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A Comparative Study of the Role of Values in Reasoning about Socio-Hydrological Issues in Undergraduate Students from Developed and Developing Countries

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A COMPARATIVE STUDY OF THE ROLE OF VALUES IN REASONING ABOUT SOCIO-HYDROLOGICAL ISSUES IN UNDERGRADUATE STUDENTS FROM DEVELOPED AND DEVELOPNG COUNTRIES

By

Destini N. Petitt

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A COMPARATIVE STUDY OF THE ROLE OF VALUES IN REASONING ABOUT SOCIO-HYDROLOGICAL ISSUES IN UNDERGRADUATE STUDENTS FROM DEVELOPED AND DEVELOPNG COUNTRIES

Destini N. Petitt, M.S.

University of Nebraska, 2018

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In a world that is becoming increasingly connected and exploited, it is essential to understand how students' values influence socio-scientific reasoning, particularly when dealing with complex, multifaceted, ever-connected water-related issues. This research strives to better understand stakeholder reasoning to provide teachers and decision-makers with ways to implement those stakeholders' ideals into choices about complex socio-hydrological issues. Moreover, with 96% of research behavioral research being conducted on peoples from developed countries – who only represent 17% of the world's population – this study strives to understand how peoples from developing countries – who represent 83% of the world's population – reason. For this study, I asked questions focusing on the values undergraduate students from developed and developing countries identify with, how those values are used in socio-hydrological reasoning, and if the quality of reasoning differs between the two groups. Results show a significant difference between the two groups' value identification, as well as the use of those values in their socio-hydrological reasoning. Additionally there was a statically significant difference in the overall quality of reasoning between the two groups. This study begins to shed light on how students use their values in reasoning about socio-hydrological issues.

Dedications

I would like to dedicate this thesis to my amazing parents, Roy and Sheila Petitt, who have sacrificed and worked extremely hard their entire lives to afford me the opportunity to pursue my dreams.
To my husband, Nick Stow, who has always believed in me even when I did not believe in myself.
And in memory of my brother, Toby Petitt, who is missed every day.

“If there is magic on this planet, it is contained in water.” – Loren Eiseley

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Multimedia Objects

Chapter 1 Introduction

Earth has been called the Blue Planet due to the abundance of water on its surface. In fact, roughly 71% of the surface of Earth is water-covered. However, 97% of water on Earth is unusable, having too high saline concentrations for consumption, and of the 3% that is usable, roughly 2% is locked up in glaciers or as groundwater while less than 1% is easily accessible freshwater from sources such as rivers and lakes. According to the Food and Agriculture Organization (2015), demand for water is predicted to increase as irrigated areas expand, thus causing competition for water resources to increase. Furthermore, with water being ubiquitous – cutting across national, cultural, and religious boundaries – and providing jobs that directly employ half the global workforce (WWAP, 2016), it is important to understand how global stakeholders reason about ever-increasing socio-hydrological issues.

As such, it is critically important that all global citizens be prepared to reason and make decisions about socio-hydrological issues. According to the Theory of Planned Behavior (TPB) (Lam, 1999), many factors (i.e. values and culture) influence an individuals' beliefs which lead to a behavior toward socio-hydrological issues (SHIs). Each stakeholder involved in a SHI may perform a different end behavior than other stakeholders based on several background factors and beliefs. Furthermore, although researchers and conservationists have tried to develop plans for the benefit of stakeholders' natural resources, these plans have not always been accepted for various reasons such as financial concerns, lack of stakeholder participation, and fear of losing control (Schuett, Seli, & Carr, 2001). Coincidentally, research suggests that including multiple stakeholders in natural resource management can be extremely beneficial (Schuett et al., 2001). Therefore, being able to create and implement natural resource management plans that reflect stakeholders' priorities and values increases the likelihood of those plans succeeding; furthermore, it is also imperative to provide stakeholders with information about the issue in a way that they can easily understand and evaluate with their current knowledge (Wilson & Arvai, 2006).

