the 1960s, Finland initiated a common curriculum for all students and as of 2014, their students' international test scores vary by less than 5 percent (Oliver and Hodges, 2014). Finland's success with a common curriculum suggests that the same initiative in the United States could reduce the current achievement gap. Making outreach programs from higher education, STEM, and medical professionals available to all students, rather than only high-achieving students or students in special programs, could increase the number of students belonging to groups that are underrepresented in science who choose to pursue STEM-related careers as well. Although we tend to think of science as strictly objective, part of the nature of science is that it is subjective and affected by culture. A person's background and worldview strongly affect how he or she learns and understands science (Parsons, 2014). Because of this, it is important to make meaningful science activities available to all students in order to bring about diverse perspectives in the scientific community.

Although the research clearly shows the importance of increasing the number of outreach programs from higher education, STEM, and medical professionals in elementary schools, there are some complications with implementing them in K-5 classrooms. Many of the demonstrations and activities performed by these scientists are so sophisticated that they do not leave lasting impressions on young students because they are beyond their cognitive levels (Wilson and Chizeck, 2000). Along the same line, the activities often consist of demonstrations for the students, but research has shown that it is more effective to teach science through inquiry (Osborne, 2014). In addition to the gap between the level of the activities and the cognitive levels of the students, these activities often focus on topics that are not covered in the K-5 Virginia Standards of Learning (SOLs). Because of that, they are unattractive for elementary school teachers who are already struggling to have enough time to teach required material. Furthermore, these higher-level science activities are not a feasible model for elementary school teachers to adopt and implement on their own. Because of these issues, a K-5 traveling science outreach program was created from an institute of higher education in 2014. This program is designed to (1) make science enrichment experiences accessible to all students by visiting heterogeneously-grouped classrooms during the school day, (2) deepen students' understandings of foundational life science concepts using guided inquiry, and (3) demonstrate for elementary school teachers effective and engaging methods of teaching science. There are six different standards-based instructional activities for students, rather than entertaining science activities that simply capture students' attention, but do not develop student understanding. Outreach programs like this one need to be assessed in order for them to be sustainable and effective. However, it is difficult to assess the long-term goals of these types of outreach programs (i.e. a larger and more diverse STEM workforce) due to the short duration and infrequency of the programs (Laursen *et al.*, 2007). This study aims to look at the short-term goals of outreach, specifically changes in student understanding after a lesson has taken place.

The lesson analyzed in this study - "Hoooo Has Energy?" - focuses on food chains and energy transfer through the trophic pyramid. This lesson was chosen for this study because (1) it was the most requested of the six lessons (65 of the 120 outreach visits), (2) it is foundational for understanding of future science content, and (3) the concept of food chains is generally not taught using inquiry. "Hoooo Has Energy?" is designed for third grade classes, as it is critical that students understand food chains and energy transfer when they learn about plant anatomy and photosynthesis, niches, ecosystem interactions, and natural resources after third grade. The Next Generation Science Standards state that by fifth grade, students should understand that the food of any organism can be traced back to plants (LS2.A), as well as energy transfer in ecosystems (LS2.B) (NGSS Lead States, 2013). Using inquiry to give students a deeper understanding of food chains and energy transfer sets them up for success in future science classes.

In this study, drawings were used to assess the students' understanding of concepts on both assessments. Drawings are a beneficial way to uncover the thoughts of young students, since it is often difficult for them to clearly and fully explain their ideas verbally (Anderson *et al.*, 2014, Holliday, Harrison, and McLeod, 2009). Because of this, drawings can often expose students' misconceptions (Anderson *et al.,* 2014). Drawings are much more open-ended than written questions, which allows students to express themselves without striving to come up with the "correct" answer to the question and reveals what the students consider important information (Anderson *et al*., 2014, Rennie and Jarvis, 1995). When students construct a drawing, it also promotes reflection about the content and can often help children think at the metacognitive level and understand more complex scientific concepts, as well as encourage higher-level thinking (Anderson *et al.,* 2014). A study by Lin and Hu (2010) and a study by Villarroel and Infante (2014) both had students create drawings and classified drawings based on certain key elements. Villarroel and Infante (2014) classified drawings as Type 1 ("Full Understanding"), Types 2 and 3 ("Incomplete Understanding"), and Type 4 ("Insufficient Understanding"). Lin and Hu (2010) had students draw food chains and classified the drawings using numbers from zero to three. They designated three key words - producers, consumers, and decomposers - and assessed the relationships between them in the drawings (A score of three - mentioned all the key words and appropriately showed the relationships among them; A score of zero, mentioned few to none of the key words and failed to show any relationships among them.). Similar to those studies, a rubric was used to assess drawings in this study using numbers from zero to two. However, rather than using scores to classify drawings, the drawings were scored for four different rubric items and then data were analyzed for each rubric item individually.

For the sake of clarity and interpretation, students were given stamps to represent the organisms in their drawings for this study. The rationale for this approach was based on prior observations of elementary school students completing this task. Most third graders have trouble drawing organisms in a way that would be easily identifiable for scoring, but asking them to label each organism could deter children from the accurate representation of multiple pictures of one organism. The use of stamps did not create any restrictions on the number of animals on the paper as drawing or stickers would have.

