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Exploring Elementary Students' Scientific Knowledge of Agriculture Using Evidence-Centered Design

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ABSTRACT

The public is more disconnected from agriculture than ever. Americans are now two to four generations removed from the farm with a majority of Americans having no direct experience in agriculture. As a result, the public lacks the knowledge and appreciation of the food, fuel, and fiber it demands. The National Agricultural Learning Objectives (NALOs) were recently developed to describe students' agricultural knowledge but have, as yet, not been used to guide research into students' agricultural literacy. The purpose of this project is to further understand students' agricultural literacy through NALO-based assessment of students' knowledge. This study focused on the NALOs in the areas of agriculture and the environment (AgE) and the STEM dimensions of agriculture (STEM) using a sequential exploratory mixed methods design. Thirty-five students participated in semi-structured interviews surrounding the NALOs. Interview data were coded and analyzed while using the evidence-centered design process to create empirically grounded assessments that were administered to a sample (n=400) of elementary students. Results suggest that students are more knowledgeable about the STEM dimensions of agriculture than the agricultural and environmental topics. Recommendations are provided to guide future research and development around the NALOs.

Keywords: agricultural literacy; agricultural education; STEM integration; assessment development; elementary students

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Introduction

As Thomas Jefferson observed centuries ago, "Agriculture is our wisest pursuit because it will in the end contribute most to real wealth, good morals, and happiness" (1787). His words speak to the importance of agriculture in the United States and globally, magnified by the contemporary challenge of feeding an ever-growing human population. During Jefferson's life, the majority of Americans were farmers, growing a variety of crops and livestock that fed their

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immediate families. However, today less than 2% of the population is involved in production agriculture (American Farm Bureau Federation, 2015). As Powell and Agnew (2011) observe, "Americans are two to four generations removed from the farm, and a majority of Americans, even in rural agricultural states have no direct link to agriculture" (pg. 155). To be adequately prepared to address the food, energy, and water challenges of today and tomorrow, Americans need to learn about food systems and the science, technology, engineering, and mathematics (STEM) concepts upon which they are based (NGSS Lead States, 2013).

Agriculture isn't a primary focus in most K-12 school curricula in the United States. As a result, research has shown that elementary, middle, and high school students in America's schools have limited understanding and/or harbor misconceptions about food systems (Hess & Trexler, 2011; Mabie & Baker, 1996). Their agricultural literacy, defined as understanding and possessing knowledge of the food and fiber system (Frick, Kahler, & Miller, 1991), is underdeveloped. The National Research Council (1988) reports that "agricultural education in U.S. high schools usually does not extend beyond the offering of an agricultural education program" (p. 2) and suggests incorporating agricultural literacy throughout the curriculum because agriculture "is too important of a topic to be taught to only the relatively small percentage of students considering careers in agriculture" (p. 1). However, definitions, targeted learning outcomes, and instruments to measure agricultural literacy can vary widely, leading to widely variant reports on students' agricultural literacy. The need to operationalize the construct of agricultural literacy exists in parallel with the need to foster it in K-12 classrooms.

To address these needs, we have engaged in a multi-year project to design, validate, and report findings from a new assessment to measure upper elementary (3^{rd}-5^{th} grade) students' agricultural literacy as defined by the National Agricultural Literacy Outcomes (NALOs; Spielmaker & Leising, 2013). The NALOs were written in response to the National Agricultural Literacy Logic Model (Spielmaker, Pastor & Stewardson, 2014) developed by a team of researchers, practitioners, and government officials. The resulting NALOs were then reviewed by key stakeholders and members of the National Agriculture in the Classroom Curriculum Matrix Committee to ensure significance and grade level appropriateness (Spielmaker & Leising, 2013). Here, we focus on two sets of NALOs - agriculture and the environment (AgE) and the scientific, technological, engineering, and mathematical dimensions of agriculture (STEM) – as key learning outcomes reflecting the STEM dimensions of agriculture. In this mixed-methods study, assessment development and implementation was grounded in Evidence-Centered Design (ECD; Mislevy & Haertel, 2006) and empirical results were used to address the following research questions: 1) *Are students more knowledgeable about agricultural/environmental topics than STEM topics?* and 2) *How does students' agricultural literacy compare across upper elementary grades?* This study addressed Research Priority 3 set forth by the AAAE National Research Agenda which involves creating a "sufficient scientific and professional workforce that addresses the challenges of the 21^{st} century" (Roberts, Harder, & Brashears, 2016).