According to Wilson and Arvai (2006), accounting for the values of stakeholders in natural resource management reduces the number of tradeoffs that occur due to all stakeholders having a say in the issue's resolution. Combining the input of stakeholders with the facts and knowledge of science allows for a more robust environmental choice (Gregory, 2000). However, most behavioral research conducted is done so on people from developed countries (Henrich, Heine, & Norenzayan, 2010), whereas the majority of people on Earth reside in developing countries (UN, 2015). Additionally, as populations in developing countries continue to grow at a faster rate than those in developed countries, the natural resources in those countries are becoming ever more strained, thus it is increasingly important to study how these peoples view, value, and reason about SHIs. Moreover, these goals are also emphasized and tied directly with the UN's 2030 goals (UN, 2015a), some of which include, "end[ing] poverty in all its forms, promot[ing] sustainable agriculture, ensur[ing] availability and sustainable management of water and sanitation for all, and mak[ing] human settlements sustainable".

To help future citizens, policy-makers, and professionals develop the ability to reason about SHIs, these skills must be cultivated in formal classroom settings. There have been significant efforts to innovate educational experiences for students about water, particularly at the undergraduate level (Halverson, Siegel, & Freyermuth 2009; Sadler & Zeidler, 2005). Research has shown that with gaps in students' hydrological knowledge, it is essential for innovative water education efforts to transcend traditional educational approaches in order to provide students with an education that affords them the opportunity to be better prepared for real-world, transdisciplinary experiences. However, little is known about how students, from both developed and developing countries, use their values in reasoning about real-world hydrological issues. Therefore, this research strives to better understand stakeholder reasoning in students from both developed and developing countries to provide teachers and decision-makers with information to better implement those stakeholders' ideals into choices about complex SHIs. With a focus on current undergraduate students, this study builds upon a broader effort to reform undergraduate Science, Technology, Engineering, and Mathematics (STEM) education (NRC, 2012) and, specifically, a body of work to support effective interdisciplinary undergraduate education about water (Noll, 2003; Sabel et al., 2017; Smith, Edwards, & Raschke, 2006; Willerment, Mueller, Juris, Drake, Upadhaya,, & Chhetri, 2013).

Key Terms

These terms and definitions are important to understand the array of ideas and concepts being expressed throughout this paper. Key terms that will be used in the study include the following:

- W.E.I.R.D. is an acronym used to differentiate Western, Educated, Industrialized, Rich, and Democratic nations (also referred to as developed countries) from all other countries (i.e. non-W.E.I.R.D. countries or countries which, for the purposes of this study, are not developed) (Henrich et al., 2010).
- Developing countries term is synonymous with non-W.E.I.R.D. countries and encompasses those countries that were listed as developing by the United Nations (2015b).
- Developed countries term is synonymous with W.E.I.R.D. countries and encompasses those countries that were listed as developed by the United Nations (2015b)
- Stakeholders are defined as anyone who is involved in any way in the matter of interest.
- Socio-scientific issues (SSIs) are defined as complex scientific issues that have a large anthropogenic component in which multiple stakeholders are present.
- Socio-hydrological issues (SHIs) are defined as complex water-related scientific issues that have a large anthropogenic component in which multiple stakeholders are present.
- Values, for the purposes of this research, are defined as the importance, worth, or usefulness something has that is not monetary. That is, the perceived non-monetary worth of something to the stakeholder. In other words, values are what is important to the stakeholder (Schwartz, 2012).

- Reasoning, for the purpose of this research, is defined as any idea, motive, purpose, or concept presented by stakeholders that helped lead them to a decision. Additionally, arguments consist of various reasoning, while reasoning functions as a support to, or the steps forming, argumentation (Hugo, 2011).

Chapter 2 Literature Review

Scientific Literacy about Water Systems

Currently, there is no ecosystem on Earth that has not been impacted by humans (King, O'Donnell, & Caylor, 2012). As the world's population is forecasted to reach 9.8 billion by 2050 (UN, 2017), now is an extremely critical time to consider how a rapidly expanding population will continue to strain ecosystems (Rockstrom et al., 2009). Science literacy is ever important in a world that is increasingly connected and becoming metaphorically smaller. Although there are many definitions, science literacy has been loosely defined as what everyone should know about science, including an appreciation of nature, understanding of important ideas, and the general limitations of science (Surpless, Bushey, & Halx, 2014). However, science literacy is more than this in that it aims to move people past basic understanding of core scientific concepts to a more robust level. In many perspectives on scientific literacy, a parallel core element involves students using this knowledge of natural phenomena in conjunction with knowledge of political, economic, and cultural dimensions of real-world issues, to reason effectively and engage in decision-making within the bounds of their day-to-day lives. Fundamentally, science literacy has the goal of producing scientifically conscious people who are committed to using science for the betterment of global society (Anderson et al., 2007).

