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Measuring Agricultural Literacy: Grade 3-5 Instrument Development and Validation

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Abstract

Modern societal functions for meeting basic needs contribute to the lack of understanding many Americans have about agriculture's connection to human health and environmental quality. Consequently, this limited understanding has produced a need to measure agricultural literacy to develop programming or enhance existing agricultural educational efforts. Research literature has identified the need for agricultural literacy instruments to be developed that measure current understandings. The National Agricultural Literacy Outcomes (NALOs) served as the conceptual framework for the development of an agricultural literacy criterion referenced progressive measurement tool for grades 3-5. A theoretical framework using assessment models was used to develop items to measure agricultural literacy in three proficiency stages: exposure, factual literacy, and applicable proficiency. A modified Delphi method was used to create the Longhurst Murray Agricultural Literacy Instrument (LMALI) with the intent of assessing elementary student understanding of the NALOs. Items were tested with students from regional representative states using exploratory factor analysis, confirmatory factor analysis, and discriminant analysis in the investigation. The development process resulted in a validated 15-item instrument for grades 3-5. Overall, the instrument provides a way for educators and stakeholders to measure agricultural literacy based on proficiency stages within the five NALO themes.

Keywords: agricultural literacy; agriculture; proficiency stages; agricultural assessment; agricultural benchmarks

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Introduction

As our agrarian society has transformed over the last century, increasing productivity and efficiency distanced our understanding of the sources for food, fiber, and fuel (National Research Council, 1988). Today, a growing need exists for citizens to have the "ability to understand and communicate the source and value of agriculture" (National Agriculture in the Classroom, 2013, "What is agricultural literacy?" para. 1). Currently, less than 2% of our citizens work to produce agricultural products (American Farm Bureau Foundation for Agriculture, 2013). Powell and Agnew (2011) and others indicated that substantive links to agriculture are absent in the lives of a majority of Americans (Vallera & Bodzin, 2016; Kovar & Ball, 2013). As a result of limited connections to agriculture, fewer

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jobs in farming production, and declining agricultural literacy; the need for effective agricultural education efforts by stakeholders is necessary to achieve acceptable levels of agricultural literacy.

Society should be able to develop and enact policy and legislation grounded on scientific principles that support safe, affordable, and sustainable food systems. The development of an agriculturally literate society is dependent upon the development of accurate understandings and knowledge. To update previous benchmarks and standards and provide updated grade-banded standard benchmarks or outcomes, Spielmaker and Leising (2013) led the development of the National Agricultural Literacy Outcomes (NALOs) using the Food and Fiber Literacy project as a framework (Leising et al., 1998). The goal of this research was to develop an assessment instrument to evaluate students' agricultural proficiency, in grades 3-5, based on the NALOs. Previously, instruments to measure the agricultural literacy of elementary students were limited (Fischer, 2017). An assessment instrument aligned to the standards of agricultural literacy would offer educators a tool to measure growth and acquisition of agricultural understandings resulting in instructional inputs to improve the agriculturally literacy of our communities.

Need for Assessments of Agricultural Literacy

Although the NALOs provide uniform outcomes for agricultural literacy, knowing if students are meeting these objectives without sound assessments is challenging. Standardized national agricultural literacy assessments, based on the NALOs, are necessary for teachers and other stakeholders to inform their instruction and evaluate gains with summative data. Prior research shows that despite a variety of programs focused on agricultural literacy, many learners remain agriculturally illiterate (Kovar & Ball, 2013; Vallera & Bodzin, 2016). In many cases, low literacy levels have contributed to scientific misconceptions about agriculture leading to negative attitudes about the production and processing of food and fiber systems (Trexler & Hess, 2004). Ultimately, low literacy levels foster misinformed public perceptions and indefensible public policies.

Limited agricultural literacy has resulted in multiple efforts from formal and nonformal education entities to enhance the exposure to and literacy of agriculture in society. Specifically, literacy benchmarks and assessment measures have been developed to assess K-12 agricultural literacy levels over the last 30 years (Frick, 1993; Leising et al., 2000; Powell et al., 2008). Moreover, previously developed measures for agricultural literacy were based on the Food and Fiber Systems Literacy project (Leising et al., 1998) adding to the need for updated assessments aligned with current educational standards (Brandt, 2016; Jones, 2013). These previously developed instruments also measured only one level of understanding, thereby limiting the interpretation of the results. The limited current research in this arena demonstrates the need for an agricultural literacy instrument that aligns with the NALOs. In order to meet the deficiency of agricultural literacy, researchers have indicated the need for standardized assessments of foundational agricultural understandings (Brandt, 2016; Fischer, 2017).

Problem Statement

The need for this research was grounded in two fundamental challenges to the status of agricultural literacy. First, the literature demonstrated a lack of consistency and alignment regarding the criterion and constructs of agricultural proficiency stages, resulting in limits to validity across instruments (Vallera & Bodzin, 2016). The second challenge centered on the outdated nature of the valid assessments that lacked capacity to align to current needs (Jones, 2013; Brandt, 2016). The recognition and adoption of the NALOs established a valid national framework consistent with agricultural literacy goals and outcomes (Spielmaker & Leising, 2013). The establishment of national agricultural outcomes necessitated the development of validated assessment instruments based upon those outcomes in order to measure progress on instructional objectives.