The purposes of this study were to (1) gain a better understanding of children's ideas about foundational life science topics, (2) uncover students' misconceptions about food chains,

(3) determine if these short-duration "scientist in the schools" programs can provide students with experiences that will allow them to successfully transfer knowledge, and (4) provide evidence of the impact of outreach that could be used to encourage other higher education institutions to adopt the model in their own communities. We hoped to see students being able to transfer knowledge from the lesson to the post-assessment, meaning that they would be able to apply their understanding of food chains gained through the "Hoooo Has Energy?" lesson to the creation of a food chain on the post-assessment. The key elements looked for in the students' drawings to indicate levels of understanding were (1) the presence of a plant at the beginning of the food chain (after the sun), (2) multiple examples of an organism consuming another organism, (3) the presence of the sun at the beginning of the food chain, and (4) the presence of a triangular shape, indicating that the amount of available energy decreases at each increasing level of the trophic pyramid.

Methods

"Hoooo Has Energy?"

This lesson is designed for third grade classes and aligns with Virginia SOLs 3.1 and 4.1 (The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science), 3.5 (The student will investigate and understand relationships among organisms in aquatic and terrestrial food chains), and 4.5 (The student will investigate and understand how plants and animals, including humans, in an ecosystem interact with one another and with the nonliving components in the ecosystem) (VDOE, 2010).

This lesson addresses the connection between energy transfer and the trophic pyramid. To begin this lesson, students are asked what they know about food chains. Their ideas are recorded on the board for them to refer to and to quickly gauge their initial understandings. Then, students are shown an image of a lion chasing a cheetah and are asked what they think is occurring in the photo. When students state that the lion is trying to eat the cheetah, they begin to build the food chain of a lion as a class. A picture of a lion is placed on the board and students are asked if the lion would eat one or two cheetahs. After two cheetahs are placed on the board, students are asked if the cheetahs would eat one, two, or three zebras. Finally, after three zebras are placed on the board, the students are asked if one, two, three, or four producers should be placed at the bottom of the trophic pyramid. The students are not told how many organisms to place at each level, but rather the pyramid is created using guided inquiry. The creation of the trophic pyramid is followed by a discussion of its triangular shape. Students are then asked how they could figure out what a lion eats by investigating a dead lion rather than researching the answer. The students conclude that they could look into the lion's stomach, analyze the body parts found inside, and identify the animal from which the parts came. Students then apply this method of investigation to the dissection of owl pellets, purchased from Carolina Biological, to learn about the variety of prey one owl consumes by finding and identifying bones from rodents, shrews, moles, and birds. Students are given a worksheet with images of bones to help them identify each bone and the organism from which it came. Students find numerous skulls that indicate that one owl ate multiple organisms, reinforcing the triangular shape of the trophic pyramid. Students can observe their bones under a dissecting microscope to see them in more detail. The dissection is followed by dramatic play to act out a trophic pyramid. Students dress up as organisms representing three levels of a food chain and receive energy from the level below them, consume some of it, and pass up the remaining energy. The producers initially receive the energy from the sun. The students test this in a 1:3:5 ratio and a 3:2:2 ratio and find that only the former allows energy to transfer from the producers up to the top level. This allows students to discover the reason for the triangular shape of a trophic pyramid.

The assessment of this lesson consisted of a pre-assessment and an identical post-assessment to determine the change in understandings, if any. On both the pre- and post-assessment, the students were asked to use the stamps and a pen or pencil to draw a food chain. Drawings were blindly analyzed (no student names attached) by single-subject design (Creswell, 2012) to determine the scope of children's understandings and then a rubric was developed based on observed patterns (Table 1). The four rubric items were generated based on the Virginia SOLs that align with the "Hoooo Has Energy?" lesson. Specific sections of the Virginia SOLs that were explicitly taught in the lesson were each included as one rubric item - producers, consumers, energy from the sun, and flow of energy through food webs. Three scoring categories were created for each of the four rubric items, with the top score (2) indicating complete understanding for that rubric item, the lowest score (0) indicating that there was no evidence of understanding for that rubric item, and the middle score (1) indicating that there was some evidence of understanding, but not complete understanding. The drawings were then blindly coded by two raters based on the rubric.

Table 1. Rubric used to score drawings.

Key Concept	2	1	0	Item Letter
Producer SOL 3.5, 3.6, 3.10	The student placed a plant at the beginning of the food chain, indicating that it is the producer.	The student placed a plant in the food chain, but did not clearly show that it was the producer.	The student did not place a plant in the food chain.	A
Consumer SOL 3.5, 3.6	The student included more than one logical (likely to occur in nature) example of one organism consuming another.	The student included one logical (likely to occur in nature) example of one organism consuming another.	The student did not include an example of one organism consuming another **or** the example(s) included were not logical (likely to occur in nature).	B
Energy from the sun SOL 3.11, 4.4	The student included the sun in their drawing and clearly showed that the energy from the sun was being used by plants.	The student included the sun in their drawing, but did not clearly show that the energy from the sun was being used by plants.	The student did not include the sun in their drawing.	C
Trophic pyramid SOL 4.5	The student showed the number of organisms decreasing at each new trophic level (as the trophic levels increased).	The student showed the number of organisms decreasing at some new trophic levels (as the trophic levels increased).	The student did not show the number of organisms decreasing at any new trophic levels (as the trophic levels increased).	D

After the rubric was created, the two raters discussed each rubric item in order to establish a consistent method of scoring. Before the drawings were scored, the two raters looked at a sample of the drawings together, again to ensure consistent scoring. Although two raters scored the drawings in this study, a calculation for inter-rater reliability was not performed because all of the scores generated were identical between the two raters.

