Refining a Quantitative Assessment of Socioscientific Reasoning

by

Oswaldo Lobo

Spring 2020

A thesis

submitted in partial fulfillment of the requirements

for a baccalaureate degree in Biology

in cursu honorum

Reviewed and approved by:

(John Ruppert PhD.)
Thesis Supervisor

Submitted to

the Honors Program, Saint Peter's University

Date of Submission

Table of Contents

Preface and Acknowledgments

Special thanks to Dr. Ruppert for all his work and dedication to this research and helping me all the way here. I would have never been able to do this without his knowledge and help. Thank you to all my professors, faculty, friends, and family for the unconditional support and the knowledge they have taught me. I'm grateful for them.

Abstract

Socioscientific Reasoning (SSR) is the reasoning practices that a person uses to make sense of and think of solutions for SocioScientific Issues (SSI). In 2016, Romine et al. designed a Quantitative Assessment of Socioscientific Reasoning (QuASSR) to assess and characterize SSR; however, characterization of the independent dimension of SSR was not achieved. Our study builds upon and improves QuaSSR by using a new model of epistemic cognition called the vAIR model, which is a community-oriented framework that accounts for limitations of the previous SSR model. The vAIR model of SSR is designed to more clearly distinguish the dimensions of SSR and their interactions in evaluating information in the context of how students reason through a complex issue regarding their school and their diet. The instrument's design consists of a survey-type assessment programmed to select personally meaningful context through a series of questions and then present the participant with an argument exchange scenario, embedded with elements of SSR, that asks them to evaluate and choose which side makes the best arguments based. The instrument records the participants' selections and helps observe epistemic cognition patterns that can help us understand how SSR takes place and how it is affected by epistemic dimensions.

Keywords: Socioscientific Issues, Socioscientific Reasoning, Epistemic Cognition.

Introduction

As society advances both scientifically and technologically, complex issues originate that require scientific knowledge and community knowledge to find possible resolutions as society and science interception (Roth and Lee, 2002; 2004). Societal issues that are ethically charged, deeply entangled with science, and have no clear solution are known as Socio-scientific Issues (SSI) (Sadler, 2004). To some extent, people experience SSI in their daily lives and, for some people, SSI may even have an emotional or moral value. It has been a goal for educators and researchers in the field of education to better prepare students to confront these issues and have a sense of their complexity and implications when experiencing them in real life. In recent years, the use of SSI has been adopted in science classrooms to teach students concepts of science while exploring societal issues in more engaging ways that involve the students inquiring about the issue, recognizing its complexity, analyzing available information, and negotiating possible resolutions for those issues. Such activities not only require knowledge of basic science concepts, but also active engagement in the construction and evaluation of knowledge for solving personal and community problems; this is also known as epistemic cognition. Epistemic cognition is also used in real-life experiences when dealing with issues where answers cannot be achieved to which decisions are tentative and can always be informed by more and more sophisticated understandings. Though SSI-based instruction has been thoroughly used to improve engagement of students to enhance the understanding of science concepts for students (Romine et al., 2016), it is also a belief that it can also be used to teach students skills that are essential for civic scientific literacy.

Understanding basic concepts of a science discipline and its applications has been part of the core definition of scientific literacy (SL) since the 1950's and though, definitions about scientific literacy have evolved over time, the emphasis on science for civic life has not been disputed. In 1958, John DeHart Hurd first used the term SL to refer to the understanding of science and its application to an individual's experience as a citizen (Hurd, 1958, Bybee 2015). Roberts (2007), refined this definition of SL and distinguished it into two perspectives, Vision I and Vision II SL. Vision I describes the domain of science and the way it derives from the study of a discipline from the understanding of what is science? How is it developed? And what constitutes good science? Vision I SL can be used to support familiarity with science concepts, the ability to evaluate information available, make decisions concerning controversial topics, and be able to engage in discussions regarding their concerns (Pouliot, 2008). SSI-based teaching was first established to advance engagement of Vision I.