NALO Development

The development of any agricultural literacy instrument must be integrally linked with current definition of agricultural literacy, the established NALOs, and ancillary work supporting the current agricultural literacy standards (Spielmaker et al., 2014). As part of the NALO development, an agriculturally literate individual is defined as "a person who understands and can communicate the sources and value of agriculture as it affects our quality of life" (National Agriculture in the Classroom, 2013, "What is agricultural literacy?" para. 1). The NALO framework focuses on agricultural literacy and is grounded in national educational standards, namely the Next Generation Science Standards (NGSS), the National Curriculum Standards for Social Studies, and the National Health Education Standards. Spielmaker et al., (2014) employed a modified Delphi method to establish the agricultural literacy benchmarks, which followed the conceptual process used to craft the NGSS (Next Generation Science Standards Lead States, 2013).

Theoretical Framework and Literature Review

The National Research Agenda for Agricultural Education includes a priority for scientific researchers to demonstrate the impact of agricultural literacy efforts (Roberts et al., 2016). Aligning evaluation instruments with a modern agricultural literacy framework is essential to achieve this agenda. In their work with the Programme for International Student Assessment (PISA), Sadler and Zeidler (2009) defined science literacy in broad perspective that included science content mastery as well as the ability to recognize social and cultural issues through enacting public policy supported by scientifically sound principles. Our use of this sociocultural framework within assessment of agricultural literacy also includes operationalizing literacy outcomes through competencies, contexts, and knowledge constructed within each NALO theme. The development and implementation of the Common Core State Standards (National Governors Association, 2010), the Next Generation Science Standards (Next Generation Science Standards Lead States, 2013), and the National Curriculum Standards for Social Studies: A Framework for Teaching, Learning, and Assessment (National Council for the Social Studies, 2010), necessitates the updating of historical assessment tools. These updates require instruments to more accurately measure agricultural literacy and effectively assess the impact of current agricultural literacy programs. Finally, the use of assessment theory is strengthened by the incorporation of proficiency levels, which offer a purposeful and specific boundary for the development and description of agricultural literacy achievement.

Agricultural Literacy Frameworks and Assessments

Leising et al., (1998) crafted the seminal Food and Fiber Systems Literacy (FFSL) framework. This framework provided the literacy expectations for K-12 learners through five agriculturally-themed standards. The FFSL framework included (a) Understanding Agriculture; (b) History, Geography and Culture; (c) Science and Environment; (d) Business and Economics; and (e) Food, Nutrition and Health (Leising et al., 1998). The establishment of the FFSL was a major milestone in agricultural literacy because it provided a model to measure achievement based on grade-banded benchmarks (Pense & Leising, 2004).

Case study research, using the FFSL framework, demonstrated effectiveness in evaluating elementary learners' understanding of agriculture (Leising et al., 2000). However, most school-based agricultural programs did not show increases in literacy (Kovar & Ball, 2013). Additional research demonstrated increases in student engagement and agricultural awareness but, in some cases, significantly below average literacy achievement (Crawford, 1998; Colbath & Morrish, 2010; Jones, 2013; Pense et al., 2005). A number of additional, small scale investigations were conducted targeting a particular intervention topic, grade level, a single state, or population with unique instrumentation based on outcomes similar to the FFSL (Hess & Trexler, 2011; Meischen & Trexler, 2003; Terry et al., 1992; Trexler, 2000). Although these studies provide some understanding of agricultural literacy levels, they are limited in the ability to generalize to larger populations. Kovar and Ball (2013) provided a synthesis of agricultural literacy research where they determined that agricultural literacy programs could be successful in increasing literacy when used by formal and nonformal educators. Although attempts to improve agricultural literacy have increased over the last two decades, additional investment in agricultural instruction appears to be warranted.

Researchers noted that many programs, materials, and resources are available to improve agricultural literacy; however, the materials seem disconnected (Terry et al., 1992). Trexler et al., (2013) indicated that previous grade-banded benchmarks were established by "best guesses" rather than being based on age and developmental appropriateness. Meischen and Trexler (2003) questioned the thorough testing of benchmarks for suitability in specific grade levels or age groups. Finally, Jones (2013) acknowledged that the modernization of the FFSL should include current understanding of sustainable agriculture, alternative energy, climate change, and environmental literacy. The NALOs are foundational principles of the FFSL benchmarks incorporating developmental appropriateness with the outcomes being cross-walked and aligned with national education standards. The NALOs provide learning benchmarks to unify future agricultural literacy teaching and outreach efforts.

Conceptual Framework for Instrument Development

The previous discussion demonstrates the need for strong standards and instruments to effectively assess student proficiency stages of agricultural literacy. In order to respond to this need, a modified version of the PISA item construction was used as a foundational framework (OECD: Programme for International Student Assessment, 2016) for the development of the Longhurst Murray Agricultural Literacy Instrument (LMALI) presented in this research. The criterion referenced (NALO) assessment items in the conceptual framework included specific stages of proficiency, experiential learning, and item response. This modified framework (discussed in greater detail in the methods section) uses the Delphi technique to obtain expert input to craft appropriate assessments. Repeated design and writing iteration strategies in the Delphi technique establish consensus (Hsu & Sandford, 2007). Using a Delphi method involves experts giving initial feedback, reassessing initial input, and modifying personal ideas based on input from other committee members. The iterative process intentionally counters common challenges of group input based on opinions, pressure to agree, or influences of dominant ideas (Dalkey et al., 1972). Hsu and Sandford (2007) reported that in most instances three iterations of expert input provide ample consensus building opportunities.