Theoretical Framework

Agricultural literacy is defined as understanding and possessing knowledge of our food and fiber system which allows individuals to synthesize, analyze, and communicate basic information about agriculture (Frick, Kahler, & Miller, 1991). In 1999, the National Council for Agricultural Education (1999) defined goals for literacy in terms of a person becoming "conversationally" literate about agriculture. Meischen and Trexler (2003) broadened the definition of agricultural literacy to include science– and technology–related concepts "required for personal decision making, participation in civic and cultural affairs, and economic productivity" (p. 44). Over the past twenty years, efforts to define agricultural literacy have moved from the mostly technical aspects of production and distribution of agricultural goods to include a sense of broader environmental and global social significance. More recently, there have been efforts to define agricultural literacy in terms of conversational knowledge, critical analysis, and value-based judgment (Powell, Agnew, & Trexler, 2008).

For purposes of this work, we adhere to a knowledge-based perspective on agricultural literacy, which foregrounds the understanding of core concepts students should possess and be able to illustrate through various learning performances. However, consistent with the interdisciplinary nature of the NALOs and construct of agricultural literacy, we recognize knowledge underlying agricultural literacy spans a variety of disciplines, including science, mathematics, engineering, geography, and history, just to highlight a few, as illustrated in Figure 1. In this study, we specifically focus on a subset of this knowledge base focused on the *overlap between scientific concepts and food systems*. This perspective aligns with that of the National Research Council (2009), which argues that, "Agriculture now so thoroughly combines basic and applied aspects of the traditional STEM disciplines of science, technology, engineering, and mathematics that the acronym might rightly expand to become STEAM, joining agriculture with the other fundamental disciplines" (pg. 3). The AgE and STEM dimensions of agricultural literacy studied here are grounded in the Next Generation Science Standards (NGSS Lead States, 2013), as well as the NALOs.

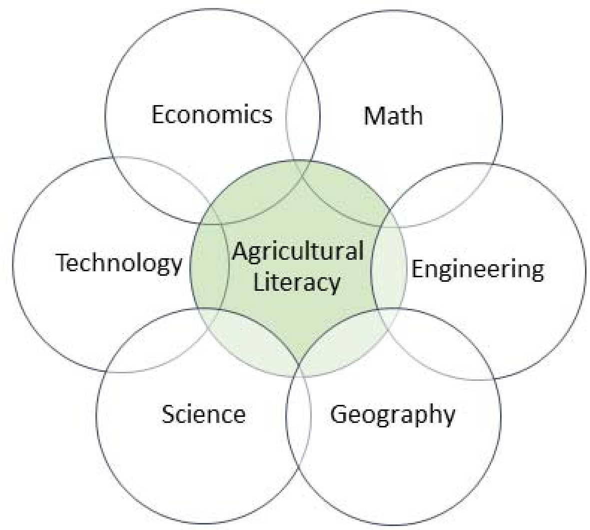

Figure 1. Theoretical Framework for Agricultural Literacy

Prior Research

Prior research efforts have investigated elementary students' agricultural literacy. Researchers have concluded that elementary school children know relatively little about agriculture (Trexler, Hess & Hayes, 2013), its social and economical significance, and, particularly, its links to human health and environmental quality (Hall, 2011; Hess & Trexler, 2011; Mabie & Baker, 1996; Meischen & Trexler, 2003; Swortzel, 1997). Students' ideas about agriculture are often guesses, underdeveloped, or contradictory to expert conceptions (Hess & Trexler, 2011). When asked "what is agriculture?", only a small percentage of students could give a basic definition (Mabie & Baker, 1996). Students consistently fail to convey an understanding of the types and variety of farms, the purpose of farms, or the cultural practices dominating conventional farming (Hess & Trexler, 2011).

While empirical results have indicated that urban citizens lack the most knowledge of agriculture, rural non-farm citizens also lagged behind their on-farm peers (Meischen & Trexler, 2003). Children living and going to school in rural areas may have no more ties to agriculture than urban youth (Meischen & Trexler, 2003). For example, Terry, Herring, and Larke (1992) discovered that school age children from rural communities in Kansas had limited understanding of the food and fiber system. Students struggled to explain the complexity of modern agriculture, careers in agriculture, and bi-products of agricultural products.

Studies have shown that students do possess some understanding of our food and fiber system (Mabie & Baker, 1996; Meischen & Trexler, 2003; Trexler et al., 2013). Children who have the most direct experience growing food and preparing meals had the greatest understanding of the food system (Trexler et al., 2013). Students know that farms and ranches are the places where farmers and ranchers raise plants and animals (Trexler et al., 2013). Most students understood the connection between tortillas and corn, bacon and pigs, t-shirts and cotton, and wool blankets and sheep (Mabie & Baker, 1996). Most students had a basic understanding of meat's journey from farm to plate (Meischen & Trexler, 2003). Urban fourth through sixth grade students were aware that water, soil, and light are requirements for plant growth (Trexler et al., 2013).

Resources have been developed to improve the agricultural literacy of elementary students. National programs such as "Agriculture in the Classroom" and "Food and Fibers Systems literacy" aim to increase students' agricultural literacy. Most of these efforts are focused on elementary school students. However, definitions, targeted learning outcomes, and instruments to measure agricultural literacy can vary widely, leading to widely variant reports on students' agricultural literacy. The need to operationalize the construct of agricultural literacy exists in parallel with the need to foster it in K-12 classrooms

Methods And Procedures

National Agricultural Literacy Outcomes (NALOs)

To address this need, we developed an assessment to measure agricultural literacy for elementary students based on the National Agricultural Learning Outcomes (NALOs). The NALOs emphasize a variety of topics that span disciplines and are organized by grade level benchmarks from elementary to high school (Spielmaker, 2013). This paper describes the development of assessment items relevant to the 3^{rd}-5^{th} grade bands of two NALO content standards (see Table 1). We chose to focus on the upper elementary NALOs because students in this age range should have well developed language skills and be able to communicate clearly.

Table 1

NALO Content Standards for 3rd-5th Grade Students

AgE - Agriculture and the Environment	STEM – Science, Technology, Engineering and Mathematics
AgE-1: Identify the major ecosystems and agro- ecosystems in their community or region (e.g., hardwood forests, conifers, grasslands, deserts) with agro-ecosystems (e.g., grazing areas and crop growing region.	STEM-1: Describe how technology helps farmers/ranchers increase their outputs (crop and livestock yields) with fewer inputs (less water, fertilizer, and land) while using the same amount of space
AgE-2: Explain how the interaction of the sun, soil, water, and weather in plant and animal growth impacts agricultural production	STEM-2: Identify examples of how the knowledge of inherited traits is applied to farmed plants and animals in order to meet specific objectives (i.e., increased yields, better nutrition, etc.)
AgE-3: Recognize the natural resources used in agricultural practices to produce food, feed, clothing, landscaping plants, and fuel (e.g., soil, water, air, plants, animals, and minerals)	STEM-3: Compare simple tools to complex modern machines used in agricultural systems to improve efficiency and reduce labor
AgE-4: Identify land and water conservation methods used in farming systems (wind barriers, conservation tillage, laser leveling, GPS planting, etc.)	STEM-4: Provide examples of science being applied in farming for food, clothing, and shelter products
AgE-5: Describe similarities and differences between managed and natural systems (e.g., wild forest/ tree plantation and natural lake/ fish farm)	

Evidence Centered Design Process

This empirical study was embedded in a broader process of assessment design and development - Evidence-Centered Design (Mislevy & Haertel, 2006). The long-term objective of this work was the development, validation, and testing of an empirically grounded assessment instrument designed to measure K-12 students' knowledge about STEM in food production systems. Evidence-centered assessment design (ECD) is an approach to constructing, designing, producing, and delivering educational assessments in terms of evidentiary arguments (Mislevy, Almond & Lukas, 2003), the objective of which are valid and reliable assessment tools. The present study focuses on the first three stages of ECD: 1) domain analysis; 2) domain modeling, and; 3) conceptual assessment framework (Mislevy & Haertel, 2006).

In the domain analysis stage, research was conducted to write a complete summary of each NALO, including all relevant information surrounding the NALO. Information about each standard in the domain analysis stage was then used to establish relationships among proficiencies, tasks, and evidence in the domain modeling stage (Mislevy et al., 2003). This work led to the articulation of an assessment design space for each targeted outcome. The third stage of ECD involves the development of the conceptual assessment framework which includes the task model, evidence model, and student model. Information from the previous two steps was used to articulate levels of student understanding related to the NALOs, identify appropriate assessment tasks, and make decisions about how to evaluate evidence of students' thinking.