A vital part included in this betterment of society is water literacy. Moreover, science literacy is more than just content knowledge. It is the ability of a person to be able to "describe, explain, and predict natural phenomena… identify scientific issues…

evaluate the quality of scientific information… [and] pose and evaluate arguments based on evidence" (NRC, 1998, p. 22). Furthermore, King and colleagues' (2012) show that water literacy is more than just the understanding of core concepts. King et al., (Figure 2:1, 2012), illustrates the importance of not only understanding core concepts, but also understanding the context-dependent variables associated with water-related issues. These context-dependent variables encompass the various political, cultural, and economic dimensions associated with these issues. Therefore, in order to be water literate, a person must obtain not only a basic understanding of core hydrological concepts, but they must also understand the various human dimensions of these issues.

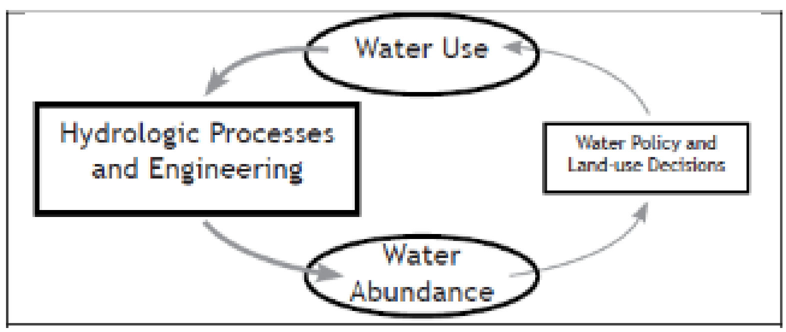

Figure 2:1 A Wide Dynamic View (King et al., 2012)

Science Literacy and Knowledge of Science

In an aim to equip students to reason effectively about SSIs, science educators should strive to afford students opportunities to understand core science ideas surrounding SSIs while allowing the student to reason through the issues in ways uniquely their own. That is to say, students should be guided through scientific knowledge in a way that allows them to see beyond their own interpretations and novice conceptions to scientifically accepted explanations for the natural world (Cardak, 2009). Knowledge of science is a key component of scientific literacy. In order to become scientifically literate, people must obtain a level of scientific competency that will afford them the ability to knowledgably approach and make decisions about these important issues.

The basis of scientific competency is an understanding of scientific concepts. However, research on students' conceptions and learning of science in a variety of disciplinary domains continues to document gaps between students' thinking and scientifically accepted explanations for natural phenomena. Students' misconceptions about the natural world may stem from their own reasoning, improper education, misunderstanding of taught or read materials, and misunderstanding of the scientific process – all of which present significant obstacles to development of scientific literacy (Cardak, 2009; Surpless et al., 2014). These misconceptions start at early ages and if not confronted early and often, they become difficult to overcome (Cardak, 2009). The Next Generation Science Standards (NGSS Lead States, 2013) and other K-12 STEM education standards firmly emphasize the core content students should learn, as well as the important role of scientific practices and student-centered curriculum and instruction in supporting science learning. However, even at the undergraduate level, students may hold many scientifically inaccurate ideas about natural phenomena. This, in part, provides a rationale for the more recent emphasis on effective undergraduate STEM education (National Research Council, 2012) and growing discourse around STEM education reform at the undergraduate level.

As a component of science literacy, water literacy involves the ability to explain, identify, and evaluate issues in which there is a water component. While science literacy encompasses the overarching ideas of science, such as the ability to read and understand general scientific content, water literacy relies on a more specialized understanding of hydrological concepts. That is not to say that in order to become water literate a person must be an expert in the field. However, it is to say that in order to be water literate, an individual must possess a working understanding of hydrological concepts and how those concepts are interrelated. These concepts include understanding phase changes of water, the connections formed by the water cycle, the movement of water, water use and quality, the policies governing water, and hydrological processes (Ewing & Mills, 1994; King et al., 2012; Figure 2:1).