Multiple researchers identified committee selection as the most critical part of using the Delphi method (Jacobs, 1996; Judd, 1972; Taylor & Judd, 1989). Committee selection should be based on skill demonstrated stakeholder investment and expert knowledge in the content arena in order to establish content validity (Okoli & Pawlowski, 2004; Winkler & Poses, 2004). Goodman (1987), Messick (1993), and Sireci (1998) all described how content reliability can be established through the use of experts in specific domains. The collective knowledge of experts within the Delphi method, combined with the use of national standards, provided the internal consistency necessary to make appropriate and reliable instrument decisions.

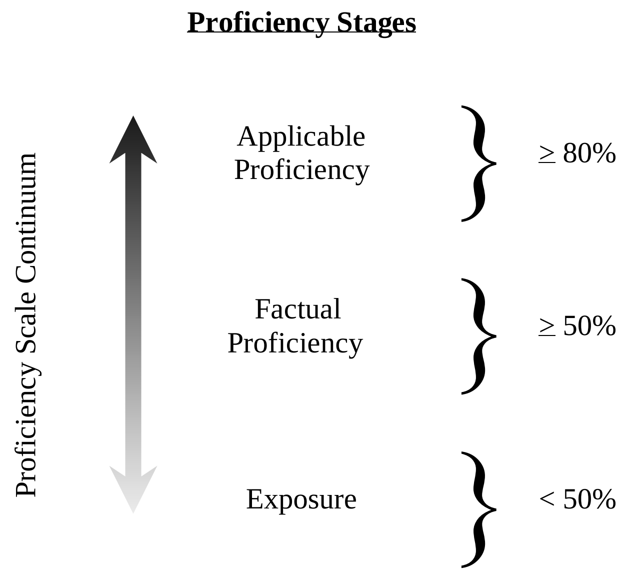
A learner demonstrating proficiency of agricultural knowledge not only knows specific terms, facts, principles, procedures, or processes, but also is able to translate ideas, express understanding in novel ways, and apply skills to new settings (Guskey, 2005). This type of learning takes individuals beyond simple recall of facts and enables them to synthesize key outcomes of learning. Generally, assessments identify the knowledge of a learner at a particular time, relative to a set of learning standards. The National Research Council (2009) indicated that measures of learning should identify the development of increased scientific understandings and how learners progress to more sophisticated knowledge. As learners increase along this proficiency continuum, they gain content knowledge skill in applying practices of science and crosscutting concepts essential to scientific and agricultural literacy.

Based on this literature, assessments that employ "proficiency" reporting scales provide data on what a student can do within levels of development, rather than simply offering a standardized score. The PISA "assessed students and used the outcomes of that assessment to produce estimates of students' proficiency in relation to the skills and knowledge being assessed in each domain" (OECD: Programme for International Student Assessment, 2016, p. 276). Similar to PISA, this work evaluated a student's ability level to determine placement on the proficiency scale.

Connecting Agricultural Literacy and Assessment

Using proficiency scale modeling for agricultural education and assessment is not new. A precedent was set by Pense et al., (2005), who first showed the FFSL framework incorporated multiple aspects of Dewey's (1938) Experiential Learning Theory (ELT). ELT gives learners opportunities to demonstrate proficiency between grade-level and concept overlaps. This foundational theory is rooted in the work of educational theorists like Dewey (1938), Lewin (1951), and Piaget and Cook (1952). It seems apparent that learners of agricultural concepts bring some level of understanding to each learning experience. Within this theoretical framework, the idea of no exposure is generally an impossibility. Even learners who are unable to respond to the items on a particular instrument still possess some level of exposure. Joplin (1981) and Roberts (2006) supported Dewey's theory (1938) that experiential learning is a constant and fluid process and rejected the idea that students enter learning experiences as blank slates (Collins et al., 2001). Seeing learning as a continuum is essential in the use of a framework in order to understand that all learners exhibit some level of understanding. As a result, every learner is on the continuum in regard to their experience, knowledge, or understanding of agricultural concepts. An instrument grounded in proficiency stages could appropriately measure growth along this continuum (see Figure 1). The instrument designed in this research employed proficiency stages starting with exposure (E) moving to learners demonstrating factual literacy (L) and ultimately applicable proficiency (P). The student skill levels for grade-grouping from the PISA techniques were foundational in the development process.

Figure 1
Proficiency Scale Continuum



Note: Adapted from PISA participant proficiency scale model (OECD: Programme for International Student Assessment, 2016).

Joplin (1981) and Roberts (2006) both provide sequences of learning that initially identify learners at an exposure stage. Subsequent stages are similar with Joplin (1981), while Roberts (2006) describes the more sophisticated stages as identification and dissemination. In both models, learners progressed in their ability to communicate and display deeper stage of proficiency as they moved along the trajectory.

In summary, agricultural literacy assessments used in the past demonstrate how assessment instruments can inform critical decision making (Vallera & Bodzin, 2016). Basing future agricultural assessment instruments on the current body of literature is important. The synthesis of research and current definition of agricultural literacy form the foundation of the NALO benchmarks (Spielmaker & Leising, 2013). Basing any assessment instrument on these foundational frameworks provides an appropriate evaluation of the growth and understanding in agricultural literacy. The current approach of the NALOs allows for curriculum, content, and assessments to be integrated and blended across multiple disciplines. Vasquez et al., (2013) indicated that the solutions to real-world problems are aided when this type of multidisciplinary instruction occurs. Finally, using a proficiency scale model to measure agricultural literacy helps address the gaps in student understanding. An agricultural literacy instrument should be used by stakeholders to infuse the knowledge from research into teacher professional learning, outreach programs, and classroom instruction.