Student Interviews

To identify levels of third through fifth grade students' understanding of outcomes in Table 1, we planned and conducted clinical interviews with a sample of 35 third, fourth, and fifth grade students (n_{3rd} =12; n_{4th} =14; n_{5th} =9). Student interviewees were recruited from classrooms in two elementary schools from the same school district serving K-5 students in a large Midwestern city. Students were primarily from suburban backgrounds, though each school held an 'ag day' event and included elements of agriculture in the K-5 curriculum. Interviews were semi-structured (Patton, 2001) in nature. Interview protocols were designed around each of the target outcomes in Table 1 and included additional sub questions for interviewer probing around each target outcome. Interviews ranged from 11-26 minutes, with an average time of fifteen minutes. All interviews were audio recorded and transcribed for analyses. Students were not required to participate in the study. Parent consent and student assent forms were collected prior to conducting interviews.

Student Assessment

Interview data guided the development of student assessment items. Three questions were developed to reflect a high, medium, and low understanding of each standard in the AgE and STEM NALOs (see Table 1). The resulting assessments were composed of fifteen or twelve questions respectively. The assessment included questions of a variety of types, including true/false, matching, and multiple choice. Teachers from nine public and private elementary schools in two cities participated in the administration of the assessment. Teachers or a member of the research team introduced the project to the students. Students were allotted 20-30 minutes to finish the assessment. Students completed the assessment during non-core subject class time. Four hundred students completed the assessment (n_{3rd} =110; n_{4th} =108; n_{5th} =182). Students either received an AgE (n=206) or STEM (n=194) assessment.

Student scores on the assessment were used to further understand students' agricultural literacy. Student scores were recorded as percentages to normalize differences in assessment length. These percentages were used to compare scores across assessments and grade levels. Subscores were calculated for each NALO as the percentage of students that answered the particular question correct. Subscores for the low, medium, and high understanding questions for each NALO were used to determine student understanding of each topic. The assessment data were normally distributed for each NALO category and each grade level, so standard parametric statistical tests were used to analyze the data.

Results and Findings

Student Understanding of Agriculture & Environment and STEM Topics

In research question #1, we asked, "Are students more knowledgeable about agricultural/environmental topics than STEM (Science, Technology, Engineering and Mathematics) topics?" To address RQ#1, we performed an independent-samples t-test to compare student scores (percentage of questions answered correctly) between the AgE and STEM assessments (α=0.05). Students' scores on the STEM assessment was significantly higher (M=0.643, SD=0.019) than the scores on the AgE assessment (M= 0.596, SD= 0.030) topics; t (396) = 2.99, p = 0.0015, d = 1.87. The effect size for this analysis (d = 1.87) was found to exceed Cohen's (1988) convention for a large effect (d = 0.8) and can be interpreted as a 'strong' effect. These results suggest that upper elementary students are significantly more knowledgeable about the topics covered by the STEM assessment than the topics covered by the AgE assessment.

Responses to individual assessment questions were used to further explore student understanding of specific underlying topics. Comparisons were made to determine if increasing difficulty level resulted in a decreased percentage of correct responses on each NALO content topic (see Table 2). The combined percentage of correct student responses to all three difficulty levels for each NALO content topic was also calculated.

Table 2

Percentage of Students Answering Questions Correctly by NALO and Difficulty Level

NALO Content Topic	Difficulty Level			Combined
	Low	Medium	High	
AgE Overall	74.8%	59.0%	45.2%	59.6%
AgE-1: Identify the major ecosystems and agro-ecosystems in their community or region with agro-systems.	83.0%	48.5%	49.0%	60.2%
AgE-2: Explain how the interaction of the sun, soil, water, and weather in plant and animal growth impacts agricultural production.	79.6%	70.4%	36.4%	62.1%
AgE-3: Recognize the natural resources use in agricultural practices to produce food, feed, clothing, landscaping plants, and fuel.	74.3%	85.0%	71.4%	76.9%
AgE-4: Identify land and water conservation methods used in farming systems.	87.0%	48.5%	14.1%	49.9%
AgE-5: Describe similarities and differences between managed and natural systems.	50.0%	42.2%	55.3%	49.2%

Table 2 (continued)

Percentage of Students Answering Questions Correctly by NALO and Difficulty Level

NALO Content Topic	Difficulty Level			Combined
	Low	Medium	High	
STEM Overall	80.9%	66.9%	44.8%	64.3%
STEM-1: Describe how farmers/ranchers increase their outputs with fewer inputs while using the same amount of space.	79.9%	95.9%	57.2%	77.7%
STEM-2: Identify examples of how the knowledge of inherited traits is applied to farmed plants and animals in order to meet specific objectives.	83.5%	48.0%	29.4%	53.6%
STEM-3: Compare simple tools to complex modern machines used in agricultural systems to improve efficiency and reduce labor.	98.0%	28.9%	51.0%	59.3%
STEM-4: Provide examples of science being applied in farming for food, clothing, and shelter products.	62.3%	94.8%	41.7%	66.3%