Feinstein (2012) noted that SL is not only crucial for those interested in a career in science but it can also help solve personally meaningful problems in people's lives such as material and social circumstances, shape behaviour, and inform practical and political decisions. Vision II SL takes science out of its disciplinary domain and looks at how people derive science from everyday events (Roberts, 2007). Vision II SL, in this sense, does not limit science for only a group of individuals with scientific background from doing science, but extends its application for the use of everybody regardless of their education background. Roth & Lee (2002) portrayed science as "a resource that people can draw on in everyday collective decision-making processes." Achieving SL that satisfies both Visions requires alignment between the underlying goals of classrooms and the authentic civic life of learners and scaffolding a complex SL that can serve both future scientists and science outsiders. SSI research aims to support teaching that can advance such SL, looking into knowledge construction and analytic skills that emphasize a culturally/civically meaningful education where the application of science is more than simple answers.

Despite the fact that SSI-based instruction has been able to promote SL from Vision I perspective on specific topics such as genetics (Sadler, Romine, & Topçu, 2016; Venville & Dawson, 2010), ecology (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007), and ecology and chemistry (Klosterman & Sadler, 2010), there have been few studies that have looked into study how it can also improve Vision II SL. However, unlike Vision I SL, the nature of Vision II SL does not provide a ground for assessment of factual knowledge but more of assessment of cognitive capabilities. For the same reason, in order to characterize advancement in Vision II SL or the extent to which someone derives science from daily experiences, it was necessary to identify the dimensions of reasoning that people use to achieve epistemic (knowledge-related) goals on a daily basis. Romine et al. (2016) sought to construct an assessment capable of monitoring the advancement of learners' Vision II SL based on a model of SocioScientific Reasoning (SSR) developed by Sadler and Colleagues (2007). SSR describes the thinking practices that a person uses to: make sense of, consider solutions for, and work to resolve complex SSI. Romine and colleagues, instrument, ‘A Quantitative Assessment of SocioScientific Reasoning (QuASSR),’ was intended to analyze the students' improvement in each of four dimensions of SSR:

1) Complexity.

2) Perspective-taking.
3) Inquiry.
4) Skepticism.

Up to now, other researchers have debated and used a range of dimensions which are deemed to be integral in SSR, however, there's no general consensus about the ontological distinctions between them. Despite the fact that the assessment yielded results in support of small growth of SSR through SSI-based learning, the group found no ontological distinctions between the dimensions (Romine, et al., 2016). The issue with that is that there are still difficulties characterizing the dimensions of SSR, and thus, no yet effective way to observe what is helping or hindering the advancement of Vision II SL.

The primary purpose of this research is to build upon and improve the instrument "the *Quantitative Assessment of Socioscientific Reasoning* (QuASSR)," by Romine and group (2016), to be capable of characterizing the dimensional distinctions of SSR and the interactions between them by looking into how students deal with complex issues in the real world. Our tool is grounded in a new framework for SSR that is able to more clearly distinguish dimensions of reasoning and may, therefore, provide a clearer account of the complex set of components of students' reasoning and provide teachers with better information for targeted scaffolding. The framework, vAIR is described in more detail in the Theoretical Framework. Our new assessment of SSR addresses personal aims (accounting for biases and beliefs) addressing that in the real world people have biases that affect their reasoning practices, evaluation of information, and perspective taking framed by a constructive reasoning framework that derives from an important aspect of SSI which is the moral/ethical context. By putting these elements together and characterizing the dimensions of SSR, this research seeks to create an instrument for educational scaffolding for the advancement of Vision II SL.

Theoretical Framework

Experts in science education have long studied how people's biases affect their reasoning (e.g., Irwin, 1996; Feinstein, 2014; Bubela, 2009; Brownlee et al., 2011) pointing out that cognitive and epistemic resources are better demonstrated when people have authentic engagement with science (Feistein, 2014). It is, therefore, imperative that any assessment of Vision II SL reasonably have a personally meaningful connection that might affect an individual's reasoning practices during the analysis of complex issues. By presenting the students with a debated topic that is personal to them, this research expects students to engage in an authentic way.

