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Development and validation of the environmental literacy instrument for adolescents

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ABSTRACT
Environmental education (EE) practitioners struggle to consistently and rigorously evaluate their programs, particularly when little time is available for evaluation. Since environmental literacy (EL) is the goal of environmental education, a very short EL instrument – amenable to use when longer tests are not practical for practitioners – would address an important EE need. We describe the development and validation of the Environmental Literacy Instrument for Adolescents (ELI-A) that is short enough for use in field applications (i.e. 5–15 min) and measures four domains of environmental literacy (ecological knowledge, hope, cognitive skills, behaviour). Factor analysis, item response theory, and concurrent validity tests were used in the validation process. Structural equation modelling supported the fit between the ELI-A and prevailing EL frameworks. The results support a valid and reliable instrument that is short enough for practical use but comprehensive in measuring four primary components of EL. This instrument could help fulfil the call to evaluate EE programming in both formal and informal settings.

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Introduction

Environmental challenges such as water conservation and quality (UNEP, 2016), climate change (IPCC, 2014), and biodiversity loss (Secretariat of the Convention on Biological Diversity 2014) are becoming increasingly pressing. Addressing these issues requires a citizenry who understands ecology, cares about the environment, has the skills to analyse complex issues, and is motivated to act (Hollweg et al. 2011). These attributes are associated with the four components of environmental literacy (EL): ecological knowledge, affect (e.g. pro-environmental attitudes, environmental sensitivity, self-efficacy), cognitive skills (e.g. issue analysis and problem solving), and environmental behaviour (Hollweg et al. 2011; Marcinkowski et al. 2014; Stevenson et al. 2013). The goal of environmental education (EE) is to build EL (North American Association for Environmental Education 2017; UNESCO-UNEP 1977), and research suggests EE can effectively do so, especially when it includes educational time spent outdoors (Goldman, Assaraf, and Shaharabani 2013; Hsu 2004; Stevenson et al. 2013).

Encouragingly, there are growing numbers of EE programs and associated tools for evaluating programming impacts on EL. Many of the instruments have been developed for specific programs (Bruni

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et al. 2017; Collado, Staats, and Corraliza 2013; Randler, Ilg, and Kern 2005; Stern, Powell, and Ardoin 2010), answering recent calls for more evaluation in environmental education (Carleton-Hug and Hug 2010; West 2015). Several instruments focusing on one or two components of EL may be useful for measuring parts of EL across programs (e.g. attitudes and knowledge in the Children's Environmental Attitudes and Knowledge Scale (CHEAKS) (Leeming, Dwyer, and Bracken 1995); attitudes in the Children's Attitudes Towards the Environment Scale (CATES) (Musser and Diamond 1994). However, as the goal of many EE programs extends beyond knowledge and attitudes, measurements more fully addressing EL are needed. In part responding to the need for more comprehensive EL measurements (The National Environmental Education Advisory Council 2005; Wilke 1990), developers of The Middle School Environmental Literacy Survey (MSELS; McBeth et al. 2011) pioneered a national survey of EL of U.S. middle school (11–14 year old) students in late spring 2007 (McBeth et al. 2008, 2011). Additional EL instruments have been developed for junior high students (Goldman, Assaraf, and Shaharabani 2013); youth movement members (Goldman, Pe'er, and Yavetz 2017); elementary students (Erdogan 2015); secondary school students (Marcinkowski et al. 2014; Nowak et al. 1995); college undergraduates (Shephard et al. 2014; Teksoz, Sahin, and Tekkaya-Oztekin 2012); and elementary and secondary teachers (Liu et al. 2015; Pe'er, Goldman, and Yavetz 2007).

Despite the increase in both academic EL research studies and number of EL instruments, emphasis on rigorous EE evaluation by EE practitioners is lagging for several reasons (Bourke 2011; Heimlich 2010; Stern, Powell, and Hill 2014; West 2015). First, some instruments tackle specific outcomes that may not be relevant for many practitioners (Li and Monroe 2017; Powell et al. 2011; Sattler and Bogner 2017). Second, more general instruments that may be applied in diverse contexts (Erdogan 2015; Goldman, Pe'er, and Yavetz 2017; McBeth and Volk 2010; Meuth 2010; Stevenson et al. 2013) often create challenges for informal and outdoor education settings including being too long (45–75 min for administration; Erdogan 2015; McBeth et al. 2008) and too expensive (for proprietary instruments). Given these challenges, it is not surprising that most EE programs have not integrated systematic, rigorous program evaluation (Blumstein and Saylan 2007; Heimlich 2010; Norris and Jacobson 1998; O'Neil 2007; West 2015). O'Neil (2007) found only one-third of 37 EE projects reviewed had formal evaluations. In addition, many evaluations are of poor quality (West 2015), as indicated by evaluations that do not match the program's long-term objectives (Stern, Powell, and Hill 2014). Some barriers to evaluation require institutional change (e.g. budget constraints [Carleton-Hug and Hug 2010]), but others, notably limited time (Carleton-Hug and Hug 2010; West 2015), can be addressed in part with shorter evaluation instruments that can be utilized with less impact on program delivery.

In this paper, we present the development and validation of a concise (i.e. 5–15 min) EL instrument for older adolescents (i.e. 14- to 19-years-old). We examine the theoretical foundation, development, construct validity, and reliability of four scales that together make up the ELI-A. This instrument is the first widely available EL instrument designed for adolescents which is short enough for use in field applications or when longer tests are not practical. In particular, it addresses the need for further EL study in the United States beyond elementary audiences (McBeth and Volk 2010; The National Environmental Education Advisory Council 2005). Further, by examining how well our survey data fit with accepted models of EL, we empirically explored the theoretical relationships between components of EL. We compared the utility of several models based on the relationships presented in literature specific to EL.