Purpose and Objectives

The purpose of this study was to develop an age appropriate agricultural literacy assessment instrument for grades 3-5 that could be used as a formative and summative tool to guide instruction and programming for educators and agricultural stakeholders. The following research questions guided the development process of this study:

1. Is the Longhurst Murray Agricultural Literacy Instrument (LMALI) a valid and reliable measure of the National Agricultural Literacy Outcomes?
2. Does the Longhurst Murray Agricultural Literacy Instrument (LMALI) effectively distinguish between proficiency stages of agricultural literacy in the 3-5 grade band?

Methods and Procedures

The proficiency stage model, adapted from PISA, was used to develop an agricultural literacy assessment to better understand a learner's level of understanding. The assessment tool, the LMALI, was developed using a Delphi method for valid and reliable alignment to the NALOs. The following methods explain the development of the LMALI, the population involved in the study, and the analysis design.

Instrument Development

The LMALI assessment was developed using the foundational concepts from the NALOs and a theoretical framework to determine proficiency stages, context, competencies, and knowledge of agricultural literacy. A teacher advisory committee was formed consisting of expert teachers in the field, following the PISA Delphi format. Members represented the grade levels within the 3-5 grade band and were selected based on expertise in grade-level content. Grade-specific assessment questions in the five NALO themes were designed. Questions were developed for each of the five NALO themes to identify student comprehension at the exposure, factual literacy, and applicable proficiency stages. The Teacher Advisory Committee constructed a pool of 45 items to assess the NALO themes at each proficiency stage in each theme. This initial item pool consisted of three items for each proficiency stage within each NALO theme. The entire item pool was then tested with a national student population.

In conjunction with the teaching experts, the agricultural advisory committee was formed to review item pool questions ensuring that agricultural and scientific accuracy was inherent in each of the items. This committee determined if the assessment items directly aligned with the NALO benchmarks. The expert committee was formed from national agricultural stakeholders representing Florida, Minnesota, Pennsylvania, and Utah. As with the teacher committee, the Agricultural Advisory Committee followed a similar iterative agreement and consensus building approach to item approval. This process resulted in 45 total items that were reviewed by both the Teacher Advisory Committee and the Agricultural Advisory Committee for accuracy and scientific consistency. The multiple iterations of consensus building by these experts provided construct validity as they crafted items for targeted NALO themes and proficiency stages. All Delphi interactions among the committee members were initially conducted face-to-face or through video conferencing software. Subsequent communication occurred by email, phone, or interactive online documentation (Google documents).

Figure 2 illustrates the conceptual framework and the literature supporting the creation of the LMALI. The framework presented distinguished how each aspect informed the next step of the development. Using the NALOs in combination with a proficiency stages framework, allowed the creation of a progressive assessment that more accurately measured student development in agricultural literacy. The LMALI was written for best understanding at the highest-grade level within the NALO grade-group (i.e., written for understanding at the 5th grade level in the 3-5 grade band). Students in lower grades may still use the assessment, but it is anticipated that they may only be able to answer exposure stage questions. A student who could only answer questions correctly at the exposure stage would have the most limited understanding of the agricultural literacy standard. A student who answered questions at the factual literacy stage would display understanding related to content knowledge or the challenge skills identified by Joplin (1981). Students correctly answering questions at the applicable proficiency stage would display agricultural literacy at the highest performance stage of comprehension (Roberts, 2006). Additional detail and development of the proficiency framework is shown in Table 1. The experts determined that the final form of the LMALI required 15 items; one question for each proficiency stage in each of the five NALO themes. The final version of the LMALI provided a continuum within each theme to appropriately assess the learners' level of agricultural literacy. The number of items selected offered an instrument with efficient utility for the classroom and non-formal education stakeholders. The instrument was then formatted for delivery to regional student populations. Although eight states were randomly selected to participate in the testing of the LMALI, only seven states completed the delivery of the instrument to students during the testing window due to unforeseen constraints.