As of today, there is much to be done to properly assess SSR growth. For instance, finding a construct that allows assessing the components of SSR that are ontologically distinct. To measure students' socioscientific reasoning (SSR), we use a framework grounded in Epistemic Cognition. Epistemic cognition is a term that concerns how people acquire, understand, justify, change and use knowledge in formal and informal contexts (Grene, Sandoval, & Braten, 2016; Feucht, Brownlee, & Schraw, 2017) and how people actually evaluate it and use it in order to achieve epistemic goals (Chinn et al., 2014). Our assessment tool does not specifically look into participants' awareness of dimensions of SSR of characteristics of SSI; rather, it uses a cognition model that affords identifying the status of ontologically separate components of reasoning students use to evaluate and derive conclusions for SSI.

Models of Epistemic Cognition

There are many epistemic cognition models that have been constructed over the years, from which there are three are the predominant ones: multidimensional, developmental and situational resources model (Green & Seong, 2014). Schommer (1990) first proposed the need for multidimensional models that characterized epistemic dimensions that are independent but related to each other. Initially these dimensions were composed of: fixed ability, quick learning, simple knowledge, certain knowledge, and source of knowledge. However, other researchers that also adopted multidimensional sought the need to refine the original model by eliminating the dimensions of fixed ability and quick learning because they extended beyond the scope of epistemic concerns (DeBacker et al., 2008; Muis et al., 2006). Other changes that have happened over the years is the characterization of simple knowledge and complex knowledge as parts of a broader dimension known as the Nature of Knowledge (NOS) (Hofer and Pintrich, 1997). Hofer and Pintrich suggested that the dimension of NOS is the view of knowledge can be simple and complex. Simple refers to thinking that facts are not related to one another, on the other hand, complex refers to realization that facts are highly connected to one another. This aligns with the original views of simple knowledge referring to the view of knowledge as discrete and unrelated facts, and complex knowledge referring to evolving highly connected facts (Greene and Yu, 2014).

Developmental models originate from the work of Perry (1958/1969), who studied ethical and intellectual development of Havard college students through interviews with them. From his work, he proposed that progress happens in a continuum of positions and hierarchical stages that he called dualism, multiplism, relativism, and commitment to relativism. Many other researchers adopted the same concept of hierarchical developments and models that resemble Perry's in nature but using different frameworks (e.g. Baxter, 1992; Belenky et al., 1986; King & Kitchener; Kunh, Cheney & Winston, 2000). Developmental models of epistemic cognition, among other things, suggest that knowledge becomes increasingly contextualized (from a solely objective understanding of knowledge, to subjective, to then a coordination of both understandings of knowledge, with progress along the developmental continuum (Khun, Chiney, & Weinstock, 2000; Greene and Yu, 2014). Going back to the context of SSI, the QuASSR, by Romine and group, identified a similar hierarchical growth in students. It's worth noting that the SSR construct used in the QuASSR study still posed many questions such as how are dimensions characterized? Specifically they found that the scenario/context presented to the students had little influence on the results that four dimensions of their model (i.e. complexity, perspective taking, inquiry, and skepticism) have unidimensional development. They suggested that complexity might be a good starting point for developing SSR because of how easy it was for students to identify the complexities of the issues. However, different views of complexity might be problematic when utilizing a developmental model of epistemic cognition. For instance, in the context of SSR models, there's a range of epistemic factors that may influence how one reasons about SSI. Sadler, Barab, and Scott (2007) included the epistemic beliefs that SSI are both complex and subjects of ongoing inquiry. However, according to Hofer and Pintrich (1997) there are versions of complexity; one version of complexity can catapult one to further inquiry by showing the person the limitedness of knowledge, and, in some other context, it can hinder inquiry as it is in the case of the heuristic 'everything is complex,' thus why should it matter if everything is complex? This research argues that these different views of complexity may be important to parse out in order to create an effective instrument. Particularly considering how other researchers have seen the importance of framing issues (Chinn, Rinehart, Buckland, 2014; Berland et al., 2016). Therefore, a new model needs to be implemented if there is to be distinctions between contexts.

Lastly, in situated resource models of epistemic cognition, “learner’s epistemologies are actually fine-grained cognitive resources that exist at a level of specificity beyond that of beliefs or theories” (Hammer and Elby, 2002; 2003). Situated resource models account for changes in epistemic behaviour based upon context. In some contexts, a particular set of cognitive resources may be used more over others, whereas in a different situation a very different set could be activated to influence learning. For instance, someone trying to learn about diet might look into health-related research to understand diets; their learning process is driven by a goal of understanding about diet. In a different context, the same person likes fast food and avoids reading about the health risks of eating fast food. In this case, her alterior aim affects her epistemic aim which is learning. Chinn et al., (2014) developed a situated resource model that we suggest integrates SSR dimensions with alternative aims and beliefs calling it the AIR model of epistemic cognition. AIR stands for: *Aims, Ideals,* and *Reliable Processes*.

The AIR model posits that there are different *aims*, either epistemic or non-epistemic, that can interact with one another and either boost or inhibit each other based on the value that a person has given to each specific aim. Epistemic aims are goals related towards knowledge such as understanding, argument, explanation, scenarios, etc. Non-epistemic aims relate to goals that are not knowledge-related such as: diet, health, economics, personal care, etc. More interestingly, the interaction between these aims changes upon context just like the previous example of the person interested in learning about diet in which her epistemic aim for understanding was inhibited by their non-epistemic aim for 'fast food.' In contrast, if the person cared about the environment (non-epistemic aim of care for the environment), and they read a lot of how diet can help the environment, their non-epistemic aim would bootstrap their epistemic aim.

The second component of the model consists of epistemic *ideals*, "which are the standards that a person uses to evaluate whether epistemic ends have been achieved." For example: If someone were to look into health research and stumble upon a paper that tried a new treatment that showed promising results for a disease but the treatment was too simple. If then, this person is asked if they believe the results are good, they would most likely choose not to believe that they're good because of the simplicity and would look for other variables. Alternatively, when encountering information related to agricultural research and if the design of the paper is simple, and they accept it thinking that agricultural research does not need to be as complex as health research, then they would be using two standards or epistemic ideals to evaluate information based upon their non-epistemic aims. In this sense, epistemic ideals emerge in situations based on interactions with one's aims. These hypothetical examples highlight how non-epistemic aim health biases, like other non-epistemic aims (e.g., cleanliness, space, personal gain, pain avoidance, agriculture, etc.) likely influence epistemic aims and ideals about the appropriateness complexity, source, justification of knowledge (Chinn, et al., 2014).

The third component of the AIR model consists of *reliable processes* used to achieve epistemic aims meeting one's ideals. However, this research ran into a minor issue with the naming scheme of this component, as the word 'reliable' can be confused as an epistemic ideal for reliability. Thus, through communication with the authors of the AIR model, it was agreed that calling these processes ‘reliable’ can lead to some issues when defining ontological distinctions between epistemic processes and epistemic ideals; therefore, in this research they’re going to be referred to as *reasoning practices*. Interestingly, other researchers (Bryce and Whitebread, 2012; Perry, 1970/1999; Barzalai and Zohar, 2016) have studied and observed a pattern of reasoning practices which they have called “the most critical point of intellectual development in which students learn how to think further, how to think about thinking.” Examples of these practices include: individuals that may stop to question or identify their own epistemic/non-epistemic aims, and problematize their own reasoning in order to evaluate fairness and/or consideration of others. These practices are said to be Meta- level practices. Based on available literature, this research accounts for these events as part of the constructive-oriented cognitive practice and defines them as *Meta-Epistemic Processes* (MERPs) which are monitoring processes that regulate and support consistent and sophisticated, epistemic cognition.

The AIR model’s framework might be capable of looking into the SSR’s individual components in regards to specific context and be able to characterize them. However, in the context of Vision II SL and SSR, SSI are not isolated issues that require the knowledge of one individual to find resolution, rather, they are complex issues that affect communities and society and encompass a wide variety of multiple perspectives. Since SSI are fundamentally societal issues, communities and society are to be considered a valuable source of information when reasoning to find solutions. Roth and Lee (2002), noted that science is not only a product of individuals but also of communities. They noted that “collectively (as a community), much more advanced forms of scientific literacy are produced than any individual (including scientists)”. Therefore, this research establishes the importance that in an assessment of SSR, community and multiple perspective awareness and concern should be reflected in constructive reasoning through the interactions of the dimensions of SSR. By applying a pluralistic framework to the AIR model to allow the instrument to capture constructivism at the community level while also looking into the individual components of SSR through the dimensions of the AIR model of SSR, this framework for SSR combines both ontic resolution between its dimensions and various perspectives of ethical reasoning. This SSR framework is called the *vAIR SSR Framework,* which stands for *virtuous Aims, Ideals, and Reasoning Practices.* The foundation of its features lay on literature showing that constructive SSR and Vision II SL take place in the civic world where knowledge is not just a property of a community of praxis.