Science Literacy and Values

Scientific literacy, including water literacy, involves more than mere mastery of disciplinary concepts. However, the purpose of scientific literacy is to enable individuals to use science to address problems and challenges they encounter in everyday life. To do that, they must employ their understanding of science alongside other individual commitments, including their values. Lederman (2007) explains that the nature of science is subjective, involves human inferences, and is socially and culturally embedded. That is to say, a person's background and the interactions that she has been involved in, influences how she views science. However, it has been shown that active, hands-on learning can greatly influence students' science literacy (Ryder, Leach, & Driver, 1999; Surpless et al., 2014) without forcing an abandoning of personal backgrounds and values. That is, educators can use SSIs for instruction and help students express their values while also being environmentally conscious. This should be a goal of educators for when personal values are used in the resolution of SSIs, those resolutions have fewer tradeoffs (Wilson & Arvai, 2006) which may lead to an increased probability of success. Citizens should also be emotionally and behaviorally engaged; that is, citizens should have care and concern for water and also adapt their behaviors to become more water conscious (Dean, Fielding, & Newton, 2016). Moreover, while knowledge is an essential aspect of behavior, it can be a weak predictor of behavior and reasoning. However, attitudes and intentions work to strengthen the link between knowledge and values, and thus the behavior and reasoning.

Fostering Water Literacy in Undergraduate Education

There are many ways to increase scientific literacy, such as improving students' technical knowledge, teaching problem solving, and critical analysis skills – most of which can be achieved through SSIs (Arvai et al., 2004). One context in which to cultivate scientific literacy is undergraduate education at postsecondary institutions of higher education. In order to provide scientifically-literate citizens, past research has focused on teaching students to make decisions informed by scientific information, better understanding the science behind those decisions, helping students make connections across disciplines, and reframing water science to include human components – just to name a few (Arvai et al., 2004; Bell & Lederman, 2003; Eisen, Hall, Lee & Zupko, 2009; King et al., 2012). Taken as a whole, prior research provides important insight into how students learn about science as well as providing ideas on how to increase students' conceptual understanding of science in general. This study aims to build upon these past topics by including another facet of increasing student science literacy – exploring the role that personal values play in student scientific reasoning – with the hopes of: 1) illuminating if values influence reasoning and 2) how to incorporate those values into undergraduate science education.

The various facets of water and the many input and output variables (i.e. precipitation and runoff) make water literacy a difficult goal for many learners across the K-16 spectrum and into adulthood (Ewing & Mills, 1994; Williams, Lansey, & Washburne, 2009). According to Ewing et al. (1994), roughly one third of students along the K-16 continuum have very rudimentary knowledge of water. Cardak (2009) further explains that even high school students lack efficient mental models needed to understand water processes causing misconceptions that are still prevalent in undergraduate students. In other words, these students have only basic knowledge of water and are unable to delve into the deeper connections of the water cycle to Earth processes. To best understand those connections, all the variables involved must be identified and understood (King et al., 2012; Pathirana, Koster, Jong, & Uhlenbrook, 2012). Therefore, it is essential to produce water literate citizens that understand the importance of water and its interconnectedness to all aspects of life. Some effective ways of engaging students in water science while increasing their understanding of the interconnectedness of water and Earth processes, and thus their science literacy, are through nurturing interdisciplinary thinking (Eisen et al., 2009), exposure to college level science courses (Surpless et al., 2014), and through the use of SHIs (Sivapalan, Savenije, and Blöschl, 2012; Sivapalan, Konar, Srinivasan, Chhatre, Wutich, Scott, Wescoat, & Rodríguez-Iturbe, 2014).