Figure 2
Conceptual Framework Development Process of LMALI

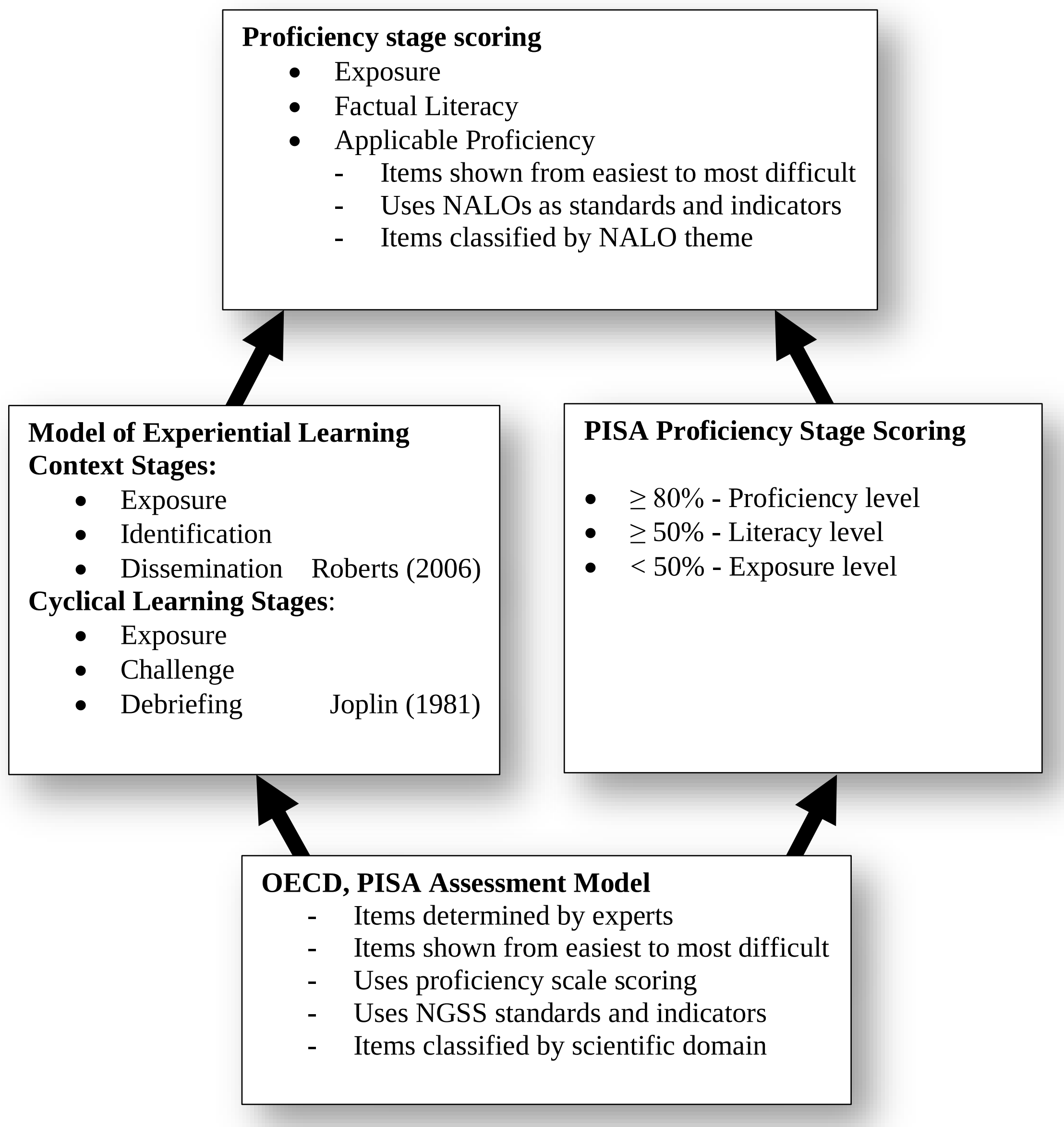


Table 1
Summary Descriptions of the Proficiency Stages for LMALI

Proficiency Stage	General Proficiencies
Exposure	Learners at this stage demonstrate limited agricultural literacy. Recognition and identification of everyday agricultural products, tools, plants, or animals represent this exposure proficiency stage. Learners will be capable of making comparisons and using simple pictures or descriptions.
Factual literacy	Learners at this stage demonstrate operational ability to make simple predictions. They show the ability to make connects among varied contexts of agriculture and determine relevancy. Learners are capable of sequencing agricultural events such as planting, watering, fertilizing, and harvesting.
Applicable proficiency	Analysis of complex data and the ability to link multiple inferences to practical solutions is represented in this stage. Learners are able to draw on inter-related ideas and apply provided concepts to novel settings or situations. Learners also demonstrate the ability to explain complex situations in terms of impacts and outcomes.

Note. Proficiency stages adapted from the works of Joplin (1981), Roberts (2006), and the PISA technical report (OECD: Programme for International Student Assessment, 2016).

Population

The student respondent population consisted of fifth-grade classrooms from eight states within the United States (Maryland, Michigan, Nevada, North Carolina, Pennsylvania, Utah, and Wisconsin; $N = 227$). State selection was random with school selection based on convenience. Participating schools and districts were selected by Agriculture in the Classroom representatives from each state who had been certified to administer the instruments. Secondary populations of participants consisted of (a) fifteen classroom teachers; (b) six K-5 teachers formed the Teacher Advisory Committee; and (c) five members of the Agricultural Advisory Committee. The classroom teachers participated in a self-reported classroom survey to collect information about school region, potential student exposure to agricultural-related events or activities, and student population demographics.

Appropriate Institutional Review Board (IRB) approvals were sought and obtained through sponsoring Institutions of Higher Learning (IHE) and Local Education Agencies (LEA). Prior to administration within the participating schools, Letters of Information (LOI) were provided to the participants in order to allow individuals to decline participation. During the day of administration, participants were provided with a verbal explanation of the LOI. Instruments were then collected by research-trained representatives in schools from each of the participating states.

Research Design

The LMALI was crafted using the Delphi model for content and construct validity pertaining to the NALO benchmarks. Further analysis for validity related to the proficiency stages was conducted using factor, item, and discriminant analysis. Descriptive data analyses followed by exploratory factor analyses (EFA), a confirmatory factor analysis (CFA), and a discriminant analysis (DA) were performed using SAS (SAS Version 9.4). Additional item analyses were conducted as appropriate. Examination of the results of these statistical methods provided evidence to remove or include particular items in the final instrument. A DA was deemed necessary because of the known limitations to the validity of a CFA when items are scored only 0/1 with possible multi-collinearity among these items (Hatcher, 1994). Additionally, because the five NALO themes have known associations, the adequacy of a CFA might be reduced. Consequently, EFA, CFA, DA and additional item analyses were used together to build and assess the final 15-item instrument. Establishing the validity of the instrument substantiates the claims that the information in the research, evaluation, or literacy examination is appropriate (Stewart, 2009).

Frequency groups of student responses were first examined by the research team. The total scores and partial scores were analyzed. Based on the recommendations of best statistical practice, the highest score on the assessment was used as the maximum score. Scores greater than or equal to 80% of the highest score were classified at the proficiency stage. Scores between 79-50% of the highest score were classified as factual literacy, and scores below 50% of the highest score were categorized at the exposure stage. Partial scores were calculated to determine if individual items should be included in the instrument. Potential questions for the final version of a 15-item LMALI were examined using both a CFA and a DA to assess how each item helped differentiate the three proficiency stages.