Research Questions

(1) Can SSR be characterized reliably and validly through the vAIR SSR framework?

(2) Can constructivism and SSR growth be captured through the dimensions of SSR?

(3) What role does each dimension play in SSR and how can they hinder and/or enhance Vision II SL?

(4) How can this assessment be adapted to be used as a tool for educational scaffolding in a classroom setting?

Methods

The structure of this refined QuASSR starts with a small narrative of a school scenario in which the school changes the dining services to only offer vegetarian options for students. This research utilizes an emotionally relevant context by presenting participants with a scenario that contains familiar and valuable elements for students such as food, school, and freedom of choice. Additionally, the study design incorporates concepts that most science and non-science students have heard at some point in class, TV, or even social media such as diet, health, economy, and ecologic issues. The instrument is designed as a survey for online administration which allows for later adaptation for different contexts. The software for the distribution of the survey is Qualtrics? which adds versatility and greater deployment capabilities. Primarily, this survey is expected to be rolled out for the students from Saint Peter's University but as stated before, the survey can be adapted to different contexts thus expanding its capabilities to be used in different settings. Additionally, the instrument's design is systematic in structure for standardization.

First, the participants are presented with a series of questions. The first question corresponds to their level of agreement, using a 5-point Likert scale of agreement, on the scenario proposal for a totally vegetarian menu for the school (1= Dislike entirely; 5= Love the idea!). This was done to avoid dichotomous choices (like/dislike). The first question aims to help conceptualize their beliefs around the proposal and have a rough idea about their aims.

An additional item asks the students to select multiple options to answer the question: what do you think other people might think about this proposal? This question is constructed with the purpose of characterizing the participant's awareness of multiple perspectives as well as their own aims. The students are presented with multiple options they can select from, for example:

- I think most people would easily see this is a good idea.
- I think most people would find it a bad idea and not be easily convinced.
- I think most people would find it a bad idea but be open about it.
- I think there will be a mix of opinions.

- I think most people would find it a bad idea but after being told the facts would see it's the right thing.

A third item is set in place to gather context about the participant. The item asks the participants about their current eating habits. This item is used as a checkmark to assess if their non-epistemic aim for or against the vegetarian menu proposal fits their current experiences or habits. Having framed that, the instrument asks them to select, from multiple perspectives, reasons that they think people might legitimately have for being in support of, or against, the proposal. The instrument provides participants with two perspectives for each reason (against/support of), each of them framed after a specific non-epistemic aim such as:

1) Health

2) More food options

3) The environment

4) Farmers

5) Economics

6) Animal rights

7) Culture/tradition

The purpose of this item is to assess whether the participant's reasons to believe that other people might support or be against a particular aim is the same as their own reasons to support or be against such aim. The item is framed to capture the participant's non-epistemic *aims* and whether it relates to the participant's exploration of others' aims. Additionally, it conceptualizes their awareness of the existence of other's non-epistemic aims and assesses their knowledge of the aim through a modified 6-point Linkert scale (I'm certain some people believe this, me included; I'm certain some people believe this, NOT me; Some might believe this; I'm not really sure; I doubt many believe this; I don't see how could someone believe this).

Consequently, a second tier item asks the participants to rank the *aims* they selected from the previous item in order from most important to less important. This allows the instrument to assess authenticity by singling out their most personally important non-epistemic aim.

Upon recognizing the most important non-epistemic aim of the participant, the instrument proceeds to present the participants with a 5-tier series of arguments, written in the format of a conversation, that support or counter their non-epistemic aim. Additionally, each argument in support of the participant's aim is countered by another argument written in the same conversational format but from a different perspective or aim. For each tier, the participants are asked to select "which of the two argument do you like better?" For instance, if the participant chooses that *health* is their most important non-epistemic aim and are in support of the proposal, the instrument presents them with an argument that follows:

> *I really think this is a great idea. Meat consumption is pretty bad for people's health. It's linked to cancer, heart disease, and a bunch of other issues, so it's probably best to just help everyone eat healthier to focus on a vegetarian diet.*

At the same time, the instrument presents them a counter argument against the proposal but from the perspective of someone with the non-epistemic *aim* for *economics,* for example.

> *I see where you're coming from, it might be healthier for people to not eat meat, but the meat industry is a huge part of our country's and global economics. Now, SPU (Saint Peter's University) isn't really like that important overall, but when*

thinking about this, are we setting a precedent that might get picked up elsewhere and spread? I'd be cautious about who we're harming by doing this.

Each argument from the same tier is constructed using the components of the vAIR model of SSR, and they are characterized to have different epistemic ideals or epistemic *reasoning practices*. As for the first examples, the first argument in support of the proposal is rooted in the non-epistemic *aim* of "health" and epistemic *ideals* such as: "simplicity, attends the thing I care about (health), it's something I have heard before, fits personal experience, relies on simple facts." In contrast, the counter argument is rooted in the *aim* of *economics* and ideals of: "integrating different ideas together, scale of things, personal concern, etc.." As stated before, *ideals* are standards that people use to evaluate information. This item seeks to present the student with an epistemic dilemma that exposes their non-epistemic aims to different ones that can also make a case for themselves. The objective is to determine whether, at least in this context, the participants have a preference for non-epistemic aims or a specific set of ideals that may enhance or hinder SSR.

A second item is presented after the participants choose the argument they like the most and asks them about which thoughts did they have in their mind when choosing the argument they liked the best. This item, additionally, presents a list of the epistemic *ideals* used to construct both arguments. Participants are able to choose using a non hierarchical 6-point Linkert scale (0= I wasn't actually thinking about that. It doesn't seem necessary; 5= Was part of my decision-making) the qualities they liked about their chosen argument (i.e. “I was thinking about how the arguments attended the things I care about, I liked its simplicity, I like it because it uses key facts that are proven right, etc.).

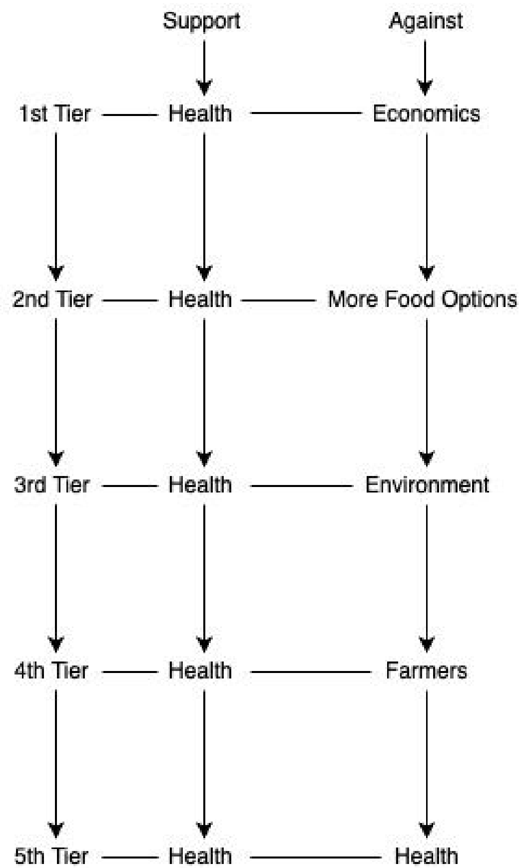

Figure 1. Structure of argument flow for a participant in support of the proposal for the non-epistemic aim of “health.”

The instrument is systematic in structure as each argument in support or against the proposal corresponding to the same tier of arguments, regardless of the non-epistemic *aim,* possesses the same set of ideals (i.e. if Tier 1-argument for “health” has simplicity as one of its epistemic ideal, Tier 1-argument for “food options” has simplicity as an epistemic ideal). Additionally, the instrument is structured to follow a pattern of constructiveness in the arguments used to counter the participant’s non-epistemic aim.

For instance, in Figure 1, the arguments against the proposal, when going down the list of tiers, incorporate new perspectives and MERPs such as the "incorporation of science and other disciplines to get a more holistic picture of the issue; the argument was not just an argument but also seemed like they were trying to understand different perspectives, etc." whereas the arguments from the health perspective grow in strength, however, they do so to win the argument, do not explore perspectives, and put science as the only way to find a solution for the issue. For instance, a 5-tier arguments for and against the proposal from the perspective of health:

For proposal, "HEALTH:" Yeah but there you go again, making things more complicated than they need to be. I don't mean to be offensive, so sorry about that, but farmers will adapt. We gotta keep our eye on the big picture. Fundamentally, meat is considered bad for our health, and so many studies have supported this. It's also a major contributor to climate change so our environmental health, so like, while these details might all be 'interesting', we can't deliberate forever.

Against Proposal, "HEALTH:" Well, I think making it too simple is just really problematic. I mean we haven't even talked about the potential negative consequences for health. First off there are several nutrients in meats that are not available in fruits and vegetables, so unless they are supplemented, students can suffer from nutritional deficits. Also, some students might have sensitivities to certain food groups. Like me, I'm sensitive to legumes, which is an important staple in vegetarian diets, so it's pretty hard to be fully vegetarian. Now if students can't get their basic nutrition because of mandated restrictions placed on them by the school, might that open the school up to *liability? Like what seriously would be the policy ramifications of this type of rule? Do we start to offer exceptions, but then it becomes an issue where some students would feel unfairly treated. I just really think there's so much more to consider about how this type of rule would play and being fair in our complexity is really, really important to making informed decisions.*

The instrument, by having the participants choose between an argument set per tier, assessed if:

1) The participant prefers his/her non-epistemic *aim* over other aims.
2) The participant prefers a specific or set of ideals over others.
3) The participant seems to put science as the only source of knowledge and solutions.
4) The participant prefers a set of epistemic practices either rhetoric practices over virtuous (community-oriented) reasoning practices or vice-versa.

By studying the interactions of the dimensions of SSR characterized by the vAIR model, this research intends to map the interaction and the way each dimension is used to reach an epistemic goal.

Discussion

At the time this paper was written, the instrument was not rolled out for testing. Testing is necessary to establish validity of the instrument's hypotheses. Changes might be made accordingly after testing. Though the instrument is a Refined version of Romine's and group "Quantitative Assessment of Socioscientific Reasoning," the instrument is not meant to measure SSR quantitatively. Instead, it takes on the limitations of Romine's and group QuASSR to assess the utilization of the dimensions of SSR under a framework of constructive reasoning, which involves working towards a solution that takes into account multiple perspectives and knowledge about science and other disciplines. This is fundamental for studying the advancement of Vision II SL. This research hopes to create a model that can help instructors make adjustments in SSI-instruction to address individual features of SSR according to what the students need the most. However, testing and mathematical analysis must be done before releasing any results.

References

Barab, S. A., Sadler, T. D., Heiselt, C., Hickey, D. T., & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology*, 16, 59–82.

Barzilai, S., & Zohar, A. (2016). Epistemic (meta) cognition: Ways of thinking about knowledge and knowing. *Handbook of epistemic cognition*, 409-424.

Baxter Magolda, M. B. (1992). Knowing and reasoning in college: Gender-related patterns in students' intellectual development. San Francisco: Jossey-Bass.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). Women's ways of knowing. New York: Basic Books.

Berland, L. K., Schwarz, C. V., Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2015). Epistemologies in practice: Making scientific practices meaningful for students. *Journal of Research in Science Teaching*, 53(7), 1082–1112.

Brownlee, J., Schraw, G., & Berthelsen, D. (2011). Personal epistemology and teacher education: An emerging field of research. *Personal Epistemology and Teacher Education:*, 3-21.

Bryce, D. & Whitebread, D. (2012). The development of metacognitive skills: Evidence From Observational Analysis of Young Children's Behaviour During Problem-Solving. *Metacognition and Learning,* 7 (3), 197-217.

Bubela, T., Nisbet, M. C., Borchelt, R., Brunger, F., Critchley, C., Einsiedel, E., ... & Jandciu, E. W. (2009). Science communication reconsidered. *Nature biotechnology*, *27*(6), 514-518.

Bybee, R. (2015). Scientific literacy. *Encyclopedia of science education*, 944-947.

Chinn, C. A., Rinehart, R. W., & Buckland, L. A. (2014). Epistemic cognition and evaluating information: Applying the AIR model of epistemic cognition. *Processing inaccurate information: Theoretical and applied perspectives from cognitive science and the educational sciences*, 425-453.

DeBacker, T. K., Crowson, H. M., Beesley, A. D., Thoma, S. J., & Hestevold, N. L. (2008). The challenge of measuring epistemic beliefs: An analysis of three self-report instruments. *The Journal of Experimental Education,* 76(3), 281–312.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Sci. Educ*. 84(3), 287–312.

Feinstein, N. W. (2014). Making sense of autism: Progressive engagement with science among parents of young, recently diagnosed autistic children. *Public Understanding of Science*, *23*(5), 592-609.

Feinstein, Noah. "Salvaging science literacy." *Science education* 95, no. 1 (2012): 168-185.

Feinstein, N. W., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. *Science*, *340*(6130), 314-317.

Greene, J. A., & Seung, B. Y. (2014). Modeling and measuring epistemic cognition: A qualitative re-investigation. *Contemporary Educational Psychology*, *39*(1), 12-28.

Greene, J., Sandoval, W., & Braten, I. (2016). An introduction to epistemic cognition. In J. A. Greene, W. A. Sandoval, & I. Braten (Eds.), *Hand-book of epistemic cognition* . New York, NY: Routledge. 1-16.

Hofer, B. K., & Pintrich, P. R. (1997). The Development of Epistemological Theories: Beliefs About Knowledge and Knowing and Their Relation to Learning. *Review of Educational Research*, 67, 88–140.

Hurd, P. D. (1958). Science literacy: Its meaning for American schools. *Educational leadership*, *16*(1), 13-16.

Klosterman, M. L., & Sadler, T. D. (2010). Multi-Level assessment of scientific content knowledge gains associated with socioscientific issues-based instruction. *International Journal of Science Education,* 32(8), 1017–1043.

Krist, C., Schwarz, C. V., & Reiser, B. J. (2018). Identifying Essential Epistemic Heuristics for Guiding Mechanistic Reasoning in Science Learning. *Journal of the Learning Sciences*, *28*(2), 160–205.

Muis, K. R., Bendixen, L. D., & Haerle, F. C. (2006). Domain-generality and domain- specificity in personal epistemology research: Philosophical and empirical reflections in the development of a theoretical framework. *Educational Psychology Review*, 18, 3–54.

Pouliot, C. (2008). Students' inventory of social actors concerned by the controversy surrounding cellular telephones: A case study. *Science Education*, *92*(3), 543-559.

Perry, W. G., Jr. (1968/1999). Forms of ethical and intellectual development in the college years: A scheme. New York: Holt, Rinehart and Winston.

Perry Jr, W. G. (1970/1999). Forms of Intellectual and Ethical Development in the College Years: A Scheme. Jossey-Bass Higher and Adult Education Series. *Jossey-Bass Publishers*, 350 Sansome St., San Francisco, CA 94104.)

Roberts, D. A. (2007). Scientific Literacy/Science Literacy in Handbook of Research on Science Education (eds. Abell, S. & Lederman, NG) 729-780.

Roth, W. M., & Lee, S. (2004). Science education as/for participation in the community. *Science education*, *88*(2), 263-291.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *41*(5), 513-536.

Sadler, T.D., Barab, S., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education*, 37(4), 371-391.

Sadler, T. D., Romine, W. L., & Topçu, M. S. (2016). Learning science content through socio-scientific issues-based instruction: a multi-level assessment study. *International Journal of Science Education*, 38(10), 1622–1635.

Schommer, M., & Walker, K. (1995). Are epistemological beliefs similar across domains? *Journal of Educational Psychology*, 87, 424–432.

Roth, W.-M., & Lee, S. (2002). Scientific literacy as collective praxis. *Public Understanding of Science*, *11*(1), 33–56.

Romine, W. L., Sadler, T. D., & Kinslow, A. T. (2017). Assessment of scientific literacy: Development and validation of the Quantitative Assessment of Socio‐Scientific Reasoning (QuASSR). *Journal of Research in Science Teaching*, *54*(2), 274-295.

Venville, G. J., & Dawson, V. M. (2010). The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science. *Journal of Research in Science Teaching*, 47(8), 952–977