Data were collected from 66 third grade students before and after the lesson was given. Using the rubric, students were given a score of 0, 1, or 2 for each of the four rubric items. The data were then analyzed by student, rather than by averaging all student scores. Because the data were not continuous, a paired t-test could not be used to analyze pre- and post-assessment data. Therefore, the data were analyzed based on the percentage of students who decreased in score from pre- to post-assessment, increased in score from pre- to post-assessment, or had no change in score.

Data were also collected from 31 fourth grade students and 41 fifth grade students who were given the "Hoooo Has Energy?" lesson in their third grade classes. The fourth and fifth grade drawings were scored using the same rubric used for the third grade drawings. The data were again analyzed by student, rather than by averaging all student scores. Because the students had the lesson one or two years before, their data were compared to the third grade students' post-assessment data to determine whether students' ideas about food chains change between third and fifth grade. As was the case with the third grade pre- and post-assessment data, these data were not continuous and were therefore analyzed using an exact test of independence. The Bonferroni correction for multiple tests was performed, giving a significance level (α) of 0.0125.

Results

Pre- and post-assessments were collected from four third grade classes. Only students who created a pre-drawing and a post-drawing were analyzed in this study. A total of 66 third grade students' data were analyzed. Drawings were also collected from 31 fourth grade students, and 41 fifth grade students. The fourth and fifth grade students' data was analyzed and compared to the third grade students' post-assessment data. All of the drawings analyzed were from students who attend the same elementary school.

Quantitative Results

Pre- and Post- Assessment of Third Grade Students

For rubric item A, the average score on the pre-assessment was 1.7576 and the average score on the post-assessment increased to 1.8030. When the data were analyzed per student, 86.4% of students had no change in score between the pre- and post-assessment, 4.5% of students decreased in score, and 9.1% of students increased in score. The average score on the pre-assessment for rubric item B was 1.7727 and the average score on the post-assessment decreased to 1.6970. For rubric item B, 87.9% of students had no change in score after the lesson, 9.0% of students decreased in score, and 3.0% of students increased in score. For rubric item C, the average score on the pre-assessment was 0.9697 and on the post-assessment the average score increased to 1.2121. Looking at the data by individual students, 60.6% of students had no change in score, 12.1% of students decreased in score, and 27.3% of students increased in score. The average scores on both the pre-assessment and the post-assessment for rubric item D were 0.0758. For rubric item D, 93.9% of students had no change in score, 3.0% of students decreased in score, and 3.0% of students increased in score. Although there were changes in score observed after the lesson, the changes seen between the pre- and post-assessments were not found to be statistically significant (Table 2).

Table 2. Average scores and frequencies of changes in score from pre-assessment to post-assessment of third grade students.

Rubric Item	**Average Score (out of 2)**		**Change in Score**	**Percent of Students**
	Pre	*Post*		
A producer	1.7576	1.8030	-2	0
			-1	4.5
			0	86.4
			+1	9.1
			+2	0
B consumer	1.7727	1.6970	-2	4.5
			-1	4.5
			0	87.9
			+1	0
			+2	3.0
C energy from the sun	0.9697	1.2121	-2	7.6
			-1	4.5
			0	60.6
			+1	10.6
			+2	16.7
D trophic pyramid	0.0758	0.0758	-2	0
			-1	3.0
			0	93.9
			+1	3.0
			+2	0

Comparison of Third, Fourth, and Fifth Grade Students

Any changes between third, fourth, and fifth grade students for rubric item A were statistically insignificant, with a p-value of 0.037 (Table 3). Rubric items B and C both had a p-value of 0.001, which is less than the α of 0.0125 and is, therefore, significant. The results for rubric items B and C showed increases in student scores from third grade to fifth grade (Figures 2 and 3). The p-value for rubric item D was 0.015, which is greater than the α of 0.0125, but was close to significance. Although the changes seen for rubric items A and D were statistically insignificant, there were increases in those scores from third to fifth grade (Figures 1 and 4).

Table 3. Frequencies of scores per rubric item and resulting p-values from exact test of independence performed on third, fourth, and fifth grade scores.

Rubric Item	**Score**	**Percent of Score in Each Grade**			**p-value**
		3	**4**	**5**	
A	0	0	0	0	0.037
	1	19.7	12.9	2.4	
	2	80.3	87.1	97.6	
B	0	13.6	0	0	0.001*
	1	3.0	12.9	0	
	2	83.3	87.1	100	
C	0	33.3	35.5	9.8	0.001*
	1	12.1	3.2	0	
	2	54.5	61.3	90.2	
D	0	92.4	71.0	78.0	0.015+
	1	7.6	29.0	22.0	
	2	0	0	0	

* indicates significance
+ indicates close to significance

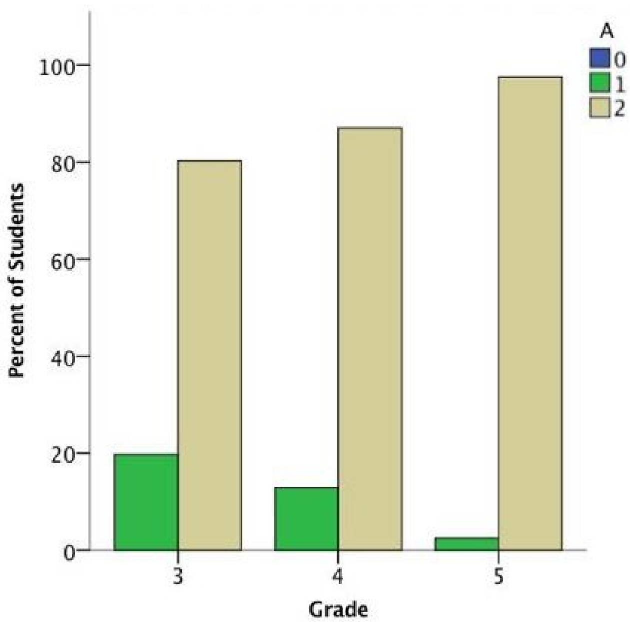

Figure 1. Distribution of scores for rubric item A. The key concept for rubric item A was producers. A score of 2 indicates the student placed a plant at the beginning of the food chain, indicating that it was the producer. A score of 1 indicates the student placed a plant in the food chain, but did not clearly show that it was the producer. No students received a score of zero for this item. p = 0.037.

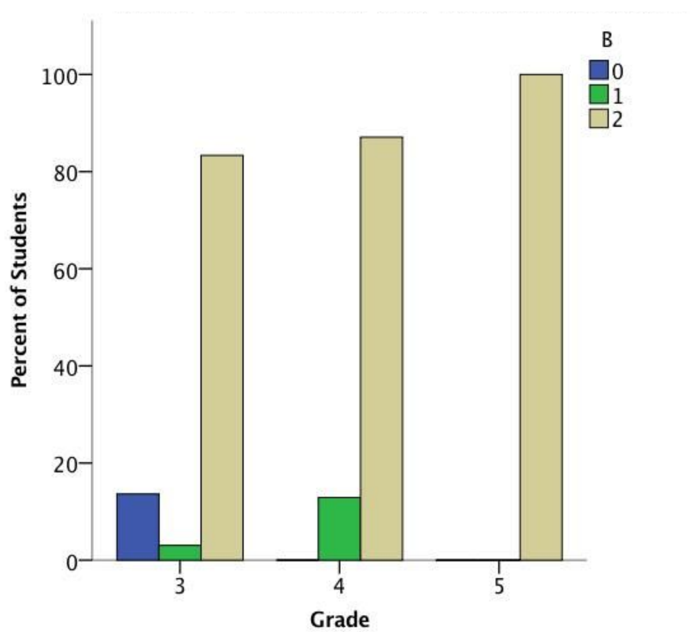

Figure 2. Distribution of scores for rubric item B. The key concept for rubric item B was consumers. A score of 2 indicates the student included more than one logical (likely to occur in nature) example of one organism consuming another. A score of 1 indicates the student included one logical (likely to occur in nature) example of one organism consuming another. A score of 0 indicates the student did not include an example of one organism consuming another or the example(s) included were not logical (likely to occur in nature). p = 0.001.

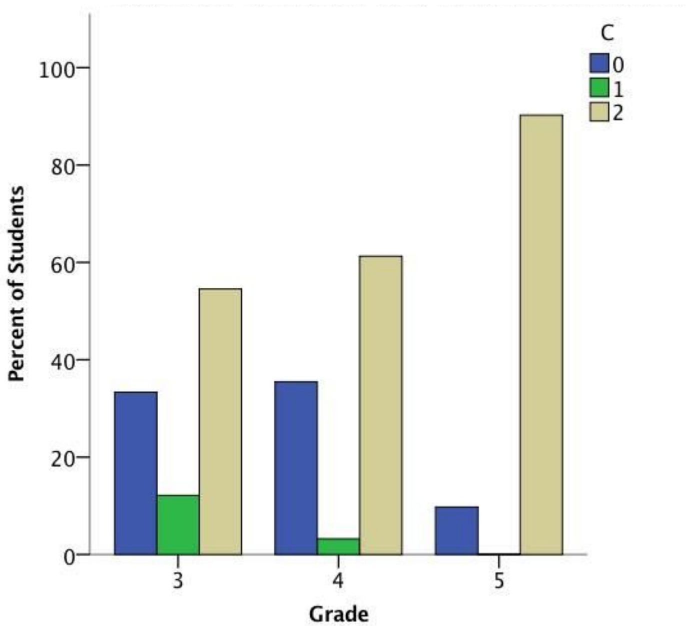

Figure 3. Distribution of scores for rubric item C. The key concept for rubric item C was energy from the sun. A score of 2 indicates the student included the sun in his or her drawing and clearly showed that the energy from the sun was being used by plants. A score of 1 indicates the student included the sun in his or her drawing, but did not clearly show that the energy from the sun was being used by plants. A score of 0 indicates the student did not include the sun in his or her drawing. p = 0.001.

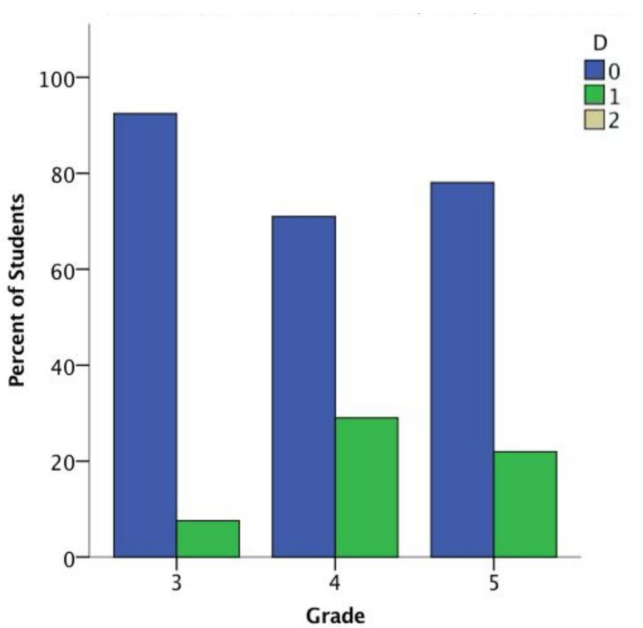

Figure 4. Distribution of scores for rubric item D. The key concept for rubric item D was the trophic pyramid. A score of 1 indicates the student showed the number of organisms decreasing at some new trophic levels (as the trophic levels increased). A score of 0 indicates the student did not show the number of organisms decreasing at any new trophic levels (as the trophic levels increased). No students received a score of 2 for this item. p = 0.015.

Qualitative Results

There were some notable trends seen in the drawings collected in this study that suggest student misconceptions. Many students created food chains that were linear in the sense that there was one organism at each trophic level, but were circular in structure with the energy starting at the sun, moving through the food chain, and then returning to the sun at the end (Figure 5). Another trend that was observed was that of placing an insect after the sun and before a plant, suggesting the student viewed the insect as a producer (Figure 6). Many students also included a sun in their drawing, but did not clearly indicate that the sun was the source of energy for the producer. For example, the student may have drawn arrows between all of the organisms in the food chain, but neglected to draw an arrow between the sun and the plant (Figure 7). Because young children typically include the sun in drawings involving nature, it is difficult to know whether the students understood that the sun is the source of energy for the plant without the presence of an arrow. Students who received a score of 1 for rubric item D (the structure of the trophic pyramid), received that score due to one or more instances of the number of organisms decreasing as the trophic level increased (Figure 8). However, in looking at these drawings, it should be noted that this trend could be due to the students' enjoyment of stamp use or desire to create a nature scene in their drawings, rather than an understanding of the structure of the trophic pyramid and the reason for that structure. It was also observed that some students included humans in the food chains as the top predator (Figure 9). This is indicative of the idea that many young children hold that plants and animals exist on Earth to benefit humans (Leeds (England) Department of Education, University of Leeds, Children's Learning in Science Research Group, 1992).

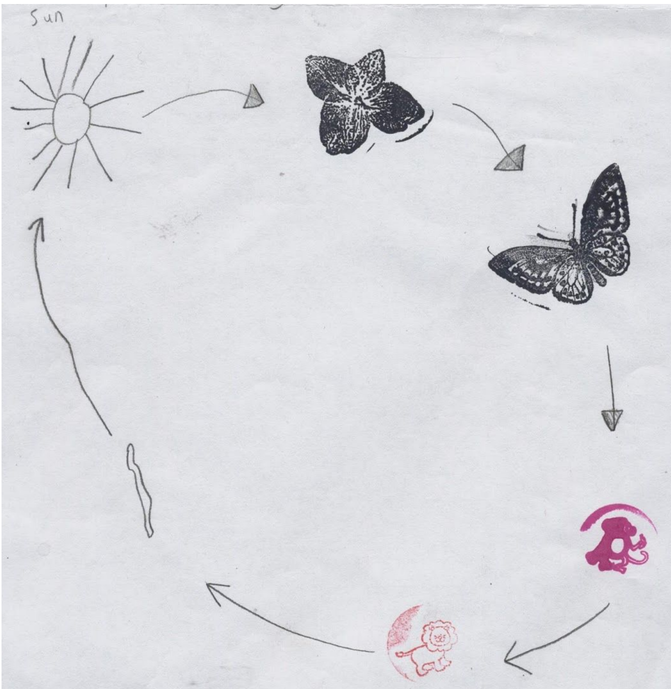

Figure 5. An example of creating circular food chains.

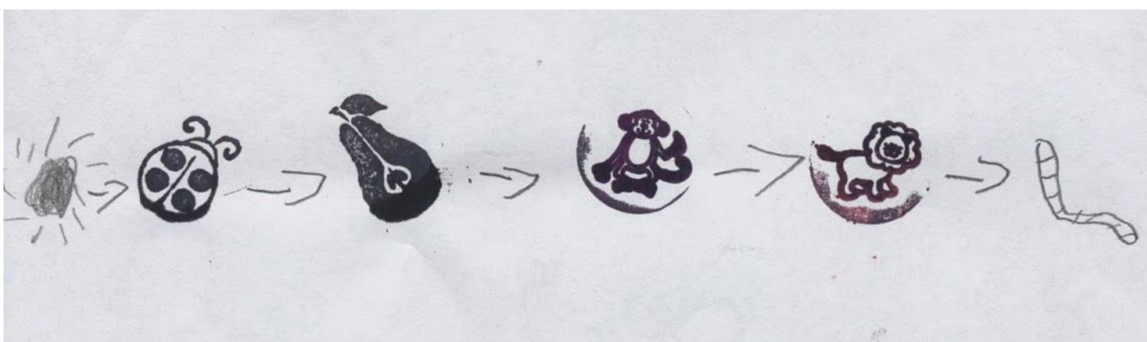
Figure 6. An example of placing an insect in the position of a producer.

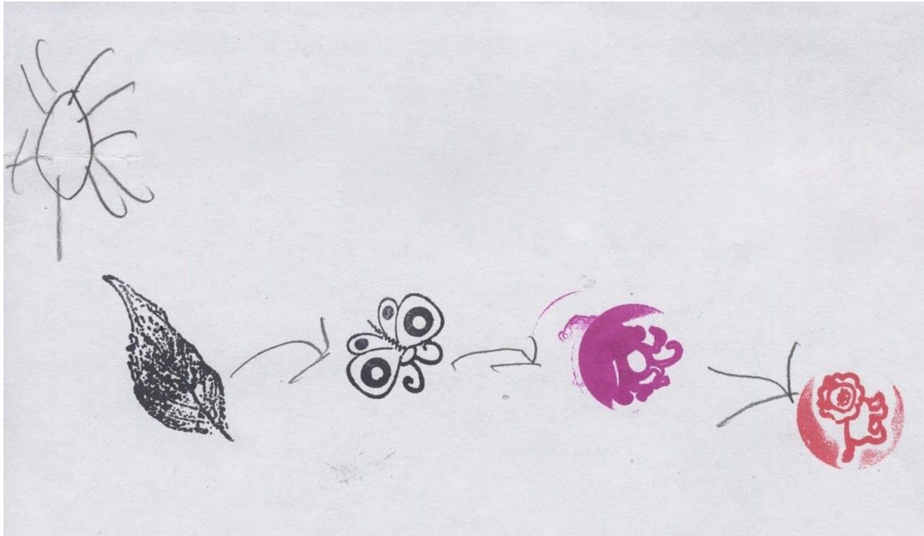

Figure 7. An example of neglecting to put an arrow indicating energy coming from the sun and going to the plant.

Figure 8. An example of a drawing that received a score of 1 for rubric item D. The score was given due to the presence of three strawberries and only one monkey at the next trophic level, but this element of the drawing could have been included because the student simply wanted to stamp the strawberry three times or because the student was creating a nature scene with the "strawberry tree."