Study population

We tested the ELI-A with a sample of students in Agriculture Applications' courses in North Carolina, USA ($n = 665$). The Agriculture Applications' course is fitting given that the curriculum aligns with many EL goals in both a broad sense, such as developing critical thinking and decision-making skills, and, more specifically, with focal content on ecology and the environment (e.g. identifying parts of a tree, their functions, and their uses). Much of the curriculum focuses on interacting with the natural world through studying horticulture, farming practices, and natural resource management (National Council for Agricultural Education 2009; NC Department of Public Instruction 2013). Validation of an EL scale

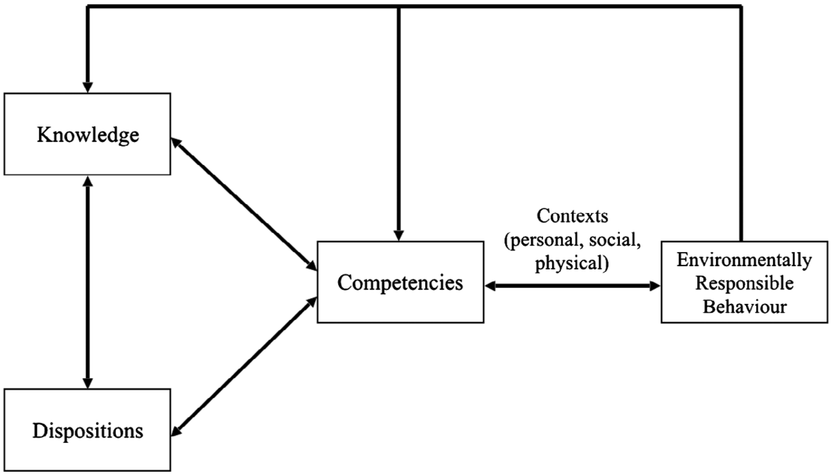

Figure 1. Domains of environmental literacy (Hollweg et al. 2011).

with the agricultural education community serves the dual purpose of capturing data on the EL of this understudied group and providing a tool that may be useful to study EL among adolescent audiences.

Conceptual framework and scale development process

Our conceptual framework for the ELI-A (Environmental Literacy Instrument for Adolescents) was based on the definition of EL established in the Tbilisi Declaration's (1977) goals and objectives which highlight four main components: knowledge, skills, affect, and behaviour (UNESCO-UNEP 1977). This framework is mirrored in U.S. national curriculum and policy, including the United States' National Environmental Education Act of 1990 which required the EPA to increase environmental literacy, defined as: awareness and sensitivity, knowledge and understanding, attitudes, skills, and participation (EPA 2018).

Researchers have recognized four EL components with various sub-dimensions: knowledge, affect, skills, and environmentally responsible behaviour (e.g. Goldman et al. 2017; Hollweg et al. 2011; Negev et al. 2008). Most recently in the United States, Hollweg et al. (2011) conceptualized these four components as knowledge, (e.g. knowledge of physical and ecological systems; knowledge of social, cultural, and political systems), dispositions (e.g. sensitivity; locus of control/self-efficacy), competencies (e.g. can identity and analyse environmental issues), and environmentally responsible behaviour (Figure 1). Although the Hollweg et al. (2011) framework includes dispositions and competencies as EL components, we chose to focus on the four components used in most versions of EL instruments to facilitate cross-study comparison as well as to minimize survey length, as shorter instruments lead to higher completion rates, lessen survey fatigue (Dillman, Smyth, and Christian 2014) and are more feasible in outdoor and informal education contexts. These four EL components are knowledge, affect, cognitive skills, and self-reported behaviour. Similarly, there are multiple dimensions for each of these four EL components (Bratt et al. 2014; Erdogan and Marcinkowski 2015; Hollweg et al. 2011; Kaiser and Fuhrer 2003); however, we chose to isolate one dimension for each scale to keep our instrument concise: ecological knowledge, hope, analysis of environmental issues, and specific pro-environmental behaviours. Among these, the affective dimension of EL may be both the most theorized but also the most variable. This dimension has been treated as attitudes (Pe'er, Goldman, and Yavetz 2007; Shephard et al. 2014), emotional connections or sensitivity (Liu et al. 2015; McBeth et al. 2008), willingness to act (McBeth et al. 2008), and self-efficacy (Hollweg et al. 2011; North American Association for Environmental Education 2010). While determining the best articulation of affect is beyond the scope of this paper, we chose to utilize hope as a measure of affect (see *Hope* sub-section).

Table 1. Initial structure of ecological knowledge, hope, and behaviour scales.

Ecological knowledge	Factor 1 loading	Unique variance
What would most likely pollinate a flower with red petals and no odor?	–	–
Burning coal for energy creates problems by:†	–	–
Phosphates are harmful in rivers because they:†	–	–
Nitrogen enters the soil through:	–	–
Ecology is the study of the relationship between:	–	–
A series of predictable changes that occur in a community over time is called:	–	–
To which population characteristic does this information refer?	–	–
What is the original sources of energy for all living things on earth's surface? †	–	–
What term refers to living organisms and their physical environment?	–	–
What process is missing in the blanks above?	–	–
Based on the image above, which do you think is the best conclusion about these animals? †	–	–
What important role do soil organisms such as worms, bacteria, and fungi play? †	–	–
As the number of animals in an area approaches the carrying capacity, what will happen? †	–	–
As nutritional energy passes through the food chain, energy…	–	–
Which type of symbiotic relationships does this best illustrate?†	–	–
Hope		
I believe people will be able to solve most environmental problems.	0.58	0.63
The actions I can take are too small to help solve most environmental problems.*	0.20	0.55
I believe scientists will be able to find ways to solve environmental problems.	0.66	0.51
Even when some people give up, I know there will be people who will continue to try to solve environmental problems.	0.61	0.55
Environmental problems are out of my control.*	0.37	0.48
Because people can learn from our mistakes, we will influence the environment in a positive direction.	0.59	0.59
Every day, more people care about environmental problems.	0.43	0.79
If everyone works together, we can solve environmental problems.	0.72	0.43
At the present time, I am energetically pursuing ways to solve environmental problems.	0.33	0.87
Environmental problems are so complex, we will never be able to solve them.*	0.50	0.61
I know that there are many things that I can do to help solve environmental problems.	0.73	0.47
I feel helpless to solve environmental problems.*	0.32	0.54
Behaviour		
Choose an environmental topic when I can choose a topic for an assignment in school.	0.23	0.52
Turn off the lights at home when they are not in use	0.73	0.34
Pick up trash that I find outside	0.59	0.54
Ask others about things I can do about environmental problems.	0.08	0.34
Turn off the water when it is not in use	0.70	0.32
Close the refrigerator door while I decide what to get out of it	0.62	0.61
Recycle at home	0.52	0.68