Before engaging students in SHIs it is essential that educators familiarize themselves with their students. Understanding the student body will provide the educator with information needed to create SHIs which will engage the students and hold their attention; that is, SSIs should involve topics that students care about (King et al., 2012). Additionally, educators should encourage the expression of personal values in reasoning about SHIs – again, this is to ensure that students are coming to conclusions that have fewer tradeoffs (Wilson & Arvai, 2006) which, in turn, may lead to an increased probability of success. Examples of SHIs include but are not limited to irrigation for agriculture, hydroelectric power use, and impacts of climate change on water availability and use. Tackling these complex, wicked subjects in which there is no clear right or wrong solution affords students the opportunity to explore ideas that juxtapose their own world views, which if done successfully, will have the end result of empowered students who are ready for real-world issues. Moreover, in a world that is becoming increasingly connected, it is essential to provide tomorrow's global citizens with the skills SHIs can deliver.

Chapter 3 Theoretical Framework

For this project, two discrete, research-based frameworks were selected to better understand student reasoning about SHIs. Each framework was selected for its ability to elicit various components from diverse populations.

Theory of Planned Behavior

The Theory of Planned Behavior (TPB) states that background factors (i.e. personality, emotions, ethnicity, religion, social norms, culture, values, etc.) effect beliefs (i.e. behavioral, injunctive, descriptive, and control) which combine with attitudes toward behavior, perceived behavioral control, and norms (injunctive and descriptive) to form an intention to perform the behavior and eventually to the behavior itself (Figure 3:1; Ajzen, 2013; de Leeuw et al., 2015). That is, the TPB states that background factors, such as the ones stated above, have a strong effect on beliefs (behavioral, injunctive, subjective, and control) which in turn influence intentions and the ability or desire to perform behaviors (de Leeuw et al., 2015). De Leeuw (2015) also states that belief scales are different between countries and even among different contexts. Therefore, differences in background factors and beliefs from developed and developing societies lead to the assumption that choice, and the reasoning that choice is based on, may also be different.

It is important to note that the TPB is being used as a framework for this study because it points out the importance of various background factors (Figure 3:1) being used in performing behaviors. That is to say, the TPB states that values, culture, etc. affect behaviors. This idea is further explored by Stern, Kalof, Dietz, and Guagnano (1995) with their emphasis on how personal values influence worldviews, and how those combine to influence attitudes, and ultimately, behaviors. Furthermore, Oreg & Katz-Gerro (2006) emphasize Ajzen's idea that the culture within which a person resides also influences their behaviors.

When using the TPB, it is essential to first outline the behavior that is being studied. For this study, the behavior of interest was students' choice about whether or not to reduce the amount of irrigation for agriculture in Nebraska. From this choice, I aim to understand students' reasoning and determine if reasoning patterns differed between the two research groups. As mentioned previously, the TPB is used as the bases of this study in that this study aims to better understand if and/or how background factors influence personal values and/or how those values influence socio-hydrological reasoning (Ajzen, 2013).

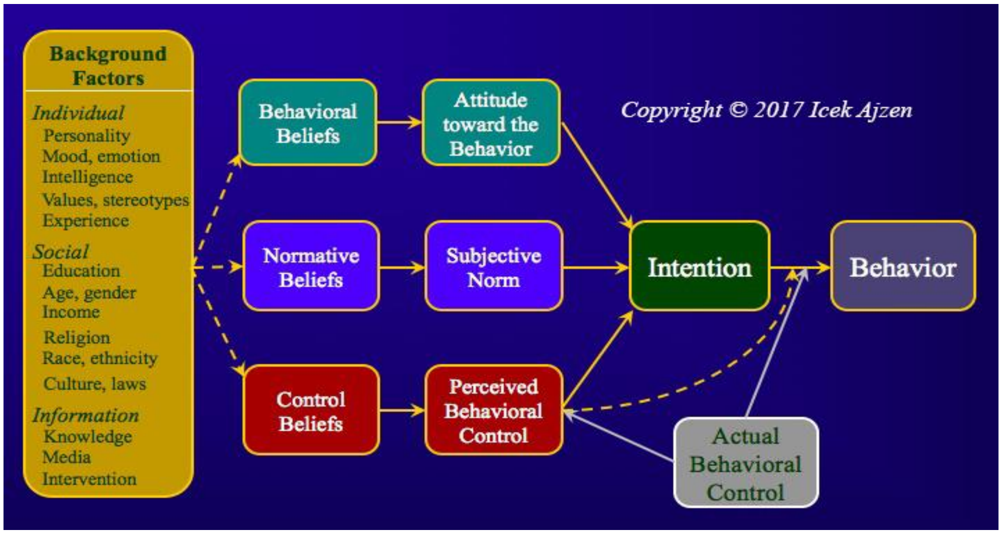

Figure 3:1 Ajzen's (2017) Theory of Planned Behavior framework with background factors