Results

Upon establishment of initial test items by the expert committees, we collected data from states (Maryland, Michigan, Nevada, North Carolina, Pennsylvania, Utah, and Wisconsin) within each of the four agricultural regions. Standard descriptive statistics from the sample of students who completed the LMALI, including the mean, standard deviation, and partial credit mean percent correct for each of the original instrument items can be seen in Table 2. The 3-5 grade level sample size (*N* = 227) provided an adequate number of responses for the intended analyses (Hatcher, 1994). The descriptive data illuminated some differences between total correct and partial correct means, indicating that, on some questions with lower overall mean percent correct, subjects failed to identify one of multiple correct responses.

The descriptive data showed that the highest score achieved was 42 out of 45 items (*max* = 42, *min* = 9, *M* = 30.14, *SD* = 6.15). Following the descriptive analysis, we conducted iterative EFAs coupled with individual item analyses to reduce the item set from the 45 original items to a 15-item final set, with at least one item retained for each theme at each proficiency stage.

Table 2
Descriptive Statistics of LMALI Student Assessment 2018

Item	*M*	*SD*	Partial Correct %
T15E1 (NALO **T**heme **1**, grade **5**, **E**xposure stage, item **1**)	.60	.49	.93
T15E2	.92	.27	.94
T15E3	.89	.32	.89
T15L1	.28	.45	.74
T15L2	.66	.48	.67
T15L3	.39	.49	.38
T15P1	.90	.31	.90
T15P2	.30	.46	.71
T15P3	.39	.49	.52
T25E1	.43	.50	.79
T25E2	.39	.49	.95
T25E3	.02	.13	.56

Table 2
Descriptive Statistics of LMALI Student Assessment 2018, Continued…

T25L1	.22	.42	.71
T25L2	.69	.46	.73
T25L3	.77	.42	.81
T25P1	.80	.40	.82
T25P2	.36	.48	.64
T25P3	.74	.44	.89
T35E1	.78	.42	.89
T35E2	.23	.42	.73
T35E3	.89	.32	.88
T35L1	.68	.47	.68
T35L2	.96	.20	.96
T35L3	.74	.44	.77
T35P1	.87	.34	.87
T35P2	.62	.49	.64
T35P3	.89	.32	.90
T45E1	.92	.27	.91
T45E2	.60	.49	.60
T45E3	.81	.40	.81
T45L1	.86	.35	.83
T45L2	.64	.48	.63
T45L3	.94	.23	.96
T45P1	.65	.48	.63
T45P2	.92	.27	.92
T45P3	.83	.38	.83
T55E1	.90	.30	.89
T55E2	.87	.34	.86
T55E3	.97	.16	.98
T55L1	.86	.35	.86
T55L2	.89	.31	.89
T55L5	.65	.48	.65
T55P1	.11	.32	.69
T55P2	.53	.50	.55
T55P4	.57	.50	.78

Note. (*N* = *227*, *M* = 30.14, *SD* = 6.16, *max* = 42). The partial scores were calculated with the consideration that students credited for correct item selection and not penalized for incorrect selections. Coding Key: T15L2 identifies NALO theme (T1), Grade level (5), Literacy stage (P=applicable proficiency, L=factual literacy, E=exposure), Item or question (2).

Exploratory Factor Analyses and Item Analyses

The latent factors were identified as the three proficiency stages: exposure (E), factual literacy (L), and applicable proficiency (P). We analyzed the factors using items from each of the five NALO themes. At each stage of the iterative process, item analyses plus the EFA results were used to determine if each item should be discarded, recoded based on the item analysis, and/or assigned to a different proficiency level from its original assignment from instrument development process. Table 3 details the recommendations and provides the determination of potential inclusion in a final 15-item instrument. We discarded some items based on showing little discrimination between each of the proficiency stages. Other items were discarded as a result of poor item creation resulting in low mean correct response percentages.

Identifying the correct proficiency stage using the EFA results required an evaluation of each question or item. Expert groups initially established item determinations; post-EFA adjustments were then made to appropriately label the proficiency level. Each item reflected how most participants within a particular learning stage would answer the item. If items showed that between 70-80% of the responses were correct, the proficiency stage was properly identified. If less than 70% of the participants responded incorrectly it would indicate that the item showed a learning gap, an ineffective question, or an incorrect response option. The research team determined if an item should remain in the instrument when learning gaps appeared. Those decisions were based on how the content aligned with particular NALO benchmarks. The team discarded items that showed more than 80% accuracy, thus demonstrating limited discrimination of literacy stages. In the process of analyzing the EFA data, inclusion and exclusion determinations were based on quantitative data and the connection to established NALO benchmarks.

Table 3
Item Analyses and Selectin Determination

Item	% Correct E_n=91	% Correct L_n=136	% Correct P_n=69	Recommendations
T15E1	42	63	77	P *
T15E2	90	90	90	Item discarded
T15E3	90	87	90	Item discarded
T15L1	17	24	52	Further item analysis
T15L2	60	57	90	P
T15L3	23	33	70	P *
T15P1	76	94	99	E
T15P2	15	24	59	Further item analysis
T15P3	25	37	62	Further item analysis
T25E1	28	41	67	P
T25E2	43	40	29	Item discarded
T25E3	0	2	3	Further item analysis
T25L1	4	15	42	Item discarded
T25L2	30	66	88	P
T25L3	23	76	97	L
T25P1	65	82	97	E
T25P2	32	29	54	Item discarded
T25P3	65	72	90	E
T35E1	79	71	90	E *
T35E2	22	13	44	Further item analysis
T35E3	86	88	96	Item discarded
T35L1	56	66	88	L *
T35L2	91	97	100	Item discarded
T35L3	77	69	81	E
T35P1	79	88	94	E
T35P2	48	57	90	P
T35P3	76	93	99	E
T45E1	80	96	100	E
T45E2	60	56	68	P *
T45E3	63	86	96	L
T45L1	79	85	94	E
T45L2	54	64	77	P *

Table 3
Item Analyses and Selectin Determination, Continued…

T45L3	88	96	99	Item discarded
T45P1	60	59	81	P
T45P2	81	96	100	Item discarded
T45P3	69	86	96	E
T55E1	78	93	99	E
T55E2	85	84	97	Item discarded
T55E3	93	99	99	Item discarded
T55L1	86	86	86	Item discarded
T55L2	77	92	100	E
T55L5	44	65	91	L
T55P1	8	3	33	Item discarded
T55P2	43	47	80	P
T55P4	44	51	88	P

Note. (N = 227, max = 42). Proficiency stages determined using participant's percentage of the maximum score forming participant groups: Exposure < 50% (< 27); Factual literacy between ≥ 50-79% (≥ 27); Applicable proficiency ≥ 80% (≥ 34). Coding Key: T15L2 identifies NALO theme (T1), Grade level (5), Literacy stage (P=applicable proficiency, L=factual literacy, E=exposure), Item or question (2).
*Proficiency stage modification occurred based on additional factors.

Confirmatory Factor Analysis

Following the recommendations of Table 3, plus further item analyses that resulted in 4 of 5 items being retained, there were 31 items eligible for inclusion in a final 15-item instrument. Subsequent CFAs, using selections of 15 items from these 31, resulting in exactly one item at each allocated proficiency level from each theme, were conducted to determine if (a) factor loadings (coefficients) were statistically significant, (b) of the same sign (i.e., items seemed to belong to the same "scale" for each factor), and (c) what overall model fit was achieved using three latent factors representing the three proficiency stages. At the end of this iterative process, a final 15-item instrument satisfied the target criteria for an adequate fit. Specifically, residual chi-square/residual DF = 1.17 (< 2 target), RMSEA estimate = 0.0281 (< 0.05 target), Adjusted GFI = 0.93 (> 0.9 target), Bentler-Bonnett NNFI = 0.94 (> 0.9 target), and all 15 factor loadings were statistically significant with p-values < 0.01, and all loadings were of the same sign (see Hatcher, 1994, for details of these target criteria).

Discriminant Analysis

Once the 15-item instrument was developed a DA was conducted from the CFA data. Each respondent was again assigned to a learning stage based on a score out of 15 on the instrument. Thus, a proficiency level was a score greater or equal to 12, a literacy level score was from 7.5 to 11.9, and an exposure level score was below 7.5. The DA then assessed whether the 15 items could successfully distinguish among the three proficiency stages based on these scores.

Table 4 provides the results of the re-substitution and cross-validated discriminant analysis. A performance report with sensitivities (percent correctly classified into their proficiency group) greater than 80% demonstrates good differentiation among the three proficiency stages. The results of the DA show that each proficiency classification exhibited extremely high sensitivity (Exposure = 91.30%; Factual Literacy = 100%; and Applicable Proficiency = 100% for the re-substitution report and Exposure = 91%, Factual Literacy = 98.8%, and Applicable Proficiency = 95.8% for the cross-validated report, all well above the threshold of 80%). The overall error rate was 3.5%, and only in the exposure group was the misclassification rate above 5%. Thus, the simple score out of 15 for the LMALI was effectively the same as the best separation of the three proficiency stages using all 15 items individually for discrimination.

Table 4
Discriminant Analysis: Resubstitution and Crossvalidation Summary

Proficiency Stage	n	Resubstitution (% Correct)	Error Rate (%)	Cross-validation (% Correct)	Cross-validation error rate
Instrument					
Exposure	23	91.3	8.7	91.00	8.7
Factual Literacy	85	100.0	0.0	98.82	1.2
Applicable Proficiency	119	100.0	0.0	95.80	4.2
Total	227	99.1	0.9	96.50	3.5

Note. Proficiency stages were determined using the maximum high score (*max* = 15) to form the following participant groups: Exposure < 50% (< 8); Factual literacy ≥ 50% (≥ 8); Applicable proficiency ≥ 80% (≥ 12).

Grouping the proficiency stages based on a score out of 15 for the instrument provided the following: a score of greater than or equal to 12 indicated proficiency, between 8-11 indicated literacy, and below 7 indicated an exposure stage. Results showed sensitivities above 90% were consistently achieved; some items were perfectly identified at 100%, indicating that selected items perfectly discriminated between the three proficiency stages. Understandably, the discriminant score is a weighted sum of the item values, so it differs from the simple score out of 15, but the data show that the LMALI has the ability to measure standardized proficiency levels.

Summary of Results

Expert teaching and agricultural committee members determined that 45 items met the criteria of the NALO benchmarks being classified in each proficiency stage for students in grades 3-5. The data analysis incorporated the following statistical measures: (a) descriptive data, (b) determination of proficiency levels using EFA, (c) CFA, and concluded with (d) a DA. The analyses culminated in the creation and validation of a single 15-item instrument for teachers, agricultural outreach professionals, and agricultural stakeholders to evaluate the agricultural proficiency levels of students in grades 3-5.

Validity and Reliability

We used quantitative statistical measures in this study to evaluate the validity the LMALI. To determine the validity of the LMALI we employed descriptive analyses, EFA, CFA and DA. The cross-validated DA provided evidence of the correct instrument calibration and that it had validity when determining the proficiency levels of agricultural literacy.

We grounded reliability measures in the Delphi method with the development of the LMALI centered in the content of the NALOs. The use of teaching and agricultural experts in the creation process provided internal consistency with the NALOs. Results showed LMALI is both a valid and reliable measure of agricultural literacy based on the proficiency levels defined in this research.

Findings and Implications

This research adds to the body of knowledge informing national agricultural literacy efforts by offering a valid and reliable assessment instrument for grades 3-5. We recommend that agricultural stakeholders use the LMALI (3-5) as a tool to assess agricultural literacy. Efforts to use improve agricultural literacy through the use of this evaluation tool is one way to answer the call to update agricultural evaluation instruments made by multiple researchers (Brandt, 2016; Jones 2013; Terry et al., 1992; Trexler et al., 2013). Further, LMALI (3-5) can be a tool to guide formal and non-formal instruction providing an effective means of evaluating student agricultural literacy. Many current agricultural literacy assessments align to the FFSL framework and are limited in the progressional assessment of learners (Jones, 2013). The LMALI offers agricultural stakeholders proficiency-based decision-making information aligned with the NALO themes. Utilizing both formative and summative instructional information is a key benefit of this instrument. This level of instructional input has not been available previously and has the potential to influence instructional practice and student learning targets on a national scale.

We recommend that researchers target validation of the LMALI through implementation and validation studies. Further investigation to increase the number of valid items to produce additional forms of the LMALI 3-5 would improve the national utility of the assessment. Research should also be directed at instructional practice and professional development targeting key areas of instruction that the data from LMALI might illuminate.

At a foundational level, the LMALI can be used to assess student proficiency stages before, during, or after instructional sequence delivery. The conceptual framework and iterative process employed while developing the LMALI (3-5) enabled the creation of a method to assess agricultural literacy proficiency (Lewis, 1972; Hsu & Sandford, 2007). The expertise accessed during the iterative development process provided a strong foundation for this form of group design (Dalkey et al., 1972; Hsu & Sandford, 2007). Therefore, items developed in this project offer a way to summatively assess learner knowledge and formatively support their ability to apply knowledge and skills to novel new settings (Guskey, 2005). We encourage educators to use this tool to formatively support teaching and summatively assess understanding. Additionally, nonformal educators should consider ways to use the LMALI during outreach encounters. We intended that the 15-item LMALI be used as one instrument. Separating items for individual delivery, while instructive, deviates from the statistical analyses that validated the instrument.

Further research is needed to develop other agricultural literacy instruments to assess grade bands not addressed by this research. Currently, a K-2 instrument is undergoing statistical analyses similar to this study, and a high school version is also being developed (Judd-Murray, 2019). As instruments are designed and implemented, proving instructional opportunities that target the entire assessment and are aligned to the NALOs will be essential. Commonly, instructors identify particular items on an assessment and focus instruction to ensure that students do well on specific instrument items. This practice must be avoided. Instructional experiences should be grounded in the overarching NALO benchmarks in order to achieve generalizable agricultural literacy. Access to the LMALI is available through the National Center for Agricultural Literacy. In order to overcome the challenges of agricultural illiteracy described by Trexler and Hess (2004), agricultural instruction and the associated assessment instruments must align to current benchmarks outlined in the NALOs. Additionally, educators may choose to employ LMALI as a formative or summative tool to positively impact student growth and understanding of agriculture. The National Research Agenda for Agricultural Education to demonstrate the impact of agricultural literacy efforts can be achieved through the effective use and implementation of valid and updated instruments like LMALI (Roberts et al., 2016).

Limitations

This research resulted in only one 15-item instrument for use with learners in grades 3-5, which is a limitation for teachers as they employ the instrument multiple times for pre- and post-assessment. Another limitation was that participating students were not asked to exceed 30 minutes of response time, but even with this time constraint, test fatigue may have been present. In order to address this concern, items were provided to respondents in multiple orders to ensure that items were seen at the beginning, middle, and end of an assessment. Another limitation was the lack of random selection for the school/student participants. While each state was randomly selected, schools were identified through convenient sampling using IRB certified state agricultural contacts.

Conclusion

In this study, we sought to add to the literature on agricultural literacy by crafting a valid and reliable instrument that could be used to measure the NALOs. Proficiency stages, experiential learning, and item response were foundational in developing a sociocultural conceptual framework for an agricultural literacy instrument (Sadler & Zeidler, 2009). An additional research question targeted the creation of an instrument that could distinguish between proficiency levels in grade 3-5. The development of the LMALI responds to a clear priority from National Research Agenda for Agricultural Education to demonstrate impact of agricultural literacy efforts (Roberts et al., 2016). Alignment to modern agricultural literacy standards such as the NALOs is essential in providing a valid and reliable tool for formative and summative assessment measures. This study shows that proficiency stages can effectively be used to determine where an individual is on the continuum of agricultural literacy. It is anticipated that, as a nation, we will continue to invest in the agricultural literacy of our citizens. Thus, better equipping society with the ability to seek informed and sustainable solutions for food and fiber. Ultimately an agriculturally-informed society will be capable of enacting public policy that is based on scientifically supported principles of safe, affordable, and sustainable food systems.

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