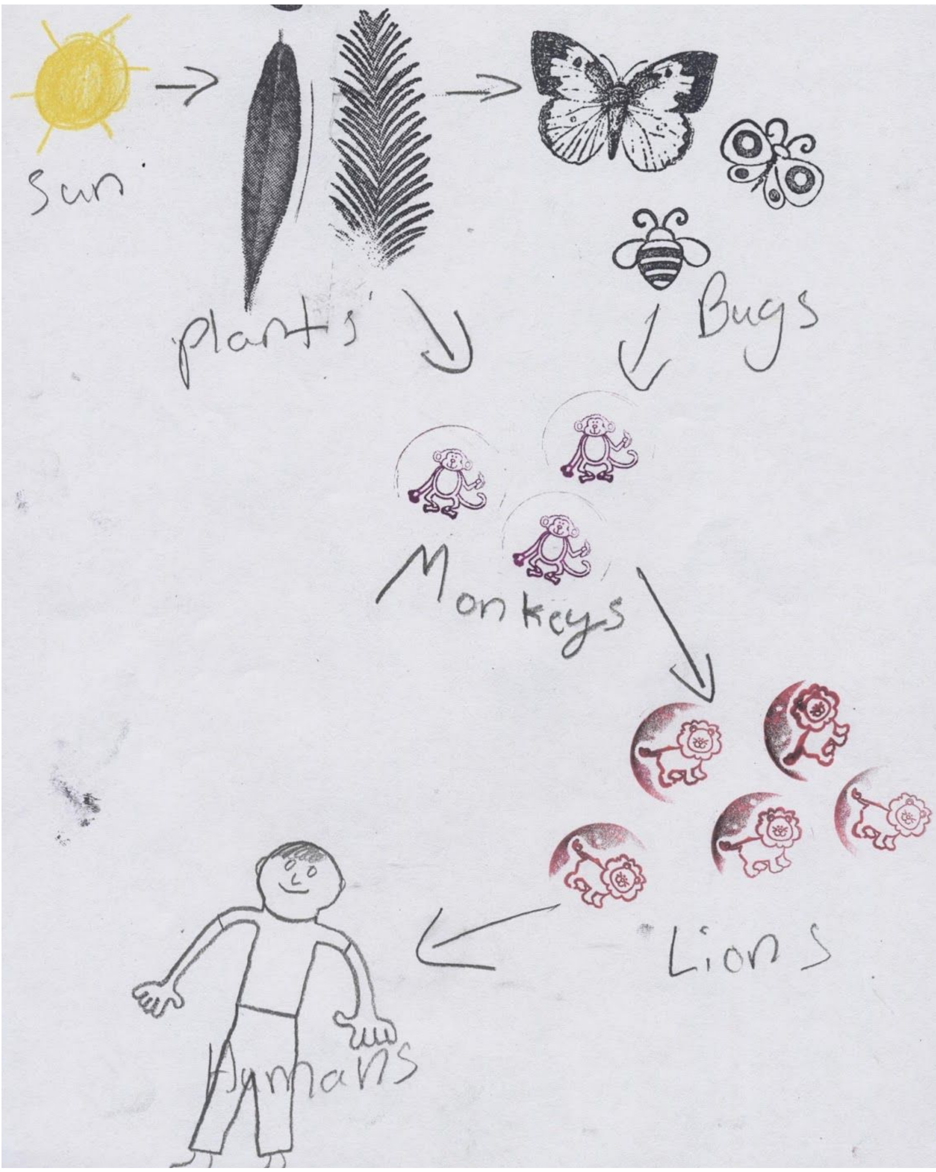

Figure 9. An example of including humans in the food chain as the top predator.

Discussion

Third Grade Pre- and Post-Assessments

Rubric Item A

The student received full points by placing a plant at the beginning of the food chain, indicating that it is the producer.

Increases in scores for this rubric item between pre-assessment and post-assessment were not statistically significant, as only 9.1% of students increased in score. That being said, the average score on the pre-assessment for this rubric item was 1.7576, suggesting that the majority of the students received full points on this rubric item before the "Hoooo Has Energy?" lesson. This suggests that most students already understood what a producer is and that plants are producers, so it is not surprising that there was not a large increase in scores. However, one of the trends observed about the students' drawings was the tendency to place an insect in the position of the producer in the food chain. Based on this observation, in the future, this lesson could be improved by addressing that misconception to help students understand that only plants are producers and perform photosynthesis. A possible limitation of the use of stamps over drawings for this rubric item is that the stamps give students specific options for organisms to include in their drawings. Our results showed that all students included a plant in their drawing, as no scores of 0 were given, but we cannot know for sure whether those students would have included a plant had they not been given a plant stamp as an option.

Rubric Item B

The student received full points by including more than one logical (likely to occur in nature) example of one organism consuming another.

Similar to rubric item A, very few students (3.0%) increased in score for rubric item B.

Again, the average score on the pre-assessment indicates that most students received full points for this rubric item before the lesson was given, because the average score was 1.7727. This is not surprising, because most young children can think of multiple examples of one organism consuming another based on their own observations of the world, as well as classroom instruction. Misconceptions about certain relationships (i.e. a butterfly eats a lion) would need to be addressed on an individual student basis, rather than by modifying the lesson as a whole. The data for this rubric item could have been skewed by students being unable to determine which organism was represented by the stamps and including an organism in the wrong place in the food chain simply because they thought it was a different organism. This issue could easily be addressed in future lessons by labeling the stamps for the students.

<u>Rubric Item C</u>

The student received full points by including the sun in his or her drawing and clearly showing that the energy from the sun was being used by plants.

Although the increases in scores for rubric item C were not statistically significant, it is notable that 27.3% of students had an increase in score for this rubric item. This suggests that the students' understandings of the role of the sun in a food chain was improved by the "Hoooo Has Energy?" lesson or the students were reminded of previous understanding of the sun's role in a food chain during the lesson. That being said, one possible limitation of this study could have been the administration of the post-assessment by classroom teachers. During the lessons, it was observed that the classroom teachers often had specific ideas about the answers students should have given and wanted to guide the students to those answers. The possible addition of classroom teacher help on the post-assessments could have affected the students' drawings and their inclusion of the sun at the beginning of the food chain. To eliminate the issue of teacher help, the post-assessment could be administered by the researchers of this study.

Rubric Item D

The student received full points by showing the number of organisms decreasing at each new trophic level (as the trophic levels increased).

Our analysis of the pre- and post-assessments showed little transfer of knowledge from the lesson to the post-assessment for rubric item D, meaning that the students were unable to apply what was discussed in the lesson to the creation of a food chain. The average pre-assessment score was 0.0758, indicating that most students were given a score of 0 for this item, and 93.9% of students had no change in score from the pre-assessment to the post-assessment. Very few students depicted the triangular trophic pyramid when asked to draw a food chain on their post-assessment. One explanation for this trend could be that the cognitive jump between the owl pellet dissection and the structure of the trophic pyramid was too large. It was observed that the dramatic play element of the lesson was often too complex for some of the students. Due to the size of the classes, not all of the students could be physically involved in acting out the food chain. The students who were watching the demonstration often seemed to get lost. Additionally, the classroom teachers often had time constraints for this lesson. Because of these issues, the dramatic play section of the lesson was removed for the classes assessed in this study. Students and teachers enjoy the hands-on, investigative nature of the owl pellet dissection; however, the guided inquiry of acting out the trophic pyramid with different ratios of organisms at each level is critical to the students' ability to connect the bones found in their owl pellets to the triangular structure of the trophic pyramid. In the future, incorporation of the dramatic play could increase transfer of knowledge after the lesson. The logistical issues with this element of the lesson could be addressed by breaking the students into groups for the dramatic play section. The outreach teachers, outreach volunteers, and the classroom teacher could each take a group of students and let them act out food chains with different ratios of organisms. Using this method, all students would be actively involved and engaged in the activity, which would likely increase their understanding of the concept.