Quantification of Reasoning Quality

Christenson and Rundgren's (2015) framework (Figure 3:2) was designed to provide a universal, clear, well-defined way for teachers to quantify student reasoning about SSIs. This framework is backed by many layers of research-based concepts that relate to quality of reasoning. First, this framework assesses quality by looking at the components provided by the students. That is, the framework emphasizes that quality reasoning includes the expression of a claim backed by a justification and that quality is increased by the ability to understand and include counterarguments (Christenson & Rundgren, 2015). Second, providing content knowledge to back up a claim is important while equally important is the ability to differentiate correct content knowledge from misperceived knowledge. Finally, the inclusion of values is also an expression of quality reasoning, and therefore, is included in the framework (Christenson & Rundgren, 2015). These concepts were adapted in ways that provided the bases for a framework that is easily adaptable to fit both classroom and research needs.

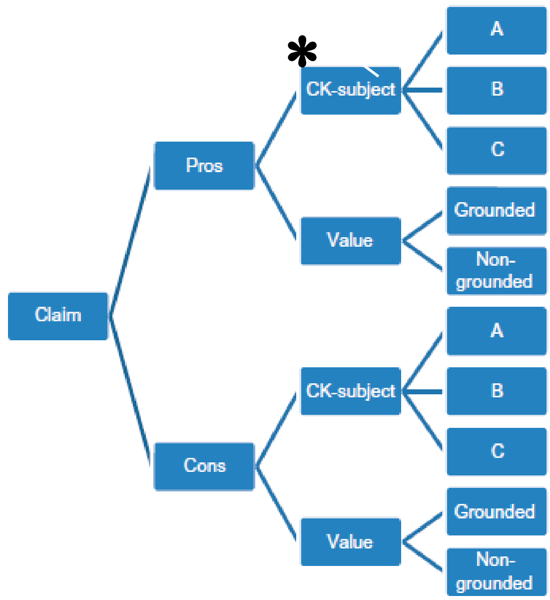

Figure 3:2 Christenson and Rundgren's (2015) Reasoning Framework (* CK-subject = content knowledge)

This framework works to elicit the quality of student argumentation by looking at both content and structure/components of student responses (Christenson & Rundgren, 2015). While this framework was designed to assess student argumentation, it is useful for analyzing student reasoning as well. Furthermore, Hugo (2011) explains that arguments consist of reasoning and that the function of reasoning is to support argumentation; therefore, reasoning patterns can be seen through argumentation. Additionally, it has been shown that argumentation analysis is an effective research methodology for investigating student reasoning (Kelly, Druker, & Chen, 1998).

For the purposes of this study, this framework is used to operationalize, quantify, and evaluate student reasoning because the components that form argumentation are the expressions of student reasoning. Students that express both content knowledge and values in their responses, as well as addressing both the pros and cons of their point-of-view, are considered to exhibit more sophisticated reasoning than those who do not. Moreover, Tal and Kedmi (2006) state that values are a constant in student reasoning and, therefore, should be considered in overall reasoning quality. Additionally, higher-order thinking includes the expression of content knowledge and values (Tal & Kedmi, 2006). The framework also takes into account whether information provided by the students is correct, incorrect, or misunderstood. Additionally, this framework further explores quality of reasoning with the inclusion of values. Although the inclusion of values is not required for and individual to reasoning, the use of values is considered a sign of quality reasoning (Christenson & Rundgren, 2015). All of these components combine to create a robust framework well-situated to quantify student reasoning in a straight-forward way.

Study Rationale

The purpose of this mixed methods study is to better understand the role priority values play in undergraduate students' socio-hydrological reasoning. This study focuses on a single class of undergraduate students enrolled in a required, introductory science course at a large Midwestern university. Students enrolled in the course were from both developed (W.E.I.R.D.) and developing (non-W.E.I.R.D.) countries. