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Assessing Student Knowledge, Values, and Personal Experience to Determine Associations with Socioscientific Reasoning

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ABSTRACT

Socioscientific issues, issues that center on the intersection between scientific and social problems in real-world contexts, are valuable tools to use in science instruction due to their association with gains in scientific literacy, argumentation skills, and content knowledge. However, due to their complex nature, crafting instruction using socioscientific issues may be challenging for many teachers. It has been theorized that students will use their knowledge, values, and personal experiences (KVP) when they negotiate a socioscientific issue, thus, finding ways to capitalized on the KVP students bring to the classroom may help students achieve the gains associated with instruction using socioscientific issues while guiding instructional efforts. This paper outlines the development of an instrument to assess KVP associated with socioscientific issues. The purpose of this instrument is to provide a tool that teachers may use to assess KVP so that they can pointedly promote the aspects of KVP in their classrooms. Implications for teacher educators and researchers in science education are also discussed.

Keywords: *socioscientific issues, student background, high school*

Introduction

Scientific literacy has evolved to reflect an understanding of how scientific problems must be discussed and approached using complementary consideration of scientific as well as social aspects of the problem (Roberts & Bybee, 2014). Roberts and Bybee (2014) emphasized that this pursuit of scientific literacy is important because it includes awareness that students will behave as decision-making citizens when they are adults, and thus they need to develop an understanding of how to discuss complex issues that require sophisticated reasoning abilities. One avenue that the authors suggest for promoting development of scientific literacy is through engagement with socioscientific issues, or SSIs.

Zeidler (2014, p. 697) explained that SSIs are issues that "allow for the cultivation of scientific literacy by promoting the exercise of informal reasoning in which students are compelled to analyze, evaluate, discuss, and argue varied perspectives on complex issues that are ill structured." Sadler, Barab, and Scott (2007) sought to explore the connection between SSIs and outcomes aligned with goals of scientific literacy, including particularly the need for science education to "help students prepare for more active participation in modern democracies" (p. 373). In pursuit of this inquiry, they described the construct of socioscientific reasoning (SSR) as a way of assessing the levels of reasoning students use when confronted with an SSI. The authors define SSR as comprised of four areas, with the term used for each component indicated in parentheses: development of nuanced solutions (*Complexity*), using multiple perspectives (*Perspectives*), expression of need for inclusion of social and scientific considerations (*Inquiry*), and ability to identify bias (*Skepticism*). Within each category, they presented a rubric consisting of four levels of sophistication for each of the four aspects. They explained the goal of the construct as providing a way to assess and support the objects for using SSIs, and the rubric can be useful to support educators in assessing SSR sophistication and considering areas where students need support in how they think about complex issues.

The scientific literacy goal and citizenship education aims of SSIs underscore the need for students to develop awareness of complex issues and SSR skills associated with reasoning about such issues. However, Chang Rundgren and Rundgren (2010) noted that these objectives can be difficult to realize without a clear guiding system for using SSIs in the classroom. To address this need, they developed a framework that describes how Knowledge, Values, and Personal experience (KVP) influence the ways in which students approach SSIs and demonstrate SSR. Researchers (e.g. Chang & Chiu, 2008; Chang Rundgren & Rundgren, 2010; Christenson, Rundgren, & Höglund, 2012) have suggested that when students engage with SSIs, they will rely upon these different KVP components, to varying degrees, as they think about the issue. Thus, KVP, used strategically, can be associated with SSR and, by extension, scientific literacy.

In order to use an SSI, teachers must support students as they face arguments that challenge their understandings of an issue (Zeidler, Applebaum, & Sadler, 2011), which is impossible if the teacher does not understand the KVP the students have with the issue. For instance, Chang & Chiu (2008) found that the core of students' thinking about SSIs is shielded by a "protective belt" (p. 1758) of their own views that makes it difficult for them to think about issues in unique ways, a type of thinking that is necessary for engaging in advanced SSR (as defined by Sadler et al., 2007). Thus, individuals will approach SSIs differently depending on their KVP, and SSI units need to be carefully constructed to highlight KVP and show how it influences decisions made (Rundgren, Eriksson, & Chang Rundgren, 2016). In doing so explicitly, teachers can show how and why different individuals come to different conclusions about SSIs and support the students in understanding diverse perspectives by explaining from where these perspectives arise, promoting scientific literacy through appreciation of complex circumstances and views that are associated with SSIs. Additionally, if teachers want to target a specific aspect of SSR, understanding how KVP appears differentially in their reasoning about different topics could suggest to teachers which SSI topics are most appropriate for teaching about different types of reasoning (Sadler & Zeidler, 2005).

In order to understand what KVP students bring to the classroom so that it may be utilized in SSI instruction, teachers need a way to formatively assess KVP. The purpose of the work presented in this manuscript is to develop a tool that teachers and researchers can use to assess students' KVP, thus informing SSI instruction that promotes more sophisticated SSR. The intent is that this tool will provide teachers with information about the background understandings that students bring with them to the classroom so that instruction can be customized to include those funds of knowledge and address areas in which student KVP is lacking. The research question is: How can an instrument to measure high school students' KVP with an SSI be characterized?

Literature Review

Instruction using SSIs, and understanding of how students reason about SSIs, matters in schools because of its connection with scientific literacy (Zeidler, 2014), argumentation (Nielsen 2011; 2012 Kolstø, 2006), nature of science (Zeidler, Sadler, Applebaum, & Callahan, 2009) and development of moral reasoning (Lee et al., 2013). Thus, a holistic understanding of how students engage in SSR depending on the characteristics of students themselves can be valuable in providing avenues for teachers to promote these skills in their classrooms. Based on these merits, researchers have begun to tease out how students may approach SSIs differently based on certain characteristics of the student.

When students discuss controversial and complex topics, they need to have an opportunity to relate the arguments that surround the issue to their own experiences (Oulton, Dillon, & Grace, 2004). This notion is supported by research that suggests that populations will reason about SSIs differently if they have a stronger or weaker cultural connection to the topic (Ozturk & Yilmaz-Tüzün, 2017). Given that SSI's contrast to other curricular approaches lies in its ability to tap into the value-laden aspect of the science-society relationship, it follows that beliefs, understandings, and experiences of the students may factor into how they work with these issues as they are presented within a context of competing interests and perspectives (Nielsen, 2011; 2012). Indeed, Zeidler, Herman, Ruzek, Linder, and Lin (2013) concluded in an intervention-based study that attention to and respect for students' perspectives, regardless of their accuracy, was a critical component of using an SSI effectively. Other researchers have determined that this influence is so pronounced that when students did not have a value connection to the topic, they had more trouble deciding about the SSI (Rundgren et al., 2016) or may reason about it with lower sophistication (Ozturk & Yilmaz-Tüzün, 2017). Other researchers have demonstrated that values (Christenson et al., 2012; Fleming, 1986; Zeidler & Schafer, 1984), emotions (Sadler & Zeidler, 2004), and personal experience (Zeidler & Schafer, 1984), more so than scientific knowledge, frame the decisions students make about SSIs.

The extent to which the individual student's characteristics factor into their approach to an SSI is worthwhile to consider because SSIs cannot be resolved purely through understanding of scientific content—values and science together, interpreted through a lens of experience, lead to decisions about these complex issues (Nielsen, 2011; 2012; Kolstø, 2006; Sadler, 2004), but often most of the weight of the decision lies in consideration of personal attributes (Christenson et al, 2012: Lee, Chang, Choi, Kim, & Zeidler, 2012). In fact, students often manipulate the scientific content to assert their arguments and meet the needs established by their pre-existing values (Nielsen 2011; 2012), and when they have trouble arriving at a decision they do not seek out more scientific knowledge (Kolstø, 2006), implying that difficulty in decision-making lies outside of the need for understanding the science more—instead students need more awareness of the social components of socioscientific decision-making. Despite this influence, teachers are often hesitant to discuss their role in SSR because they are uncomfortable doing so (Tal & Kedmi, 2007) or because they do not see value considerations as relevant to science (Allchin, 1999). Collectively, this research underscores the necessity of attending to student aspects beyond their knowledge of content in designing instruction centered on ill-structured, transdisciplinary problems such as SSIs.

SEE-SEP Theoretical Framework

The research presented in this paper describes the development of an instrument to measure KVP, which could be used to inform SSI instruction or to better understand associations between student KVP and their reasoning about SSIs for various SSI topics. The instrument is developed based on the theory of Chang Rundgren and Rundgren (2010) which asserts a connection between KVP and SSR: The SEE-SEP Framework (detailed below).

Most real-world decisions are complex and multi-faceted, consisting of several smaller selections such as those that are made automatically out of habit and those that occur with more careful reflection and weighing of alternatives (Hogarth & Karelaia, 2005). Ozturk and Yilmaz-Tüzün (2017) discussed "reasoning modes" as "factors that may influence individuals' arguments on a SSI" (p. 1277), and

Chang Rundgren and Rundgren (2010) identified through a review of SSI literature six of these modes to develop their SEE-SEP framework: sociology/culture (S), environment (E), economy (E), science (S) ethics/morality (E) and policy (P). Their model details that these six modes are connected to the KVP of an individual, and these relationships dictate approaches individuals take to developing arguments through SSR. They define knowledge as "related to people's affective domain," personal experience as "connected to their daily life," and knowledge as the use of scientific evidence based on "concepts, theories, laws, or evidence developed and discovered" (pp. 12-13).

Empirical qualitative studies using this framework have shown that values account for most of the reasoning students employ when confronted with an SSI, whereas experience contributes the least to how students think about SSIs (Christenson et al., 2012; Rundgren et al., 2016). Other research using a similar Knowledge, Attitudes, and Behaviors (KAB) framework has shown that attitudes influence behaviors (Michalos, Creech, McDonald, & Kahlke, 2011), and Olsson, Gericke, and Chang-Rundgren (2016) used the KAB framework to demonstrate the success of an intervention in promoting sustainability consciousness. These results align well with what is implied by the SEE-SEP model; namely, that positive development in certain aspects of the student (KVP or KAB) contribute to gains in sophistication in how students approach complex SSIs.

Research Methods

Existing research using the SEE-SEP framework (e.g. Christenson et al., 2012; Rundgren et al., 2016) has been qualitative, mainly conducted by assessing the influence of KVP by noting the frequency at which students bring up these three aspects when they reason about SSIs. However, some teachers and teacher educators may be interested in asking questions about the degree of association between sets of scores (KVP and SSR, for instance), understanding how KVP differs for different topics of SSI, or using quick assessments which are easier to score and interpret, all of which require a quantitative measure. To address this need, for this project I developed an instrument that could assign numeric scores for KVP components. Below I describe the development of items to measure KVP and the creation of a rubric for assessing item responses that is grounded in answers provided by a sample of public high school students.

Development of KVP Items

In developing items, I elected to use open-ended instruments in place of forced-choice alternatives such as Likert scale items allow for greater flexibility in student responses. For instance, by allowing students to express their own personal relationship with an issue, I avoided the potential to not ask a forced-choice question that would potentially fail to account for some of their experience. I used theoretical work from Chang Rundgren and Rundgren (2010) and empirical work by Christenson et al. (2012) and Olsson, et al. (2016) to construct questions eliciting KVP. Chang Rundgren and Rundgren (2010) defined each aspect of KVP, and Christenson et al. (2012) explained how each aspect of KVP may be articulated in the six SEE-SEP subject areas by coding student responses to interview questions with codes that reflect an intersection of the subjects and KVP (see Table 1, pp. 345-346 in the paper for a summary of these codes). Using this scheme allowed me to think about how each of the three KVP components may manifest in discussion of the subject areas so that I could construct items that reflected the different ways in which KVP may be considered. Olsson et al. (2016) measured KAB using Likert scale items, and, though I did not measure Attitudes and Behaviors, electing instead to adhere to the SEE-SEP framework, I used these questions to get ideas for phrasing questions to assess broad constructs such as those that comprise KVP.

To create my items, I combined the SEE-SEP subjects of sociology and ethics, economy and policy, and science and ecology. These subjects showed a lot of overlap in the way they were expressed in the Christenson et al. (2012) paper, and asking three broader questions allowed for more diversity in responses to support the development of rubrics grounded in the answers provided by the students. Additionally, I reduced testing fatigue by asking three open-ended questions rather than six for each KVP aspect (giving a total of nine rather than 18). Thus, I developed three questions for each KVP aspect, and those three questions aligned with the subject areas described in the SEE-SEP framework. Additionally, I checked for alignment between the questions and the definitions of KVP in the Chang Rundgren and Rundgren (2010) framework and the types of questions used by Olsson et al. (2016). My Values items assess the value of individual action as well as institutional action, for instance through governmental regulations. Knowledge items measure knowledge of the science as well as the controversy behind each topic, which reflects the questions that were asked by Romine, Sadler, & Kinslow (2017) in their research assessing, in part, relationships between knowledge and SSR. Experience is measured by assessing both direct and indirect experiences, as described by the Chang Rundgren & Rundgren (2010) description of personal experience. Table 1 lists the aspects, their definitions, the subject areas, and the question I asked that aligns with each subject area. In the table, [issue] is used as a placeholder for the actual issue that students would be asked to discuss. The items are listed in the order in which students answered them. The Knowledge items are listed in a different order (with the science/ecology question first rather than last) because students in this study answered the science/ecology question on paper (to allow them to draw a picture) and then logged onto a computer to answer the rest. In future reference, numbers and components are used to designate the questions.

Table 1

KVP components, how they are defined, and how they were assessed

Component	Definition	Subject area	Open-ended questions
Knowledge	Knowledge and evidence as it relates to scientific as well as social understandings	science/ecology	1. Summarize the science behind [issue] in writing or using a picture or diagram.
		sociology/ethics	2. Why might people understand [issue] differently?
		economy/policy	3. What political or economic problems can you imagine existing around the decision to use [issue] areas?

Values	Affective response to the issue, as influenced by the large and small-scale communities with which the individual associates	sociology/ethics	1. Why might people from different groups hold varied opinions about [issue]?
		economy/policy	2. Should local and/or national governments devote more resources (e.g. time, money, personnel) to learning more about [issue]? Why or why not?
		science/ecology	3. Should scientists devote more resources (e.g. time, money, personnel) to learning more about [issue]? Why or why not?
Experience	Connection of the issue to the individual's daily life or perceived personal relevance	sociology/ethics	1. What have you seen to show you that different views exist about [issue]?
		economy/policy	2. Would you devote more of your own resources (e.g time, money) to learn more about [issue]? Why or why not?
		science/ecology	3. What learning experiences have you had to help you understand the science behind [issue]?

I selected two SSIs to assess performance of this instrument: genetic screening for disorders and environmental preservation of a sensitive ecological area. Genetic and environmental issues are two SSIs that appear often in SSI research (Zeidler, 2014), thus, assessing KVP for both of these topics would allow me to check the behavior of this instrument in two contexts that are likely to be of interest to SSI education research. Additionally, both topics appear in the science standards of the state in which the data were collected.

Sampling and Sampling Procedures

The target population for this study was high school science students (grades 9-12). I selected high school students for this research because they are in a developmental stage in which they are making more independent decisions and are thus in critical need of understanding how to weigh issues as complex as SSIs. Additionally, high school students were more likely, according to the state standards of the research site, to have sufficient content knowledge to engage with the topics presented than younger students. I sampled three schools, nine teachers, and 18 classrooms using convenience sampling on the level of the school and holistic sampling on the level of the class. I selected the school based on convenience to facilitate fidelity with the protocol of administering the instrument; by selecting schools that were conveniently located and with which I have worked I was able to travel to the site to administer the instrument myself and to gain access to the schools using the trust I had already built with the administration. I sampled all the students who agreed to participate in the classes that allowed the study to take place, thus including students of a variety of grades (9 - 12) and course levels (honors and standard-level). Though some students did not provide demographic information in their survey (i.e. selected "prefer not to answer" or left demographic questions blank), students surveyed who did offer demographic details were 67% white, 42% male, and 52% upperclassmen (in grades 11 or 12). Details of these schools, based on the 2017 state annual report card, and classes surveyed are presented in Table 2.

Table 2
School and teacher characteristics

School	School student details	Teacher	Class(es)
Local public school 1	440 enrolled 15.1% in poverty 4.4% with disabilities	1-A	Science, cinema, and literature
		1-B	Anatomy (2 classes)
		1-C	Chemistry (2 classes) & Physics
Local public school 2	1040 enrolled 49.9% in poverty 12.1% with disabilities	2-A	Chemistry
		2-B	Chemistry (2 classes) & Physical Science
Local public school 3	982 enrolled 54.4% in poverty 12.8% with disabilities	3-A	Chemistry (2 classes)
		3-B	Chemistry (2 classes)
		3-C	Biology (2 classes)
		3-D	Anatomy (2 classes)

Procedures for Data Collection

Students responded to all questions online, using school-provided Chromebooks, with the exception of the first question on knowledge. The first question was answered using paper-and-pencil, as noted above, and contained instructions to log into a bitly link to access the rest of the survey. Once students completed one survey, they notified me that they were finished and most then received the paper with the knowledge1 question and bitly link for the remaining topic. There were some exceptions, for instance if a student was taking too long to finish one survey, and I decided that the student might not have time to finish the second topic, that student only took the survey for one topic. Students completed all surveys during the students' science class, though I gave one survey during an elective science class (Science, Cinema, and Literature). I arranged these survey visits with the teacher beforehand and scheduled at the teacher's convenience. I randomized at the class level the order in which I distributed each set of items (environmental or genetics) to address the concern that order of answering may affect scores. Following screening for responses that were all "I don't know" or similar or from surveys that were completed unusually quickly, there were 243 responses for the environmental topic and 242 for the genetics topic.

Developing Scoring System

Following the example of Romine et al. (2017), who assessed knowledge to determine influences on SSR, I undertook development of a four-point ordinal scale for coding these responses, following a spectrum of 0 to 3. This scale also aligns with the levels of the SSR rubric (Sadler et al., 2005), thus allowing for easier comparison between KVP and SSR scores for researchers interested in undertaking this inquiry to further test the SEE-SEP framework. Because of the uniqueness of each of the KVP aspects, the scores of 0 and 3 would suggest different types of understanding. Before analyzing any of these items, I created the rough framework of scores in Table 3 based on how KVP are described in the work of Chang Rundgren and Rundgren (2010).

Table 3
Scores for KVP measures

Aspect	0	3
Knowledge	Inaccurate	Sophisticated
Values	Does not value the issue	High value for the issue
Experience	No experience with the issue	Much experience with the issue

Note that in Table 3 I only defined levels of 0 and 3 for each aspect. Rather than defining the intermediate levels prior to conducting the study, I used random samples of responses to develop the levels of the rubric and procedures to establish interrater agreement, following the example of Romine et al. (2017) in developing their articulation of levels of Knowledge. This constant comparison method (Glaser & Strauss, 1967) allowed me to develop a theoretical basis for rating these complex constructs that is closely tied to my data and my population.

I established the appropriateness of scoring for the KVP items and developed the final rubric by measuring interrater agreement (IRA) for a subset of scores. I randomly selected 35 responses, according to recommendations of Gisev, Bell, and Chen (2013) which bases sampling on the number of levels in the instrument, to share with a doctoral student trained in this type of rating. I ensured that these 35 responses included representation of each school and grade level (9-12) surveyed. We coded all questions on a 0-3 scale based on the framework in Table 3, perceiving scores of zero and three as extremes and using scores of one and two to designate our sense of intermediates. We coded all the questions for the environmental topic but only coded two of the three questions for Knowledge and Values in the genetics topic due to time and scheduling constraints. The κ_W values for both questions ended up being nearly equal and similar to or better than those for the environmental set, which we coded first, so we felt comfortable about not coding the remaining question, particularly given the high κ_W values for the environmental items.

I calculated the κ_W statistic based on agreements for individual questions and within each category (Knowledge, Values, and Experience) for each of the two topics (environmental and genetics). The linear κ_W values (used because the difference between 0 and 1 scores is the same as the difference between a 2 and 3 score) are listed in Table 4, showing first a collective assessment of all items for the

SSI topic as well as a range of values for the individual items. Landis and Koch (1977, cited in Gisev et al., 2013) interpret Kappa values of 0.61-0.80 as *substantial*, and 0.81-1.00 to be *almost perfect*. The κ_W values in Table 4 are between .72 and .92, which indicate substantial to nearly perfect agreement. These results suggested that I could proceed coding the remaining responses individually.

Table 4
The κ_W statistic for KVP ratings

	Environmental topic		**Genetics topic**	
	κ_W	κ_W range	κ_W	κ_W range
Knowledge	.84	.80-.88	.80	.80-.81
Values	.83	.72-.87	.92	.92-.92
Experience	.87	.86-.88	.91	.80-1.0

Following that initial scoring, we discussed rationale for scores and agreed upon what scores of 0, 1, 2, and 3 should be, thus constructing the rubric, seen in Table 5. This method of establishing a rubric using rank-ordered samples enables reviewers to use relative quality to assign scores, which enhances reliability by reducing inconsistencies of grading, particularly for holistic evaluations of constructed response items (Attali, 2014). Again, note the rubric uses [issue] as a placeholder, thus allowing teachers or researchers to customize the items and scoring based on the SSI topic of interest to their classroom or study.

Table 5
Initial Rubric for KVP items

Aspect	**Question**	**0**	**1**	**2**	**3**
Knowledge	Why might different people understand [issue] differently? (sociology/ethics)	Absent or irrelevant	Describes groups and/or sides vaguely	Describes groups OR sides in detail	Describes groups and sides of the issue in detail
	What political or economic problems can you imagine in finding a solution for [issue]? (economy/policy)	Absent or irrelevant	Discusses the need for a solution but not problems	Discusses problem and need for solution vaguely	Sophisticated description of problems and need for a solution
	Summarize the science behind [issue] in writing or using a picture or diagram. (science/ecology)	Absent, inaccurate, or irrelevant	Describes vaguely an issue related to the topic	Describes vaguely the topic OR specifically a related issue	Describes specifically the issue

Values	Why might people from different groups hold varied opinions about [issue]? (sociology/ethics)	Does not see where differences in opinion could exist	Explains one side	Explains that people may disagree about the issue vaguely	Specifically discusses disagreement and reason for it
	Should local and/or national governments devote more resources (e.g. time, money, personnel) to learning more about [issue]? Why or why not? (economy/policy)	Does not think governments should devote more money	Thinks governments could devote more money but does not really care	Thinks more money should be devoted so it is better understood	Thinks more money should be devoted so the best solution is found
	Should scientists devote more resources (e.g. time, money, personnel) to learning more about [issue]? Why or why not? (science/ecology)	Does not think scientists should devote more money	Thinks scientists could devote more money but does not really care	Thinks more money should be devoted so it is better understood	Thinks more money should be devoted so the best solution is found
Experience	What have you seen to show you that different views exist about [issue]? (sociology/ethics)	No experience with the issue	Vaguely describes a source of learning	Specifically describes a source of learning	Specifically describes a source of learning and its relation to the issue
	Would you devote more of your own resources (e.g time, money) to learn more about [issue]? Why or why not? (economy/policy)	Would not devote own resources	Would devote resources if they had the resources, but not a priority	Would spend more time trying to learn the issue	Would spend more time trying to learn or to support fixing the issue
	What learning experiences have you had to help you understand the science behind [issue]? (science/ecology)	No experience with the issue	Vaguely describes a source of learning	Specifically describes a source of learning	Specifically describes a source of learning and its relation to the issue

Although in some cases we used the same level criteria for different questions (e.g. the first and third questions in the Experience section) we felt that rubric levels needed to be more specific to the question to make sense in some circumstances (e.g. each of the Knowledge questions). Using this rubric, I independently scored all remaining responses to the KVP items.

Explanation of Validity Procedures

Loevinger (1957) identified three phases of construct validation: *substantive*, in which the construct is linked to theoretical foundations and subject to expert review; *structural*, in which the organization of the instrument is critiqued for consistency and factor loading; and *external*, in which the instrument is evaluated alongside other instruments or in other contexts in which groups are expected to differ in their results. Regarding the substantive validation of the KVP instrument, my review of the items considering the original definitions of Knowledge, Values, and Experience as well as the use of actual responses from the students to construct the assessment rubric supports substantive validity through relation to the framework and input from actual members of the intended population. In the structural phase of validity, Loevinger (1957) calls for a check on how the instrument performs when it is used with the intended population. For the KVP instrument, I used a constant comparative method to construct the scoring rubric for responses (Glaser & Strauss, 1967). I conducted a reliability assessment through establishing IRA, as discussed above in the section describing the KVP instrument. Reliability can be seen as a component of internal validity (Lissitz & Samuelson, 2007) and is concerned with the internal consistency of test items. Additionally, following instrument administration, I conducted EFA and CFA on the responses to check for factor loading for the KVP components. Loevinger's (1957) external phase of validation refers to the appropriateness of the statements made as conclusions are drawn from the use of the instrument. In this study, I supported external validation through critical examination of the results against competing explanations (Kane, 2001), and I state the limitations of the work (for instance, based on the demographics of the students assessed). Attention to external validity is presented in the Discussion and Conclusions sections below.

Performance of Instrument: Results of Factor Analysis

In the next step of the instrument development I checked the performance of the items within the KVP factors (as described by the Chang Rundgren and Rundgren framework) using a series of factor analyses for the two topics using SPSS and SPSS Amos version 25.

Environmental Topic Exploratory Factor Analysis (EFA)

I used the scores of the screened sample of 243 responses to the environmental items to conduct EFA. Examination of P-P and Q-Q plots suggested multivariate normality of the data, thus I employed Maximum Likelihood Estimation (MLE) (Fabrigar, Wegener, MacCallum, & Strahan, 1999). Due to the large number of variables plotted, these figures are not reproduced in this document but will be made available upon request of the reader. I used the direct oblimin oblique rotation because there is theoretical support that the KVP factors may be correlated (Tabachnick & Fidell, 2013) given that it seems probable that knowledge of a topic may relate to experience with or value of it, for instance. The determinant value was .191, indicating absence of multicollinearity, the Kaiser-Meyer-Olkin measure of sampling adequacy was .767, above the recommended value of .6, indicating the existence of a factor structure, and Bartlett's test of sphericity was significant, $X^2(36) = 392.283$, $p < .001$, indicating an adequate correlation between variables to permit EFA. The pattern matrix in Table 6 indicates three factors. I repeated the analysis with a promax rotation and achieved the same factor loadings.

Table 6
Pattern matrix for environmental topic with direct oblimin rotation

Question	Factor 1	Factor 2	Factor 3
know1	**.296**	.190	-.112
know2	-.053	**.421**	-.005
know3	-.001	**.616**	-.131
values1	-.033	**.469**	-.005
values2	-.025	-.079	**-.801**
values3	-.018	.130	**-.548**
exp1	.258	**.624**	.075
exp2	.220	.064	**-.333**
exp3	**1.024**	-.078	-.002

Note. Bold text indicates items grouping within a factor

The three factors explained a total of 58.113% of the variance of the data, with Factor 1 explaining 33.427% (Eigenvalue 3.008), Factor 2 explaining an additional 13.152% (Eigenvalue 1.184) and Factor 3 explaining 11.534% (Eigenvalue 1.038). The Goodness-of-fit Test was nonsignificant, $X^2(12) = 19.585$, $p = .075$, meaning that the hypothesized model was a fit for the data. Table 7 indicates the questions in each factor.

Table 7
Environmental topic factors and questions from EFA results

Factor	Questions
1: Learning about the issue	know1: Using words or pictures, explain the science behind environmental preservation. (science/ecology)
	exp3: What learning experiences have you had to help you understand the issue of environmental preservation? (science/ecology)
2: Awareness of different views/opinions	know2: Why might people understand environmental preservation differently? (sociology/ethics)
	know3: What political or economic problems can you imagine existing around the decision to preserve environmental areas? (economy/policy)
	exp1: What have you seen to show you that different views may exist about environmental preservation? (sociology/ethics)
	values1: Why might different groups have different opinions about preserving environmental areas? (sociology/ethics)
3: Value for using resources to support the issue	values2: Should local and/or national governments devote more resources (time, money, personnel) to understanding more about environmental preservation? (economy/policy)
	values3: Should scientists devote more resources (time, money, personnel) to understanding more about environmental preservation? (science/ecology)
	exp2: Would you devote time and/or money to finding out more about environmental preservation? (economy/policy)

The Cronbach's alpha reliability value for the factor structure was .654. Because the alpha statistic is sensitive to the number of items (Green, Lissitz, & Mulaik, 1977), I also looked at the mean inter-item correlation value. This value is used to show if items meant to measure the same construct will score similarly, with an acceptable value ranging between 0.15 and 0.50 (Clark & Watson, 1995). The value for this factor structure was .390, an acceptable measure of reliability.

Genetics Topic EFA

I performed EFA on the genetics items separately in order to determine if a similar factor structure emerged from these data. As with the environmental topic, I used the screened data (n = 242). I again used MLE and direct oblimin oblique rotation for this factor analysis. I checked the appropriateness of EFA by examining criteria for factorability. The determinant value was .288, indicating absence of multicollinearity, the Kaiser-Meyer-Olkin measure of sampling adequacy was .715, above the recommended value of .6, indicating the existence of a factor structure, and Bartlett's test of sphericity was significant, $X^2(36) = 296.265$, $p < .001$, indicating an adequate correlation between variables. The rotated factor matrix in Table 8 indicates loadings for four factors. I repeated the analysis with promax rotation and achieved the same factor loadings.

Table 8
Pattern matrix for genetics topic with direct oblimin rotation

Question	Factor 1	Factor 2	Factor 3
know1	.125	.113	**.503**
know2	.003	-.103	**.504**
know3	**.976**	.082	.038
values1	.152	.008	**.281**
values2	.000	**.765**	-.087
values3	.004	**.649**	-.011
exp1	.005	-.009	**.579**
exp2	.090	**.407**	.199
exp3	-.184	.170	**.445**

Note. Bold text indicates items grouping within a factor

The three factors explained a total of 55.569% of the variance of the data, with Factor 1 explaining 28.410% (Eigenvalue 2.557), Factor 2 explaining an additional 15.411% (Eigenvalue 1.387) and Factor 3 explaining 11.748% (Eigenvalue 1.057). The Goodness-of-fit Test was nonsignificant, $X^2(12) = 16.997$, $p = .150$, meaning that the hypothesized model is a fit for the data. Table 9 presents the Factors with the questions loaded onto each. The Cronbach's alpha reliability value for the factor structure was .511, and the inter-item correlation value for this factor structure was .286, an acceptable indication of reliability.

Table 9
Genetics topic factors and questions from EFA results

Factor	Questions
1: Political/economic aspect of issue (Political/economic knowledge)	know3: What political or economic problems can you imagine existing around the decision to use genetic screening? (economy/policy)
2: Value for using resources to support the issue (Values)	values2: Should local and/or national governments devote more resources (time, money, personnel) to understanding more about genetic screening? (economy/policy)
	values3: Should scientists devote more resources (time, money, personnel) to understanding more about genetic screening? (science/ecology)
	experience2: Would you devote time and/or money to finding out more about genetic screening? (economy/policy)
3: Understanding of science and controversy (Knowledge)	know1: Using words or pictures, explain the science behind genetic screening. (science/ecology)
	know2: Why might people understand genetic screening differently? (sociology/ethics)
	exp1: What have you seen to show you that different views may exist about genetic screening? (sociology/ethics)
	exp3: What learning experiences have you had to help you understand the issue of genetic screening? (science/ecology)
	values1: Why might different groups have different opinions about genetic screening? (sociology/ethics)

These EFA results were difficult to defend substantively, particularly as they differ from the more theoretically sound factor structure from the EFA for the environmental topic and presented the problematic loading of a single item onto one factor. Thus, in subsequent analysis described below I relied on the factor structure from the environmental EFA. Implications of this result are discussed in the Discussion section below.

Confirmatory Factor Analysis for Each Topic

Due to the inconsistencies between the topic factors themselves and between the EFA results and the theoretical suggestion of factors, I used confirmatory factor analysis (CFA) to continue to explore the factor structure of the items. CFA differs from EFA in that it explores the fit structure of a previously defined hypothetical model. Thus, it allowed me to look comparatively at the theoretically described constructs in the KVP model and the factors identified through the EFA. Additionally, CFA is more flexible to making adjustments based on theoretically sound associations, as will be discussed below.

Environmental Topic CFA

I first constructed the measurement model in Figure 1 for the KVP aspects using the hypothesized KVP components. In this figure, as with the tables presented in this section, I abbreviated "know" for Knowledge items and "exp" for Experience items. The model fit for this model with the hypothesized KVP constructs was poor, CFI = .860, TLI = .790, RMSEA = .094 (90% CI = .070, .118). Due to this poor fit, alternative model constructions must be explored. I tried the measurement model with the factors produced by the EFA, shown in Figure 2.

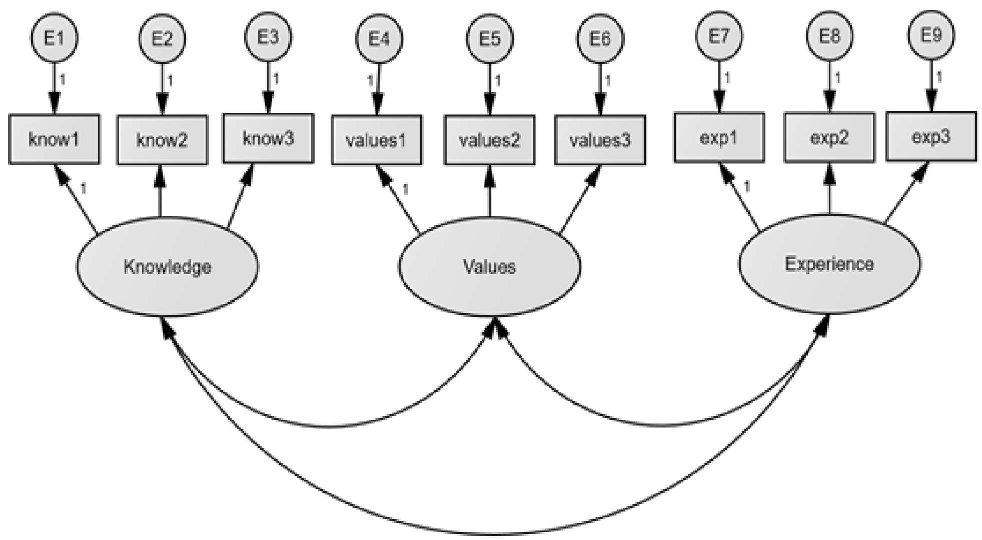

Figure 1. The measurement model for environmental topics with hypothesized KVP components reflects the SEE-SEP framework and original intended structure of the items.

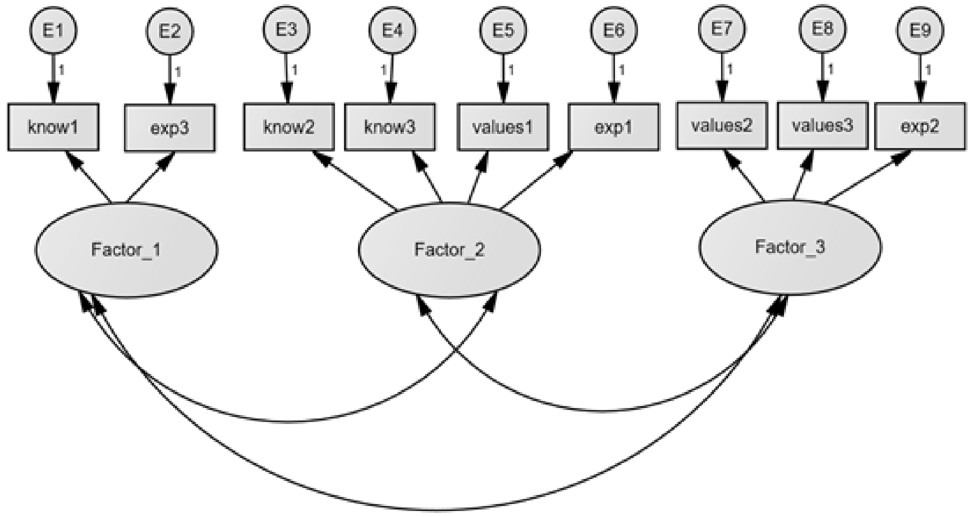

Figure 2. The environmental KVP measurement model using EFA factors shows a better fit than the hypothesized KVP structures but still requires modifications.

Here the model is still a poor fit, but better than the model with the hypothesized KVP, CFI = .918, TLI = .876, RMESEA = .072 (90% CI = .046, .098). (AIC for EFA model = 95.881, AIC for hypothesized model = 116.700). Due to the better fit of this model as evidenced by the lower AIC value, I looked for areas I could modify to improve the fit. Due to similarities between the question and responses I noted between the experience2 question and items in Factor 1, I made this adjustment, as presented in Figure 3.

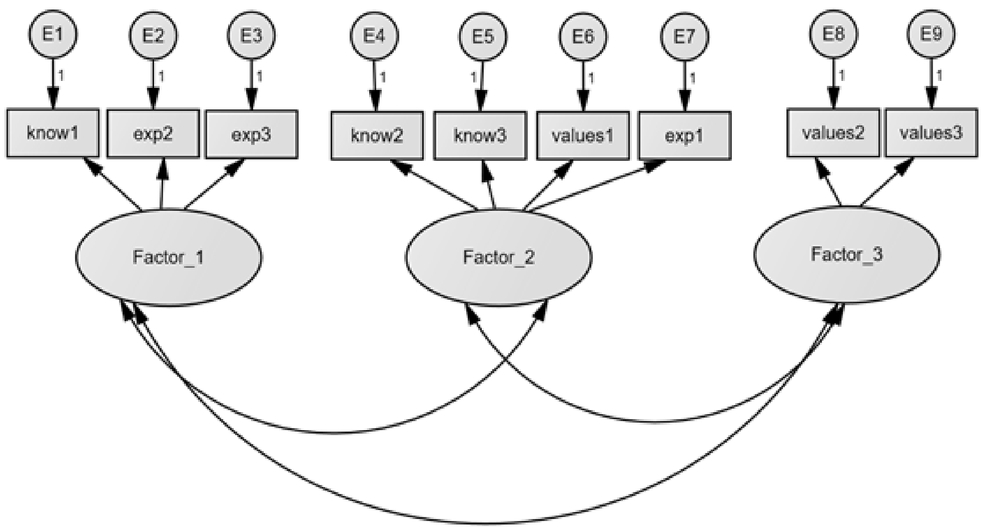

Figure 3. The revised measurement model for KVP aspects using EFA factors exhibits a better fit than the hypothesized model or the model with the original KVP factors (AIC for EFA model = 95.881, AIC for hypothesized model = 116.700).

The adjusted model achieved a good fit, CFI = .938, TLI = .907, RMESEA = .062 (90% CI = .038, .089). The regression weights and squared multiple correlation coefficients, indicating how much variance the latent variable (Factor 1, 2, or 3) contributes to the item are presented in Tables 10 and 11, respectively. For instance, Factor 1 accounts for 32% of the variance in the score for the knowledge1 item, as shown in the column beside knowledge1 in Table 11. Table 12 shows the covariance values for the correlated latent variables.

Table 10

Regression weights for environmental CFA with KVP factors

			Standardized Estimate	**Estimate**	**S.E.**	**C.R.**
know1	<---	Factor_1	.568**	1.000		
exp2	<---	Factor_1	.553**	1.338	.242	5.526
exp3	<---	Factor_1	.628**	1.321	.227	5.809
know2	<---	Factor_2	.376**	1.000		
know3	<---	Factor_2	.682**	2.186	.460	4.748
values1	<---	Factor_2	.434**	1.141	.282	4.049
exp1	<---	Factor_2	.698**	2.464	.517	4.764
values2	<---	Factor_3	.654**	.972	.172	5.642
values3	<---	Factor_3	.700**	1.000		

Note. To run SEM, the AMOS software requires some path values to be initially fixed to 1, which is why there are three paths without values for S.E. or C.R.
**Value is significant at the 0.01 level

Table 11
Squared multiple correlations for items for environmental topic KVP CFA model

	Estimate
know2	.141
exp3	.394
values3	.490
values2	.428
exp1	.488
values1	.188
know3	.466
exp2	.306
know1	.322

Table 12
Covariance values for items in genetics topic KVP CFA model

			Estimate	S.E.	C.R.
Factor_2	<-->	Factor_3	.132**	.035	3.774
Factor_1	<-->	Factor_2	.109**	.029	3.742
Factor_1	<-->	Factor_3	.195**	.045	4.285

**Value is significant at the 0.01 level

Factor loadings below .4 are low (Hair, Anderson, Tatham, & Black, 1998), and the loadings for each item here are near or above .40, with the knowledge2 item falling slightly below .40 but still loading significantly. The revision produced a different factor structure from the hypothesized KVP components and modifies the factors identified by the EFA. The resultant factors and items are presented in Table 13.

Table 13
Factors and items based on CFA

Factor number	Factor name	Item code	Items
Factor 1	Academic understanding of issue	know1	Using words or pictures, explain the science behind [issue]. (science/ecology)
		exp2	Would you devote time and/or money to finding out more about environmental preservation? (economy/policy)
		exp3	What learning experiences have you had to learn more about environmental preservation? (science/ecology)
Factor 2	Controversy about issue	know2	Why might people understand environmental preservation differently? (sociology/ethics)
		know3	What political or economic problems can you imagine existing around the decisions to preserve the environment? (economy/policy)
		values1	Why might different groups have different opinions about environmental preservation? (sociology/ethics)
		exp1	What have you seen to show you that different views may exist about environmental preservation? (sociology/ethics)
Factor 3	Value of others devoting resources	values2	Should local and/or national governments devote more resources (time, money, personnel) to understanding more about environmental preservation? (economy/policy)
		values3	Should scientists devote more resources (time, money, personnel) to understanding more about environmental preservation? (science/ecology)

Compared to the factor structure derived from the EFA, the collections of items for each factor have a greater substantive justification for association, as summarized by the factor names in the second column of Table 13. Most notably, the CFA results suggested relocating the experience2 question to Factor 1, which includes the science/ecology questions from Knowledge and Experience. Though experience2 does not ask students directly about their understanding of the science of the issue, student responses to this question were based almost exclusively on their exposure to the issue in school science. Due to the low degree of experience students demonstrated for this issue in responses to this question, fairly low-level responses such as indicating that they learned about it in biology earned high scores (a score of 2) due to their relative positioning to other responses. These types of responses contrast to the values2 and values3 questions, remaining in Factor 3, to which students answered with more depth and tended to express more of a willingness for others to devote resources, possibly because the students did not see a direct impact on themselves if scientists or governments devoted time or money to the project and were therefore more likely to be liberal in their willingness to see resources allocated. A full discussion of the implications for this revised factor structure, including more substantive support from the literature about the SEE-SEP framework, is presented in the Discussion.

Hereafter, I will refer to this collection of factors as the "KVP Factors," whereas references to the original KVP groupings I will refer to as "hypothesized KVP."

Genetics Topic CFA

I first tested the hypothesized KVP factor groupings, as illustrated in Figure 1 in the section on the environmental topic. The model fit for this model was also poor, CFI = .825, TLI = .671, RMSEA = .091 (90% CI = .067, .115). I tried the measurement model using the structure from the CFA of the environmental model with the KVP Factors, shown in Figure 3. This model using the KVP Factors gives a fit of CFI = .898, TLI = .847, RMSEA = .068 (90% CI = .042, .094), which is weak but, as with the environmental topic, better than the statistics for the hypothesized KVP model. These poor fit indices indicated the need for modifications. I added correlations between items within the same factor (knowledge1 and experience3, knowledge2 and values1, and knowledge3 and values1) as well as between the two knowledge items, knowledge1 and knowledge3, in Factor 1 and Factor 2, respectively. The fit for this model, shown in Figure 4, was good, CFI = .978, TLI = .960, RMSEA = .035 (90% CI = .000, .069).

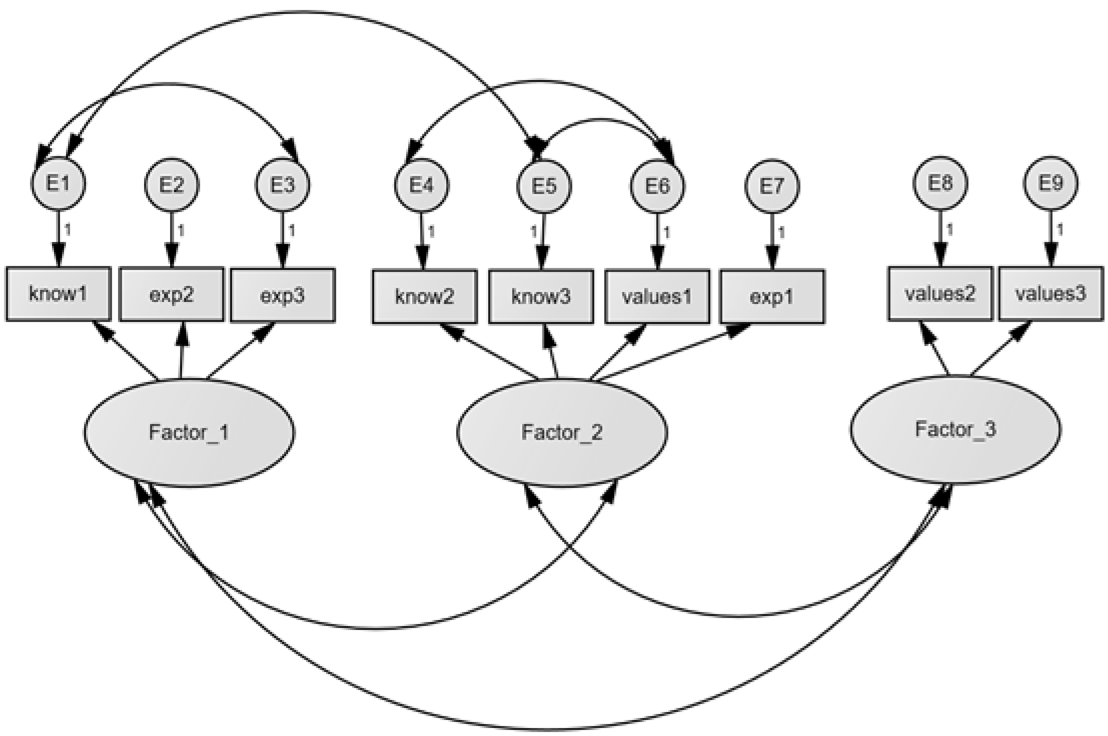

Figure 4. This modified measurement model for KVP factors for genetics topic shows correlations between items in factors 1 and 2.

Tables 14 and 15 show the regression weights and squared multiple correlations, respectively, and Table 16 shows the covariance values for the correlated terms.

Table 14
Standardized regression weights for KVP Factor items in genetics CFA

			Standardized Estimate	Estimate	S.E.	C.R.
know1	<---	Factor_1	.425**	1.000		
exp3	<---	Factor_1	.361**	.820	.179	4.572
know2	<---	Factor_2	.440**	1.000		
know3	<---	Factor_2	.313**	.846	.268	3.157
values1	<---	Factor_2	.242**	.607	.218	2.780
exp1	<---	Factor_2	.657**	1.521	.373	4.073
values2	<---	Factor_3	.714**	1.000		
values3	<---	Factor_3	.667**	.828	.158	5.237
exp2	<---	Factor_1	.524**	1.281	.260	4.922

Note. To run SEM, the AMOS software requires some path values to be initially fixed to 1, which is why there are three paths without values for S.E., or C.R.
**Value is significant at the 0.01 level

Table 15
Squared multiple correlations for items in KVP Factors CFA for genetics items

	Estimate
know2	.193
exp2	.274
values3	.445
values2	.510
exp1	.431
values1	.058
know3	.098
exp3	.131
know1	.181

Table 16
Covariance values for correlated items in KVP Factors for CFA for genetics items

			Estimate	S.E.	C.R.
Factor_2	<-->	Factor_3	.063*	.031	2.035
Factor_1	<-->	Factor_3	.245**	.057	4.309
Factor_1	<-->	Factor_2	.149**	.042	3.539
E1	<-->	E3	.219**	.069	3.178
E6	<-->	E4	.120*	.049	2.449
E5	<-->	E6	.133*	.055	2.403
E1	<-->	E5	.182**	.062	2.925

**Value is significant at the 0.01 level
*Value is significant at the 0.05 level

Unlike with the environmental model, this model showed low regression weights (below .4) for two items (knowledge3 and values1, both in Factor 2), which were also shown to have a very small degree of their variance accounted for by the factor (.098 and .058, respectively).

This measurement model demonstrated that the factor structure for the KVP components was similar for the environmental and genetics topics after the inclusion of error correlations. One of these correlations was between the items that asked students to explain the science behind the topic (knowledge1) and to detail the learning experiences they have had related to the topic (experience3). Knowledge1 and experience3 both existed within the same factor, comprised of items that measure academic understanding of the facts of the issue, and it makes sense that the learning experience students have would be correlated with their ability to explain the science behind the issue, as evidenced by the positive error correlation between the two items. This error correlation means that there is an unaccounted-for factor that positively influences scores on both items. Another correlation was between the knowledge1 and knowledge3 items, which both assessed understanding of the issue. The correlation between knowledge2 and values1 both measured awareness of different opinions that may exist about the issue, and the correlation between knowledge3 and values1 both spoke to the existence of controversy. All these error term correlations allowed the model to account for some aspect of these factors that were not measured by the instrument.

Discussion

As seen in Table 13, the factor analyses resulted in some modifications for how KVP aspects were defined. Factor 1 consisted of items from the science/ecology subject areas for Knowledge and Experience and the economy/policy item for Experience. I collectively termed these items "Academic understanding of the issue" as they related to the student's knowledge of the science of the issue (assessing the students' own understanding of the science of the issue for the science/ecology items and their willingness to devote their own resources to learning more about the issue for the economy/policy item). Although the Experience items could have been interpreted as experience leading to understanding of the controversy of the issue, students responded to these questions with discussion almost exclusively of learning of science content in school, thus placing them within this factor. The items in Factor 2 collectively assessed the Awareness of the controversy of the issue. Although this factor included Knowledge, Values, and Experience items, it included all the sociology/ethics questions in addition to the question about political or economic problems that could exist around the issue (economy/policy question for Knowledge). Considering that the items in the first factor (Academic understanding of the issue) all were answered with reflection on academic understanding and the items in the third factor (Value of others devoting resources) were all answered based on whether or not the students thought others should spend time and money on the issue, it made sense that this economy/policy Knowledge item would contribute to the factor that assessed awareness of controversy, particularly as this item asked the student to imagine political or economic problems. The final factor included the two Values items that asked students whether they felt that others (scientists and governments) should devote resources to understanding or resolving the issue. Interestingly, for these questions, students responded more in how these individuals could devote diverse resources to finding solutions, whereas their responses for the question asking if they would devote their own resources to the topic (Experience 2 in Factor 1 for Academic understanding of the issue), they predominantly discussed just devoting time or money to learning more about the science of issue, which helps explain why the items appeared on different factors.

Table 17 compares the hypothesized KVP and KVP Factor structures. As shown in the definitions listed in the table, there is some overlap between the hypothesized KVP and KVP Factor structures. For instance, the Knowledge and Academic understanding factors both included items that assessed learning about the science of the issue. However, the Academic understanding factor includes Experience items because the Experience expressed by this population of students was almost purely based on their learning in school. Most of the Knowledge items actually appeared in the KVP Factor of Awareness of controversy, which included experience1 and values1 as well. The hypothesized Values factor differed from the Value of others using resources factor by excluding values1. This item appeared instead in the Awareness of controversy factor, along with the other sociology/ethics items (experience1 and knowledge2).

Table 17
Comparison of hypothesized KVP and KVP Factor structures

Hypothesized KVP			**KVP Factors (from CFA)**		
Factor name	Definition	Items	Factor name	Definition	Items
Knowledge	Use of scientific evidence	knowledge1 knowledge2 knowledge3	Academic understanding	Use of school learning	knowledge1 experience2 experience3
Values	Use of affective domain	values1 values2 values3	Value of others using resources	Willingness to have others devote resources to problem	values2 values3
Experience	Connection to daily lives	experience1 experience2 experience3	Awareness of controversy	Understanding of diverse perspectives	knowledge2 knowledge3 experience1 values1

This factor structure did not perform as effectively for the genetics items as it did for the environmental topic items, as indicated by the lower regression weights and poorer factor structure fit outcome of the CFA. Thus, there are unobserved factors that contribute to the KVP construct for these items, a conjecture supported by the need to include error term correlations to achieve a model fit. Other researchers have suggested that attitudes and beliefs (Olsson et al., 2016) and emotions (Lee et al., 2012; Lee & Grace, 2012) could contribute to reasoning about SSIs, and that emotion may be particularly influential for genetics topics (Topçu, Yilmaz-Tüzün, & Sadler, 2011). Another potential explanation could be the lack of understanding of the issue of genetic screening; whereas all of the students surveyed would have recently taken a middle-school course that addressed environmental topics, those who had not yet completed their high school biology course would have had much less exposure to topics in genetics, possibly accounting for variances in KVP.

Collectively, this factor analysis result suggests that the delineation of the three KVP factors cannot be assumed to be discrete. The work that has previously used these factors has been qualitative, coding responses using the subjects and/or KVP aspects (e.g. Christenson et al., 2012). Because these factors had not yet been submitted to a quantitative factor analysis, it is not unsurprising that they may manifest differently when used quantitatively. For instance, in Christenson et al.'s (2012) work, they analyzed the coding distribution by calculating the degree to which each KVP factor arose in conversations with Swedish high school equivalent students about the SSIs. Across topics, they noted that the discussion of Experience was present the least, and nearly absent with some SSI topics. In their qualitative work, this could be noted as a result that suggested the absence of much Experience in constructing arguments about SSIs, but in factor analysis, responses are grouped based on factors that *do* exist in the data. Two of the Experience questions (experience2 on economy/policy and experience3 on science/ecology) grouped with the knowledge1 question because they collectively represented, in the responses students gave in this study, their learning in school about the topic. The remaining Experience question (experience1) grouped with the Values and Knowledge questions about the sociology/ethics subject area in Factor 2, Awareness of controversy.

This revised factor structure changes consideration of how the KVP characteristics of students could be associated with their level of SSR, as hypothesized by Chang Rundgren and Rundgren (2010). The SEE-SEP subject areas, rather than the KVP aspects, were more indicative of the items associated with Factors 1 and 2. Factor 1 contained two science/ecology questions (knowledge1 and experience3) and one question that was answered in the spirit of science/ecology (experience2). Factor 2 contained all the sociology/ethics questions as well as one economy/policy question (knowledge3). It is noteworthy that the economy/policy questions were the subject area questions that failed to factor together; an economy/policy question appeared in each of the three factors in the CFA analysis. Review of student responses to these questions revealed a tendency of students to side-step discussion of economics or politics in detail, particularly by exclusion of one or the other or focus on a small facet of economy or policy, such as spending money or political disagreements. When individuals have less knowledge about a topic they tend to answer an approximation of the question that is more relatable to themselves, such as how they feel about the issue or what they know about that is related to the issue, though not necessarily to the question at hand (Nielsen 2011; 2012). Answering these types of questions about hypothetical issues to which students may see little personal relevance may enhance this tendency to sidestep the question that they aren't sure how to answer (Herman, Zeidler, & Newton, 2018; Karahan & Roehig, 2017; Lee et al., 2012; Lee & Grace, 2012). Students may have answered these three questions differently because of their lack of exposure to information about economics or policy. As noted by Håkansson, Östman, and Van Poeck (2018), students' expression of political dimensions of SSIs may require more scaffolding from the teacher to manifest. Further research that involves collecting data more directly to assess understanding of these subject areas and their contribution to SSR should be conducted to support this supposition, so the results should be interpreted cautiously, with awareness that complete data to support the rationale for the factor structure still needs to be collected. The work of Håkansson et al. (2018) provides some suggestions for taking this approach.

Conclusions, Limitations, and Future Work

Because of the controversial nature of SSIs, they affect different groups of people in unique ways, and differences in KVP will lead to different directions of reasoning for a group of students presented with the same SSI (Christenson et al., 2012). Students in modern classrooms come from diverse backgrounds, and SSIs can position the diversity of a classroom as an asset for instruction. This again characterizes SSIs differently from previous approaches to interdisciplinary learning. Students from diverse backgrounds will necessarily have KVP that is unique to them and will thus influence their engagement with an SSI differently. By highlighting the ways in which KVP frames the approaches taken to reasoning about an SSI, students can appreciate and empathize with diverse perspectives. The first step in this endeavor is developing ways to measure KVP, as was presented in this research.

Recommendations for Teachers, Teacher Educators, and Researchers

This instrument and student performance measured using this instrument may be of value to teachers interested in developing SSIs that capitalized on the KVP students bring to their classrooms. For instance, performance indicating a lower level of value for a particular issue may suggest to teachers the inclusion of classroom activities that lead to development of value for the issue or guide students to recognize the value of the issue in their lives and communities. As theorized by Chang Rundgren and Rundgren (2010), this step is crucial in achieving optimal engagement with SSIs that leads to growth in SSR. Because the discussion of KVP in the classroom may be novel for many teachers, teacher educators may want to consider developing supports for teachers that will help them undertake the challenges of including attention to KVP in their curricula. The flexible nature of the instrument would allow it to be used at different points in the curricula, allowing teachers to create opportunities for their students to revisit and reflect on their KVP with different SSIs, leading to conversations on factors that construct their KVP and produce these differences. Additionally, the results of this study suggest that students may approach SSIs of different types of topics differently, which could indicate to teachers a need to reflect on using approaches to SSI instruction tailored to specific issues.

Science education researchers may find this instrument valuable in assessing connections between KVP and measures of interest, such as scientific literacy and argumentation. The provision of a quantitative tool makes this type of analysis possible to conduct large-scale, enabling complex comparisons that consider student and school characteristics and how they interact with KVP to predict scores on these other measures. Finally, the limited ability for the items to account for KVP of the genetics issue suggests that the KVP construct may define differently for different SSI topics. Researchers should continue to explore what additional factors may provide a stronger reflection of student KVP so that teachers can be better informed as to how they can customize their SSI instruction for different issue topics to better address student KVP. Finally, these results pose implications for rethinking how the KVP components are delineated, suggesting the need for further investigation of how these components should be defined, described, and utilized in research. For instance, if there is overlap in the components or if they present themselves differently for different topics, it may be worth reconsidering using them for coding frameworks, and coding protocols may need to be developed that attend to differences in SSI topic and research population.

Limitations

Because the value of SSIs can be maximized using locally relevant issues, the factor association of these items may be different if the survey is administered in a different area where issues of the environment or genetics are more or less relevant. Similarly, this research only presented two SSIs, though the topics selected were representative of what is typically seen in SSI research. Due to findings that suggest that SSR may differ in some ways or be similar depending on the topic, there remains a need for additional research to evaluate the extent of this difference and congruence across several topics and in several student populations, particularly, as noted in the citation of other relevant research above, the role of Experience may manifest more significantly in more diverse groups. Moreover, the presentation of the topics may also influence the ways in which they are approached (Berglund & Gericke, 2016), so revisiting these same topics from different angles could produce different results.

This instrument consists of open-ended items, which presents the possibility that students will give limited responses due to lack of motivation to write. Thus, data could be more suggestive that students with higher measures KVP also had higher motivation to contribute to the study. Thus, this study should be revisited using KVP items that consist of Likert scale items that will require less effort on the part of the respondents. The rubric of responses associated with the KVP questions that may be used as a guide in creating these types of questions. Additionally, this instrument was developed for a population of high school students. Students at different ages will likely need modified instruments to assess their KVP, a need which is a potential avenue of future work for teacher education researchers interested in developing strategies for using SSIs in younger populations. Readers should also note that the use of complex constructs such as Knowledge, Values, and Experience signals the need for caution in interpreting the results of this research. I used these terms as they were defined by Chang Rundgren and Rundgren (2010); other ways of defining these constructs certainly exist.

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