Note:
Multilogical thinking items on the ecological knowledge scale are indicated by †. Items related to lack of environmental despair on the hope scale are indicated by *.

Ecological knowledge

To facilitate a shorter instrument, we conceptualized knowledge as ecological knowledge. This stemmed from the physical and ecological systems dimension of the Hollweg et al. (2011) EL definition, as well as two sub-categories from the characterization of knowledge provided by NAAEE's *Guidelines for Excellence: K-12 Learning Excellence* (2010): the Earth as a physical system and the living environment. To operationalize the ecological knowledge scale for an adolescent audience, we integrated items that required multilogical thinking[1] (Morrison and Free 2001) appropriate for the 9–12 grade range, such as 'Burning coal for energy creates problems by…' (see Table 1 for full list of multilogical thinking questions). Four ecologists at North Carolina State University reviewed the first draft of questions to eliminate any potential factual errors, and we relied on the educational psychology expertise of J. Nietfeld (Professor, Educational Psychology, NCSU) to provide feedback on categorization of the difficulty of questions based on whether the question required monological vs. multilogical thinking. Using this strategy, we developed 15 multiple-choice questions (Table 1). All questions had four possible responses and one correct answer.

Hope

We conceptualized affect as hope. Our definition of hope aligns with the Snyder et al. (1991) conceptualization of hope which combines agency and pathways thinking, that is, believing you can achieve a goal (i.e. agency) and planning ways to meet those goals (i.e. pathways). These two components of hope are analogous to self-efficacy (believing you can effect a desired outcome) [Bandura 1977]) and response efficacy (believing that actions will lead to a desired outcome [Norgaard 2011]). Despite its ties to self-efficacy, hope is distinct; self-efficacy emphasizes one's perception that they *can* meet their goal, whereas hope emphasizes one's belief that they both *can* (i.e. agency) and *will* (i.e. pathways) meet their goal (Snyder, Rand, and Sigmon 2005).

Although hope is a relatively novel operationalization of affect for EL, we chose to utilize hope for multiple reasons. First, the construct is more directly tied to behaviour than some other affective dimensions, including attitudes, emotions, and sensitivity (Meinhold and Malkus 2005; Moè, Pazzaglia, and Ronconi 2010). Second, it is an important component of positive psychology linked to many types of behaviours (Ojala 2015; Snyder 1995; Stevenson and Peterson 2015; Walker et al. 2010; Youssef and Luthans 2007), including environmental behaviours (Kerret, Orkibi, and Ronen 2014). Third, the Snyder et al. (1991) conceptualization of hope provides a concise metric that parallels two key drivers of environmental behaviour identified in the literature: self-efficacy and response efficacy (Monroe 2003; McLeod et al. 2015; Zimmerman 2000). Lastly, a concise and valid measure of hope exists, facilitating a shorter instrument (Stevenson and Peterson 2015). The hope instrument we adapted was utilized to study climate change hope among adolescents (Li and Monroe 2017; Stevenson and Peterson 2015). Expressions of climate change hope include both individual and collective hope (i.e. believing that *I* can/will make a difference and that *society* can/will make a difference), as well as lack of negative thinking or despair (Li and Monroe 2017; Stevenson and Peterson 2015). We adapted Stevenson and Peterson's (2015) climate change hope and lack of climate change despair scales to align better with EL by focusing broadly on environmental topics. All questions had five possible choices: strongly disagree, disagree, neutral, agree, strongly agree.

Cognitive skills

The cognitive skills scale was conceptualized based on Strand 3 of NAAEE's *Guidelines for Excellence: K-12 Learning*, applying 'skills for understanding and addressing environmental issues' (North American Association for Environmental Education 2010). We defined cognitive skills as how well students can comprehend and analyse environmental issues. Cognitive skills have been studied in many contexts (Finn et al. 2014; Taatgen 2013) in addition to EE (Bluhm et al. 1995; McBeth et al. 2008, 2011; Stevenson et al. 2013). This prior research influenced the development and design of the cognitive skills scale. During in-person administration of the MSELS to 856 grade school students (Stevenson et al. 2013), we observed students with lower reading levels exhibiting frustration, skipping large blocks of text, randomly selecting answers to questions linked to reading assignments several paragraphs long, and taking over one hour to complete the survey. Feedback from participants in previous studies conducted by the research team (Stevenson, Carrier, and Peterson 2014; Stevenson et al. 2013) led us to prioritize a concise question format that reduced test time and reduced potential to inadvertently test reading comprehension rather than cognitive skills.

After reviewing scales on reasoning, problem solving, and cognitive skills, we determined the format of Rest's (1979) Defining Issues Test (DIT) balanced parsimony with accurately assessing the ability to analyse complex scenarios. Rest used this format to focus on moral dilemmas (e.g. shoplifting) for which respondents ranked the importance of related issues (e.g. personal need) in light of the situation presented. For our study, the cognitive skill measure provides an environmental dilemma (i.e. collapse of a fishery) and a list of five questions which might help mitigate the dilemma. Students must rank

Table 2. Cognitive skills scale.

Relative ranking	Question
1	What has been the number of new striped bass entering the population each year?
2	What size are the striped bass that can successfully reproduce?
3	What are the most important foods striped bass eat?
4	Do predators eat juvenile striped bass?
5	What do striped bass fishers use for bait?

Note:
Prompt given: Striped bass is a popular sportfish and is also harvested for food. Anglers and commercial fishers are spending more time fishing for striped bass than they used to but are catching fewer and smaller striped bass than in the past. Daniel Pinder is in charge of making sure that fishing for striped bass is sustainable over time. Therefore, Daniel must think about many issues to determine the best solution to this challenge. What are the most important questions to ask as you begin to solve this problem?
Relative rankings given from the most (1) to least (5) important question for solving the problem.

the questions by their importance in addressing the fishery collapse (Table 2). To develop this tool, we first consulted with a fisheries expert (J. Rice, Professor, Applied Ecology, Extension Fisheries Specialist, NCSU) to draft a scenario to describe an impaired fishery. Next, we asked five faculty members from the Fisheries, Wildlife, and Conservation Biology program and Applied Ecology Department to generate a list of the five most important questions to consider when deciding how to mitigate threats to the fishery (What has been the numbers of new striped bass entering the population each year?), as well as five 'red herring' items, defined as non-issues, that might seem important to someone not utilizing cognitive skills (What do striped bass fishers use for bait?). This process generated 15 novel questions, which we then asked the experts to rank from most to least important. Next, one item was selected from the top three ranked items, one from the next three ranked items, and so on, until we arrived at five items. Finally, we asked the experts to again rank the final set of five questions. This generated an average rank for each item, against which we could score the student responses. For specific scoring procedures, please see the Methods section. Utilizing experts in the design of the cognitive skills scale ensured the question tested students' real-world decision-making skills for addressing environmental issues.

Behaviour

We conceptualized behaviour as the degree to which students reported engaging in pro-environmental behaviour such as recycling or conserving water. We chose to focus on these behaviours rather than issue-related behaviours for several reasons. First, we wanted the scale to be concise enough for use by EE practitioners. Second, practitioners may use the scale in a variety of contexts, so it must have behaviours that diverse audiences can accomplish. Third, these behaviours, when taken collectively, can have substantial impact (Peterson, Peterson, and Liu 2013). Fourth, the focal behaviours reflect those from other environmental behaviour scales (Liu et al. 2015; McBeth et al. 2008). Although the final behaviour scale was built upon similar published work (Dijkstra and Goedhart 2012; Erdogan, Ok, and Marcinkowski 2012; McBeth et al. 2008), we made small changes by including frequency of behaviour and having shorter question stems. Frequency of behaviour reflects one's repeated actions across time which are central to determining traits (i.e. behaviour trends; Fleeson 2004). Using this strategy, we developed seven questions to construct the scale. All questions had five possible choices: never, rarely, sometimes, often, and always.

Methods

Pilot testing

After developing a draft instrument in spring 2014, we piloted it with a convenience sample of high school students (n = 20). Students were asked to give written and oral feedback on the instrument for items that were unclear or confusing. We examined the ecological knowledge and cognitive skills items

Table 3. Pilot instrument reliability.

Scale	Cronbach's alpha	Interitem covariance
Ecological knowledge	0.64	0.02
Hope	0.33	0.05
Behaviour	–	−0.03

for normality of responses and used Cronbach's alpha measures to test the reliability of the hope and behaviour scales. See Table 3 for a summary of pilot instrument reliability.

Sample and data collection

To further test the reliability of the instrument and validate the scale, we recruited 14 high school agriculture teachers across North Carolina who were willing to include their students in the study. Because students are assigned to teachers independently from this study, self-selection among teachers did not bias selection of student participants. During the 2015–2016 school year, selected high school agriculture teachers across North Carolina administered paper surveys to all students ($n = 748$) during the first several weeks of their Agriculture Applications classes. Because most high school classes last one semester, some students ($n = 434$) took the survey at the beginning of the fall semester (August 2015) and others ($n = 314$) took it at the start of the spring semester (January 2016). Teachers were responsible for survey administration. All classes contacted participated in the study.

Data preparation

As all scales were additive, item-level missing data would impact reliability and validity analysis. Further, structural equation modelling (SEM) excludes individuals that are missing data for any part of the model. Since SEM was a crucial part of our analysis, we ran listwise deletions to exclude any individual who did not answer all items within the hope, cognitive skills, and behaviour sections. This accounted for 14 respondents (1.9%) in the hope section, 37 respondents (4.9%) in the cognitive skills section, and 56 respondents (7.5%) in the behaviour sections; other EL studies have 3.6–18.3% missing data across similar sections (McBeth et al. 2008). Seventeen respondents had data missing in two or more sections. We used *t*-tests to compare the group of students who completed all items with those students who had items missing. We found no differences between students with missing data and students without missing data in terms of gender, ethnicity, or age. Missing data were coded as incorrect answers for the ecological knowledge scale (Tobler, Visschers, and Siegrist 2012). This resulted in 665 usable surveys.

Data analysis

We tested the reliability of each item within the ecological knowledge, hope, and behaviour scales using Cronbach's alpha. We utilized Cronbach's alpha because we intended to analyse the scales, not individual items (Gliem and Gliem 2003). We could not run reliability tests for the cognitive skills scale because of its ranking format, and it is inappropriate to test the reliability of non-opinion scales like the ecological knowledge scale (van Schuur 2003). We tested the validity of the hope and behaviour scales through principal component factor analysis; we relied on this technique to assess the degree to which each item aligned with the latent factors we identified for each respective scale. The primary analysis technique used to analyse the structure of the items was confirmatory factor analysis (CFA) via SEM. We used CFA rather than an exploratory approach to refine the EL scales because our analysis tested an existing four factor model of EL (Brown 2006; Hollweg et al. 2011; Suhr 2005). Additionally, CFA allowed us to account for measurement error (Brown 2006). The first step was to assume all scales were single-factor and would lead to a four-factor model. In this model, ecological knowledge and hope both impact cognitive skills, which influences behaviour, which reflects the framework developed by Hollweg et al.

Table 4. Final structure and factor loadings of hope and behaviour scales.

Hope	Environmental hope factor loadings	Lack of environmental despair factor loadings	Unique variance
I believe people will be able to solve most environmental problems.	0.60	–	0.63
The actions I can take are too small to help solve most environmental problems.*	–	0.68	0.54
I believe scientists will be able to find ways to solve environmental problems.	0.70	–	0.51
Even when some people give up, I know there will be people who will continue to try to solve environmental problems.	0.67	–	0.54
Environmental problems are out of my control.*	–	0.71	0.48
Because people can learn from our mistakes, we will influence the environment in a positive direction.	0.65	–	0.58
Every day, more people care about environmental problems.	0.46	–	0.79
If everyone works together, we can solve environmental problems.	0.75	–	0.42
Environmental problems are so complex, we will never be able to solve them.*	–	0.55	0.60
I know that there are many things that I can do to help solve environmental problems.	0.66	–	0.47
I feel helpless to solve environmental problems.*	–	0.68	0.53
Behaviour	Behaviour factor loadings		
Turn off the lights at home when they are not in use	0.77	–	0.42
Pick up trash that I find outside	0.55	–	0.70
Turn off the water when it is not in use	0.74	–	0.45
Close the refrigerator door while I decide what to get out of it	0.61	–	0.62
Recycle at home	0.49	–	0.76

Note:
Items related to lack of environmental despair on the hope scale are indicated by *.

(2011; Figure 1). The initial factor analysis revealed that neither the hope nor the behaviour scale was one factor (Table 1). We expected the hope scale to split into two factors along items associated with environmental hope and lack of environmental despair based on the scale we drew from (Stevenson and Peterson 2015), and all but one did. We removed this one item (At the present time, I am energetically pursuing ways to solve environmental problems) from the hope scale because it had a factor loading below 0.400. We also removed two items with low factor loadings (<0.400) from the behaviour scale. The reduced behaviour scale then conformed to a single factor, and the hope scale conformed to two factors containing environmental hope and lack of environmental despair items, respectively (Table 4).

To test the validity of the cognitive skills scale, we relied on pairwise correlation testing between the cognitive skills and ecological knowledge section, a typical approach for validating ranking-type questions (Schlaefli, Rest, and Thoma 1985). Internal reliability checks are built into ranking-type questions through the use of erroneous (e.g. red-herring) items, writing in question format, and utilizing simple vocabulary (Schlaefli, Rest, and Thoma 1985). For the validity of the ecological knowledge scale, we did not attempt to use factor analysis or make the ecological knowledge scale one factor, since factor analysis assumes items have the same frequency distribution for the latent trait (i.e. difficulty; van Schuur, 2003). The items on the ecological knowledge scale, however, vary in difficulty. The scale items were binary with one correct answer, and items differed in their influence on the latent trait. We instead chose to use item response theory because it is a standard theoretical approach underlying standardized testing today, such as the Graduate Record Examinations (GRE; Embretson and Reise 2000), which also utilizes binary correct/incorrect answers. Item response theory analyses scores using assumptions about the mathematical relationship between abilities (e.g. ecological knowledge level) and item responses (Baker 2004). Thus, it takes difficulty of items into account when computing the latent trait.

Scoring and model fit

A cumulative score was generated for each scale. For the ecological knowledge scale, one point was given for each correct answer. For the hope scale, each item was worth up to five points. One point was given for 'strongly disagree,' and options increased by one point so that five points were given for 'strongly agree.' The cognitive skills scale had a maximum score of 12.8. Each item had an average expert ranking score. Students' rank for each item were subtracted from the expert ranking to generate a difference (e.g. difference = expert ranking − student ranking). The absolute values of all the differences were subtracted from 12.8 to get the total cognitive skills score. The behaviour scale was scored similarly to the hope scale. One point was given for 'never,' and options increased by one point so that five points were given for 'always.' To generate a final score for EL, the sum of each scale was weighted equally to account for one quarter of the total score. The knowledge scale results were multiplied by 2.5, the hope scale by 0.45, and the cognitive skills scale by 1.95. The behaviour scale was not changed because the maximum score is 25. The ELI-A scores ranged from 12 to 100.

We ran iterative SEMs and generated corresponding goodness-of-fit statistics to validate our instrument and empirically compare several competing models based on current EL theory. Early EE models of environmental behaviour implied a linear relationship in which knowledge predicted attitudes, which predicted skills, which in turn predicted behaviours (Hungerford and Volk 1990). Research suggests the relationships between antecedents to behaviour are likely more nuanced, with interactions and feedback between knowledge, attitudes, and skills, which all predict behaviour (Heimlich and Ardoin 2008; Hollweg et al. 2011; Kollmuss and Agyeman 2002). The Hollweg et al. (2011) model for EL represents this more nuanced view, in which knowledge is linked to dispositions, which are in turn linked to competencies, which are then linked to behaviours (Figure 1). Because these models have not been empirically tested, we compared the utility of several models based on the relationships presented in literature specific to EL (Dijkstra and Goedhart 2012; Hollweg et al. 2011; Pe'er, Goldman, and Yavetz 2007) and environmental behaviours (Heimlich and Ardoin 2008; Kollmuss and Agyeman 2002) using goodness of fit measures. In model one, all factors of EL are correlated and equally predict behaviour (Figure 3). Models two and three reflect a progression supported by the literature (Hollweg et al. 2011, Heimlich and Ardoin 2008; Kollmuss and Agyeman 2002; Negev et al. 2008) in which knowledge and affect interact to predict behaviour, but are mediated by cognitive skills. The relationship between knowledge and affect has been theorized as correlative (Bamberg and Möser 2007; Kollmuss and Agyeman 2002; Roczen et al. 2014) and interactive (Hines, Hungerford, and Tomera 1987; Hollweg et al. 2011; Negev et al. 2008), but not empirically tested. We tested both correlative and interacting relationships between these factors in model two (Figure 4) and three (Figure 5), respectively.

To assess the utility of our competing models, we compared several fit statistics. SEM combines factor analysis and regression models to allow structural relationships among latent variables (e.g. ecological knowledge, hope, behaviour). We report on Satorra-Bentler (S-B) Scaled Chi-Square (S-B X^2); S-B Comparative Fit Index (S-B CFI); Standardized Root Mean Square Residual (SRMR); the S-B Robust Root Mean Square Error of Approximation (S-B RMSEA), its probability of close fit (pclose) value, and its associated 90% confidence interval; and the coefficient of determination (CD). We use the S-B X^2, S-B RMSEA, and S-B CFI in lieu of X^2, RMSEA, and CFI because the S-B tests account for the degree of kurtosis in the data (Satorra and Bentler 1994). The CFI is used as an incremental fit index to measure fit, it has a penalty for adding parameters. The RMSEA is an absolute measure of fit where 0.01 indicates excellent fit and 0.08 indicates mediocre fit (MacCallum, Browne, and Sugawara 1996). Additionally, the smaller its associated confidence interval, the better the fit. The pclose value indicates the probability that RMSEA is less than 0.05. This can be interpreted as the probability that the fit of the model for the

Table 5. Comparison of overall scale reliability of MSELS and ELI-A.

MSELS		ELI-A	
Scale	Cronbach's alpha	Scale	Cronbach's alpha
Ecological knowledge	0.79	Ecological knowledge	0.71
Verbal commitment	0.84		
Environmental sensitivity	0.76	Hope	0.75
Issue identification	0.39		
Issue analysis	0.70		
Action planning	0.87		
Actual commitment	0.78	Behaviour	0.62

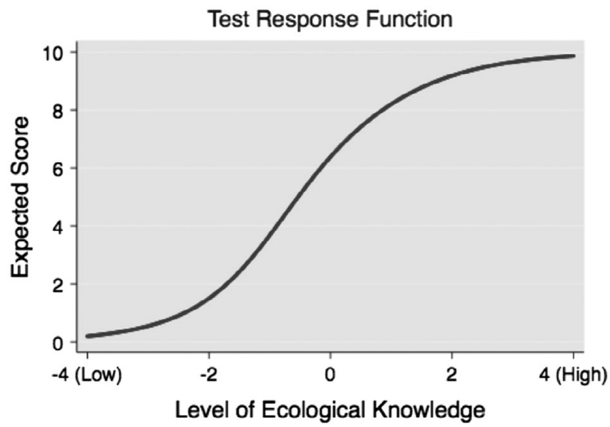

Figure 2. Test response function for ecological knowledge scale.
Expected score of ecological knowledge scale represented on y-axis. Level of ecological knowledge on x-axis, with 0 representing average student ability.

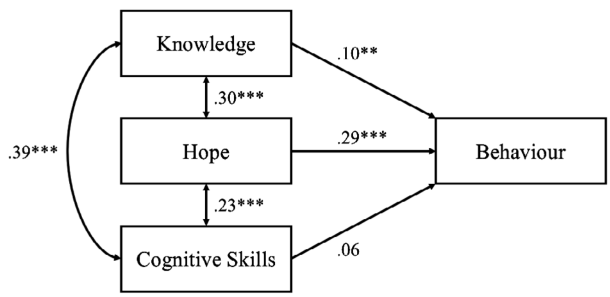

Figure 3. Model one: Initial structural equation model of environmental literacy.
Standardized path coefficients reported for single-headed arrows. Standardized covariance reported for double-headed arrows. All relationships significant at $p < 0.01$, except for cognitive skills to behaviour ($p = 0.113$).

sample is close to the fit of the model for the population. If pclose > 0.05, the fit of the model for the sample is close to the population model. The SRMR is an absolute measure of fit, like RMSEA, and is the standard difference between the observed and predicted correlation. If SRMR = 0, the fit is perfect and if SRMR < 0.08 the fit is good (Hu and Bentler 1999). The CD (i.e. R^2) is conceptualized as the proportion of variance explained by the entire model (Nagelkerke 1991). If the model has a perfect fit, the CD is 1 (i.e. 100% of variance is explained by the model). We ran a SEM on each of our competing models.

Table 6. Comparison of goodness-of-fit statistics for all models.

Model	S-B X^2	$p > X^2$	S-B CFI	SRMR	S-B RMSEA	pclose	CD
Model 1	0.000	–	1.000	0.000	1.000 (0.000–0.000)	1.000	0.132
Model 2	0.000	–	1.000	0.000	1.000 (0.000–0.000)	0.000	0.254
Model 3	0.340	0.560	1.000	0.001	0.000 (0.000–0.085)	0.794	0.266

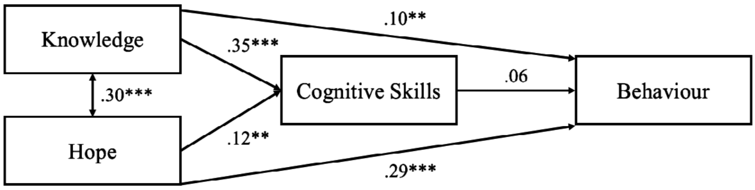

Figure 4. Model two: Structural equation model of environmental literacy.
Standardized path coefficients reported. Standardized covariance reported for double-headed arrows. All relationships significant at $p < 0.01$, except for cognitive skills to behaviour ($p = 0.113$; Hollweg et al. 2011).

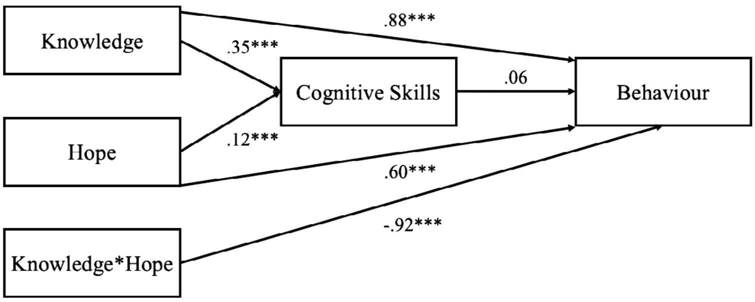

Figure 5. Model three: Final structural equation model of ELI-A.
Standardized path coefficients reported. All relationships significant at $p < 0.01$, except for cognitive skills to behaviour ($p = 0.095$).

Results

There were 665 useable student questionnaires in the 2015–2016 school year; 368 in the fall 2015 semester and 297 in the spring 2016 semester. Of the total 665 students, 41% were female, 50% were male, and 9% did not respond. Students' ages ranged from 14 or younger to 18 or older, with a median age of 15. Grades ranged from 9th to 12th with 53% reporting 9th grade, 29% reporting 10th grade, 11% reporting 11th grade, and 7% reporting 12th grade. Fifty-five percent of students reported themselves as White, 23% Black or African American, 4% Asian/Pacific Islander, 12% Hispanic or Latino, 7% other, and 1% did not respond.

Reliability of the ecological knowledge, hope, and behaviour scales was acceptable compared to results from other instruments (Bradley, Waliczek, and Zajicek 1999; Leeming, Dwyer, and Bracken 1995; McBeth et al. 2008). Cronbach's alpha for the initial scales are reported in Table 3, and Cronbach's alpha for the final scales are reported in Table 5. The results from the item response theory analyses revealed that the scale was of average difficulty with 50% of students scoring a 70% or higher (Figure 2). The correlation between the cognitive skills item and the ecological knowledge scale ($r = 0.39$, $p < 0.001$) suggests our measure of cognitive skills was related to knowledge, as should be the case, but not confounded by it (Finn et al. 2014). Preliminary testing of the final instrument with adolescents in school ($n = 67$) took students from 4 to 15 min to complete ($M = 10.28$, $SD = 2.47$).

The SEM for model one (Figure 3) had poor fit, explained 13.2% of the model's variance (see Table 6 for goodness-of-fit statistics for all models) and had one non-significant path (cognitive skills to behaviour). Model two (Figure 4) had poor fit. The model explained 25.4% of the model's variance, and one path was not significant (cognitive skills to behaviour). Model three displayed excellent goodness-of-fit. All paths were significant, except for the path from cognitive skills to behaviour, which was significant at the 0.10 alpha level ($p = 0.095$). These results support model three (Figure 5) as an appropriate model of EL among adolescents. The goodness-of-fit results indicate an excellent fitting model for a complex data-set, and the model explained 26.6% of variance in the data (Table 6).

Discussion

We present the ELI-A as a validated, concise EL instrument for use by EE practitioners, including measures of ecological knowledge, hope, cognitive skills, and behaviour. Results indicate that each measure is reliable, valid, and related to others in ways that build on current models of EL and environmental behaviour (Hollweg et al. 2011; Kollmuss and Agyeman 2002). The final model suggests knowledge and hope predict cognitive skills which weakly predicts behaviour, and the interaction between knowledge and hope also predicts behaviour.

We identify novel scales for the affective and cognitive skills components of EL. This study is the first of which we are aware that utilizes hope as a measure of affect in EL. Aligning with similar measures of climate change hope in previous studies (Li and Monroe 2017; Stevenson and Peterson 2015), the hope scale reduced to two factors: environmental hope and lack of despair. Hope provided a parsimonious way of measuring key aspects of affect in an EL context. We also present a new, concise method for measuring cognitive skills that by minimizing reading requirements may reduce the chance of confounding reading comprehension and cognitive skills. As in the use of hope, this study represents the first case that we are aware of which utilizes question-ranking to analyse cognitive skills in an EL context. Given this novel application, future research should continue to examine its utility. We encourage researchers and evaluators to test our cognitive skills measure, or similar, site-specific items, in a field setting and to examine whether the scale detects cognitive skills gains in association with EE programming known a priori to boost cognitive skills (e.g. published EE curriculum such as Project Learning Tree; Stevenson et al. 2013).

This study advances EL theory by identifying an interaction between ecological knowledge and hope that together predict self-reported behaviour. The interaction builds on learning theory indicating knowledge has the greatest impacts on behaviour when tied to affective factors such as emotions or to past experiences (Ormrod 2016a). Previous research suggests knowledge and forms of affect (e.g. emotions) likely interact to predict behaviour (Duerden and Witt 2010; Heimlich and Ardoin 2008; Negev et al. 2008). Our findings extend this research by offering hope as a useful affective variable interacting with ecological knowledge to shape behaviour, since the hope scale functioned well in our model. Additionally, our model captured a direct link from the interaction between ecological knowledge and hope to behaviour, suggesting that in addition to being mediated by cognitive skills, some behaviours are directly influenced by ecological knowledge and hope or, at least, the interaction between them. This is intuitive, given some environmental behaviours measured in our instrument, and in everyday life, do not require significant problem-solving ability to employ (e.g. turn off the lights at home when they are not in use). The direct relationship between hope and behaviour aligns with literature from positive psychology where environmental hope has been shown to predict environmental behaviour (Kerret, Orkibi, and Ronen 2014, 2016). Further, the relationship adds to research suggesting direct effects of emotions and memories on behaviour (Carmi, Arnon, and Orion 2015; Heimlich and Ardoin 2008; Larson, Cooper, and Hauber 2015; Ormrod 2016a) as well as environmental knowledge and behaviour when considering attitudes (Duerden and Witt 2010; Hines, Hungerford, and Tomera 1987; Roczen et al. 2014).

The weak relationship between cognitive skills and behaviour likely points to the need for continued scale and theoretical development. In this study, we included only one ranking exercise. Further development of similar items may strengthen the measurement of this construct as well as its utility in an EL model. Other explanations for the weak relationship include developmental and theoretical underpinnings. It is possible that students who are still developing cognitively may not be able to fully utilize these skills in their decision-making processes (Ormrod 2016b). Cognitive skills may also simply stand on its own in the EL model and not directly predict behaviours. Alternatively, the utility of cognitive skills may vary depending on the types of behaviours in question. Cognitive skills might not be a predictor of simple behaviours, such as recycling or turning off the lights, but cognitive skills might predict more complex behaviours. The quick-decision behaviours that we measure in the ELI-A may be more likely to be impacted by structural barriers and social norms (Bamberg and Möser 2007; Tanner 1999) than critical thinking skills. Behaviours that require higher-level thinking and problem-solving skills may be more likely linked to cognitive skills. This presents a challenge for future research because behaviours that require problem solving skills such as developing a successful environmental advocacy campaign are more difficult to measure and less under the control of children and adolescents than quick-decision behaviours.

Although we feel the ELI-A provides a rigorous tool for EE evaluation in adolescent contexts, our results highlight several important areas for future improvements to individual scales. First, the majority of participants in our study were 14–16 years old, and future work could evaluate the efficacy among the younger and older adolescents (i.e. 12–14 and 17–19), as well as among differing academic abilities. The test response function (Figure 2) suggested the scale had more items that were easier (i.e. more appropriate for low-achieving students) since the average ability student would score close to 70% on the scale. We suggest that future research should test the scale among older and/or higher achieving students to ensure validity with more advanced groups. Second, knowledge and cognitive skills are best measured with locally relevant questions (Hollweg et al. 2011), so compiling a bank of locally relevant cognitive skills ranking scenarios and knowledge questions on EE websites that provide evaluation tools for practitioners such as through NAAEE's eePro network (naaee.org/eepro) or My EE Evaluation Resource Assistant (MEERA; meera.snre.umich.edu) would help EE practitioners best utilize the instrument. Upon publication, we will submit the instrument in full to both of these resources and encourage other researchers and evaluators to add additional scenarios or feedback on the instruments. Similarly, although the cognitive skills item presented here was reliable and valid, future research which develops new environmental scenarios (e.g. agricultural land management, sea level rise) could help researchers understand how students respond to a range of environmental issues that may be more polarizing to some students than others. Additional scenarios will also provide evaluators using the ELI-A with a range of topics more likely to ensure a match with their programming objectives (e.g. habitat conservation for wildlife-focused program, forest management for terrestrial-focused program). Third, future studies might explore developing a behaviour sub-scale with more complex behaviours. However, some behaviours – such as shopping and green consumerism – are typically influenced indirectly by younger audiences, rendering them difficult to measure via self-reporting, and often have relatively small environmental impacts relative to decisions about transportation (e.g. walking vs. driving or getting a ride) and where to set a thermostat (Chen et al. 2016). Given these challenges, more holistic behaviour scales may need to engage households in addition to youths.

In addition to scale-level improvements, future research should continue to empirically test models of behaviour change in EL contexts. Though our model does offer support for an interaction between ecological knowledge and hope, a novel theoretical contribution, it only explained 26.6% of the variance in the sample and had a nonsignificant path from cognitive skills to behaviour. We suspect that socio-cultural factors may have impacted the explained variance (Ormrod 2016c) and that false reporting of behaviours may have affected the overall model, since self-reported behaviours can be swayed by social desirability (Collado and Corraliza 2015; Hollweg et al. 2011). Future research should analyse how contextual factors, particularly norms (de Leeuw et al. 2015; Morgan and Chompreeda 2015) and cultural context (Morren and Grinstein 2016), affect self-reported behaviours in this scale. To account for unexplained variance and the nonsignificant path from cognitive skills to behaviour, future studies could also consider scales that address subcomponents of EL (e.g. motivation as a component of affect) that have been important factors in both learning and self-reported environmental behaviours (Chawla and Cushing 2007; Collado and Corraliza 2015; Heimlich and Ardoin 2008; Ormrod 2016b) as well as scales that address behaviours requiring more problem-solving skills than the ones we include. Finally, external structural factors, such as access to a recycling program, could have influenced self-reported behaviours. These unmeasured constraints could account for a large amount of variance in the model (Kollmuss and Agyeman 2002).

Conclusion

We hope the ELI-A developed and validated in this study is useful to many environmental educators. The four scales ecological knowledge, hope as affect, cognitive skills, and self-reported behaviours represent key environmental literacy concepts that researchers (Hollweg et al. 2011), government agencies (EPA 2018), and international organizations (North American Association for Environmental Education 2017) have acknowledged as important outcomes for EE. We see the ELI-A as a starting point for open access instruments to encourage metric development, particularly in the cognitive domain. In as much as EE evaluation is hindered by access to valid, reliable scales (Crohn and Birnbaum 2010; Heimlich 2010; Monroe 2010), we encourage practitioners, researchers, and evaluators to consider testing and modifying the ELI-A to advance EE research and evaluation, with particular attention to cross-comparison of programs (Stern, Powell, and Hill 2014).

Note

1. Multilogical thinking refers to 'thinking that sympathetically enters, considers, and reasons within multiple points of view,' such as looking at an ecological problem from moral, political, and biological perspectives (Paul 1995).

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