The absence of transfer seen on the post-assessments could also be due to a lack of connection created between the owl pellet dissection and the concepts being taught. Students may have become so engaged with the owl pellet dissection that they lost sight of the "big picture" ideas being discussed. As the students dissected the pellets, teachers and volunteers moved around the room and discussed with the students about the bones they had discovered. In the future, teachers and volunteers could intentionally relate the students' discoveries back to the content during these discussions. For example, when a student shows a teacher or volunteer two skulls that were in his or her owl pellet, the teacher or volunteer could guide the student to the idea that the presence of two skulls indicates that the owl ate at least two organisms and then relate that back to the trophic pyramid structure. Students can refer to the visual of the trophic pyramid on the board throughout the dissection.

Furthermore, food chains have been embedded in most students' instruction since kindergarten and this instruction typically displays food chains linearly. It is possible that students understood the triangular shape of the trophic pyramid, but defaulted to linear food chains on the post-assessment without thinking about the "Hoooo Has Energy?" lesson a few days earlier, simply due to years of exposure to the linear format. In the future, it could help to remind students to think back to what they learned during the "Hoooo Has Energy?" lesson when they are given the post-assessment, so that they do not default to prior knowledge.

The results of this study could also have been affected by possible confusion between the terms "food chain" and "trophic pyramid." Students were asked to draw a food chain on both the pre- and post-assessments. The term "food chain" was used because the term "trophic pyramid" was thought to be leading, in that the structure is implied in the name. It was predicted that asking students to draw a trophic pyramid would skew the results by giving the students the structure. However, students may think of food chains and trophic pyramids as two separate things. As was discussed earlier, students have been instructed since kindergarten that a food chain is linear, so the use of the term "food chain" in our assessment may have contributed to the high number of linear food chains found on the post-assessments. Additionally, a chain is linear by nature, so even if students were not previously instructed to create a food chain linearly, they may consider a food chain to be linear based on inclusion of the word "chain." In the future, this lesson could be assessed without the use of the term "food chain" or the term "trophic pyramid." For example, the assessment could instruct students to draw an ecosystem and show energy transfer through the ecosystem using arrows.

The lack of transfer of knowledge seen for this rubric item could also be due to the stage of cognitive development of the students. In third grade, students are in Piaget's concrete operational stage of cognitive development (Eggen and Kauchak, 2010). In this stage, students are able to think logically, but their thinking requires concrete materials. Although all students develop at different rates, most students are in sixth grade before they reach the formal operational stage, where they can think logically about something hypothetical. This could contribute to the size of the cognitive leap students need to make between the owl pellet dissection and the structure of the trophic pyramid. Although the dissection involves concrete materials, the students are required to think about the food chain of an owl in a hypothetical manner. There is nothing concrete to help students shift their idea of a linear food chain to that of a triangular trophic pyramid. In the future, transfer of knowledge may increase if students were concretely shown a shift from a linear food chain to a trophic pyramid. For example, students could have pieces of paper to represent organisms and arrange them in a linear food chain, assign units of available energy to those pieces, and then arrange the pieces into a trophic pyramid. Based on Piaget's stages of development, it is likely that this concrete action would help students create an accurate mental model of the trophic pyramid.

Comparison of Third, Fourth, and Fifth Grade Students

Although only the p-values for rubric items B and C indicate statistical significance, the scores for all four rubric items increased from third grade students to fifth grade students. This suggests that students are gaining a deeper conceptual understanding of food chains with each year of school, which supports the idea that giving students a clear understanding of food chains in third grade sets them up for success in future science classes. That justifies future evaluation of this lesson in order to develop it further, because it reinforces the significance of giving third grade students a solid foundation in the concept of food chains.

Future Work

The use of stamps could have had complications if the students felt the need to use all of the stamps provided for them or felt restricted by the organisms on the stamps provided for them. However, based on observations of students using stamps to aid in the creation of a drawing, many students did not use all of the stamps provided and added organisms by hand that were not provided in the form of a stamp. This suggests that the use of stamps was not unduly restrictive.

This study gathered baseline data for the improvement of this K-5 outreach program. The results of this study can be used as a model for assessing the other five lessons included in the program. The assessment and development of this outreach program play an important role in the improvement of science education as a whole, since the program exposes elementary school teachers and students to inquiry-based science lessons. Further development of the program also plays a role in the improvement of outreach programs from higher education institutions, because the changes made based on the results of this study could lead to an outreach model that can be adopted in many other communities. Improvements in science education and higher education outreach have the potential to lead to significant societal changes, including the creation of more socioscientifically informed citizens, more equitable education, and a larger and more diverse STEM workforce.

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