Student scores on the individual assessment items reinforce the results that students have a greater understanding of the topics covered by the STEM assessment items. For example, the combined STEM-1 questions related to the technology farmers use to increase outputs with fewer inputs while using the same amount of space had the highest percentage of correct scores. High understanding of this topic was also evident in the student interview data through student comments on how technology has made agriculture easier and better. When asked how farming has changed in the past years, a student responded by saying, "Like in the 1920s and stuff, it would take a really long time and take a lot of people to get all those corn seeds and stuff and then to water it would be a really big pain. Now, it's not really that bad because we have those pivots and these tractors that can multitask." Students listed machinery such as combines and pivots that farmers use to make their job easier. Students talked about computers, GPS, and internet allowing farmers to be more efficient suggesting that computers can "help farmers solve problems", and GPS can help farmers "map out their fields."

A high percentage of correct scores (76.9%) was also found in the AgE-3 content area focused on recognizing the natural resources used in agricultural practices to produce food, feed, clothing, landscaping plants, and food. Nearly every student was able to identify a few natural resources during the interview. Students typically listed trees, plants, and animals as natural resources. A few students mentioned natural gas and coal as natural resources based on the reasoning that "we don't make them, the earth does." Students also recognized that natural resources affect agriculture. A student stated that "natural resources affect farming because you can't really farm without soil, sunlight or water."

Individual assessment item scores also identified topics that were less understood by students. Students struggled with the assessment questions related to the concept of inherited traits on the STEM assessment (NALO STEM-2). The percentage of correct student responses for questions related to this topic was 53.6%. The student interviews support this result of decreased student understanding of this topic. Students were asked if everyone in their class looked alike and if plants and animals resembled their parents. Student responses included descriptions of the differences between an ear of corn and a seed and the differences between a butterfly and caterpillar. These responses suggest that students were unsure how to explain trait inheritance when there were visible differences between parent and offspring. A fifth grade student stated that plants and animals take after their parents "because just like humans, they have specific genes from their parents and they kind of inherit them." Despite this confusion, the students agreed that farmers would be better prepared to raise the best crops and livestock if they understood inheriting traits "because then they can know if there's like a defect in the animal, they might have had the same thing with their parents."

Student scores were the lowest in the conservation category (49.9%) related to the AgE content standards (NALO AgE-4). The NALO reads that students will identify land and water conservation methods used in farming systems. Examples of these conservation methods could include wind barriers, conservation tillage, laser leveling, and GPS planting. The lack of understanding in this topic was supported by the student interviews. For instance, students struggled to comprehend the term "conservation." In an attempt to bypass this misunderstanding, students were asked what problems a farmer might have and what the farmer could do to prevent those problems. Student responses to these questions varied greatly. Students mentioned "drought and pests" as potential problems a farmer could experience. Students proposed different solutions to solving these problems. Students suggested using "sprinklers, hose, and pivots" to irrigate crops. Students recommended using "chemicals or pesticides" to kill pests. Few students mentioned windbreaks and crop rotation as conservation methods, however one understood windbreaks to be something that farmers put up so the "wind doesn't tear up the place."

Student Understanding Across Grade Levels

In research question #2, we asked, "How does students' agricultural literacy compare among upper elementary grades?" To address RQ#2, we conducted a single-factor ANOVA test to compare student scores across grade levels. There was a significant effect of elementary grade (third, fourth and fifth grades) on student assessment scores at the $\alpha=0.05$ level for the three grade levels examined [$F(2,397) = 12.43$, $p = .005$]. The statistically-significant difference between grades suggests agricultural understanding increased across upper elementary grades. Fifth graders achieved an average score of 65.8% (SD=0.14) while fourth graders scored an average of 61.4% (SD=0.17), and third graders scored an average score of 55.7% (SD=0.15).

Student interviews support the general trend of increased understanding in the upper grade levels. The interview responses from fifth grade students reflected a more complex understanding of agricultural concepts, while third and fourth grade responses reflected a limited vocabulary and understanding of agricultural topics. For the most part, fifth graders were categorized as high understanding, fourth graders fell in the medium understanding category, and third graders belonged in the low understanding category. This trend was also found in the assessment responses. The high-level understanding assessment questions clearly distinguished the level of understanding between grade levels.

A majority of students scored low on the questions focused on conservation (NALO AgE-4) and inherited traits (NALO STEM-2) content areas. However, differences in knowledge levels can be observed among grade levels. For example, 76.7% of third graders correctly answered the low understanding question for the inherited traits NALO while 87.8% of 4th graders answered the same question correctly, and 98.9% of 5th graders answered the question correctly. This trend also held true for the medium (3rd grade: 28.3%; 4th grade: 55.8%; 5th grade: 56.3%) and high (3rd grade: 26.9%; 4th grade: 28.8%; 5th grade: 31.8%) understanding questions.

Interview data also supports the pattern of increased agricultural understanding in higher grade levels. For example, NALO STEM-2 focused on inherited traits. When asked if new plants or animals tend to look like their parents, a fifth grade student mentioned that, "they look very similar because they inherit things from their parents." When a third grade student was asked the same question, the student responded by just saying "sometimes" offspring resembles the parents with no further explanation given. A fifth grader also explained the passing of traits as, "the grandparents give the traits to the parent that gives it to the child." A fourth grade student agreed that genetics was an important concept for farmers to understand because "they would use like the pigs that are healthier to raise more pigs. They would raise those. He would have more healthier pigs."

Student interview data suggest that most students, especially those in fourth and fifth grades, had a high level of understanding related to the interaction of the sun, soil, water, and weather in plant and animal growth impacts agricultural production topic (AgE-2). Students could easily identify the inputs needed by plants and animals to survive. Students may have learned the survival needs of living things in science classes. The high understanding question on the assessment from this NALO showed significant differences across grade levels. The specific question asked students to locate where photosynthesis occurs in a plant. In the interviews, students were not asked directly about photosynthesis. Instead, they were asked why plants needed sunlight. Students who mentioned that sunlight was needed for photosynthesis to occur indicated higher knowledge on the topic. Only 17.6% of third graders got this high understanding question correct on the assessment. However, 30.4% of fourth graders and 45.2% of fifth graders answered this question correctly.

These patterns are supported from interview conversations. Some students, especially those in higher grades, were able to give a more complete description as to why living things need resources such as sun, water, and soil to survive. In addition to saying corn needs water, soil, and the sun to grow, a fifth grade student also included that you would need pesticides "because bugs eat plants and then pesticide kills the bugs." The student also mentioned that plants would need bees to pollinate them, and sun was needed because "it [the plant] needs nutrients to make food because of photosynthesis." A third grade student answered the same question by stating that a corn plant would need "water, soil, and sun." When asked why the plant would need these, the third graders responses included, "for it to grow" or "so it doesn't die."

NALO-3 in the AgE category asked students to recognize the natural resources used in agricultural practices. Differences among grade levels existed in the high understanding question. The low and medium understanding questions asked students to identify natural resources. The high understanding had students apply this knowledge by asking students why water is needed for crops to grow. 58.8% of third grade students, 69.1% of fourth grade students, and 72.0% of fifth grade students answered the question correctly. This shows that students at a younger age may be able to identify concepts; however, they may lack the knowledge to apply that information and understand the "why and how" behind it. The low understanding question for the NALO asked students to simply circle the natural resources. Results showed that twice as many students in fourth (83.9%) and fifth (77.4%) grades correctly answered questions on identifying natural resources as students in 3rd grade (41.2%).

Students were asked to list natural resources (NALO AgE-3) during the interviews. A third grade student stated that "soil, water, and the sun" were natural resources because "you can find them outside." A fifth grade student mentioned that natural resources "could be trees, grass, the sunlight, groundwater and soil" because "we don't make them. The earth does." This student also showed high understanding by stating that "Natural resources affect farming because you can't really farm without soil, sunlight, or water."

Significant differences also existed in the low understanding question for the conservation content standard (NALO AgE-4). The question showed students a picture of a field during a drought and asked them to identify what had caused the dry, cracked soil. The interview data suggested some students would be unfamiliar with the term drought so the assessment included a clarification of "the plants didn't get enough rain" following the choice of drought. This question was answered correctly by 64.7% of third grade students, 83.3% of fourth grade students, and 95.6% of fifth grade students.

In the interviews, students were asked to describe problems a farmer might experience. Most students mentioned not enough rain or pests eating the crops. Many students agreed that drought was a problem, but differences in knowledge became apparent in how students proposed solutions to the problem. Three students mentioned using a pivot to water crops. A fourth grade student mentioned that "they [farmers] sometimes use like pivots to water it." A third grade student mentioned that "you could go out and water them yourself, but that would take a long time," suggesting unfamiliarity with the large size of fields. A fifth grade student decided that "He might use those big silver things [pivots] to squirt water. Or they could use a river, and they could get irrigation pipes."

Students scored very highly on the assessment questions related to how farmers increase their outputs with fewer inputs through technology (STEM-5). More than 72% of students answered the low and medium questions correctly. Students were asked to identify which of a given set of items was not an example of technology used by farmers for the high understanding question. Just over 50% of students across all three grades selected 'rake' as the correct answer.

Students were asked during the interviews to describe how farming has changed over time and to list specific examples of technology used by farmers. A fifth grade student stated that, "people used to have to go hand pick crops, but now they get to use combines." Students that mentioned "combines" were then asked follow-up questions regarding the use of combines. The same fifth grade student also mentioned that "it [technology] makes it go way faster. Without technology, you wouldn't have the sprayers, the combines, or any tractors. You'd just have to do it with your hands." An example of a third grader's response to the same question about technology consisted of, "they [farmers] can use big machines or something that helps crops." However, some third graders possessed a high understanding of the topics. For example, a third grade student indicated that, "a long time ago they [farmers] didn't have combines and tractors to use to harvest. They had to use shovels and hoes."

Implications, Recommendations, and Conclusions

The purpose of this project was to further illuminate students' agricultural literacy through assessments aligned with the NALOs, with a particular focus on agriculture and the environment (AgE) and the STEM dimensions of agriculture (STEM). Results from the assessment are twofold. First, study findings show that that 3rd, 4th, and 5th-grade students are more knowledgeable about STEM topics than AgE topics. Second, they provide evidence of students' increasing knowledge about STEM and AgE topics across the upper elementary grades. Both results provide additional insight into early learners' agricultural literacy and have potential implications for fostering and measuring agricultural literacy in the elementary grades.

Findings from this study support and reinforce results of prior research. A majority of elementary students do not exhibit high levels of agricultural literacy. Swortzel (1997), for example, concluded that elementary school children know very little about agriculture, its social and economic significance, and particularly, its links to human health and environmental quality. Even though the students that participated in the study were from an agricultural state, it was concluded that these students were not that familiar with agriculture. Similarly, Terry, Herring, and Larke (1992) discovered that school age children in Kansas knew little about the food and fiber system. Kansas and the state in which this study was conducted are very similar agricultural states, and this study shows that students are not aware of the agricultural topics affecting their home state.

Hess and Trexler (2011) also concluded that student ideas about agriculture were often guesses, underdeveloped, or contradictory to expert conceptions. The data presented in this paper suggests that the majority of students interviewed were not familiar with agricultural terms and practices. When discussing the need for crops to have water, students said that farmers could use "sprinklers" or "bring buckets of water to the plants." Very few students knew about contemporary irrigation methods and underestimated the large size of agricultural fields. One fifth grade student identified changes in elevation across their state and that different plants are grown in different areas. However, it was apparent during the interviews that the majority of students do not understand the diversity of agriculture. Student responses focused on corn, beans, and cattle despite the variety of agricultural crops and practices across the state, nation, and world. This result supports Hess and Trexler's (2011) findings that students failed to convey an understanding of the types and variety of farms, the purpose of farms, or the cultural practices dominating conventional farming.

However, while study results parallel those from previous studies illustrating the limitation of elementary students' agricultural literacy, they do provide encouraging evidence of students' increasing knowledge about STEM and AgE dimensions of agricultural literacy across the upper elementary grades. Fifth graders possessed the greatest agricultural literacy (65.8%), followed by fourth graders (61.4%) and third graders (55.8%). As shown in the presentation of results of qualitative analyses, evidence points to the importance of technical and disciplinary language in these differences. Differences in vocabulary and language in the interviews also supports this research finding. A majority of fifth grade students fell into the high understanding category in the interviews. These students were able to give an explanation for the responses they gave instead of just giving a one-word answer. Fifth graders were more familiar with terms such as "photosynthesis," "ecosystem," "conservation," and "inherited traits."

Researchers have addressed the difference in vocabulary and language among elementary students. For example, Pense, Leising, and Portillo (2005) administered an assessment to elementary students in grades K-6. The K-1 instrument was composed entirely of pictures, the 2-3 grade instrument used pictures and simple text, and the 4-6 grade instrument used multiple choice. By administering the same assessment to students in all three grades, we were able to see how students in different grades responded to the same question. Because the NALOs are relatively new, it was important for us to see how students' vocabulary matched with the wording of the NALOs. Work remains to be done to develop optimal measures of students' agricultural literacy that take into account these developmental factors.

Implications

Results from this study have important implications for supporting upper elementary students' learning about agriculture, including the articulation of agricultural literacy outcomes, curriculum development, and professional development for teachers. First, study findings provide insight on strategies for improving the accessibility of the NALOs for elementary students and teachers. Some NALOs include vocabulary and language that many students were unable to understand. Students responded with "what does that mean?" to some interview questions. These questions included terms such as conservation, inherited traits, and ecosystems that were taken directly from individual NALOs. Students should be comfortable with the NALO vocabulary because it is consistent with other standards such as social studies and science. Understanding the terms included in the NALOs is the first step in enhancing agricultural literacy. Using empirical data such as this to revise the NALOs would provide a better benchmark for agricultural literacy that would allow researchers to assess the current agricultural literacy of students and develop interventions to improve agricultural literacy.

Second, study findings show the synergistic relationship between core STEM concepts and students' agricultural literacy. Contemporary agriculture is founded in STEM principles (NRC, 1988). Many curricular resources already exist to help educators teach about agriculture, including National Agriculture in the Classroom, Project Food, Land, and People, and the Food, and Fibers Systems Literacy. Agriculture can serve as a motivating and engaging context for teaching and learning about STEM topics. The NALOs were developed to reflect this, aligning directly with the *Next Generation Science Standards* (NGSS Lead States, 2013). This alignment enables teachers to teach a science concept through agriculture. As such, results from this study can inform the design of curricular programs, including lesson plans and other instructional resources, based off of the NALOs and STEM standards. Results from this study reveal gaps in student understanding related to the NALO content areas. This information can be used to generate grade-appropriate lesson plans for students that integrate STEM and focus on agriculture.

Limitations

All students that participated in this study attended elementary school in a single state. Students were not randomly-selected and do not comprise a fully representative sample. Students in this study may be more familiar with agriculture than students in different locations. However, findings from other scholars (as mentioned above) state that students from a rural agricultural state may not be more knowledgeable then students from a state where agriculture is less prevalent. Student demographic information was not collected in either strand of the study. Collecting this demographic information would have allowed for a better understanding of the effect of student background on their agricultural knowledge. Agricultural experience and knowledge would vary greatly based on if someone was raised on a farm or grew up in the city.

The assessments only consisted of one question per standard per difficulty level. Most of the NALOs were written in a broad manner. With agriculture being so diverse, it was difficult to find one question that would encompass the entire NALO. Some NALOs talked about both crop and livestock systems while the actual assessment questions focused on one or the other. Additional questions surrounding each NALO and difficulty area would have provided more insight into students' knowledge of the NALOs.

Students took the assessment on paper which resulted in some students leaving assessment questions blank. Students may have left questions blank if they did not know the answer or if they were confused with the assessment format. The assessment consisted of true/false, multiple choice, and matching questions. The inconsistent question format may have confused students. Administering the assessment through an online survey would have forced students to answer every question. Vocabulary on the assessment may have also confused some students. In the interviews, students could ask for clarification to better answer the question. However, students did not get this benefit on the assessment. Some of the vocabulary on the assessment was intentionally more complex (i.e. photosynthesis) to determine if students were in the high understanding category.

Recommendations

This study looked at the NALOs in the upper elementary grade band in the areas of STEM and agriculture and the environment. The other NALO categories including social studies and food, nutrition, and health were not included in this study. Furthermore, the NALOs were created for a variety of grade bands such as early elementary, middle school, and high school. This study focused solely on the upper elementary grade band. Future research following a similar mixed methods approach grounded in Evidence-Centered Design should be conducted to develop instruments and measure student outcomes associated with the remaining NALOs.

Summary

This study contributes to the future of agricultural literacy research. This is the first study focused on the development and validation of agricultural literacy assessments grounded in the National Agricultural Literacy Outcomes (NALOs). Results from this study provide important insights into upper elementary students' ideas about fundamental intersections between agriculture and science, technology, engineering, and mathematics. This study contributes to existing bodies of knowledge about agricultural literacy, STEM learning, and assessment design and development. To date, very few studies focused on agricultural literacy have utilized a mixed methods approach. The use of the evidence centered design process allowed for the creation of assessments based on students' understanding. The present study can provide an important foundation for future work to develop empirically-grounded, valid, and reliable assessments of NALOs, as well as inform the revisions of the NALOs themselves.

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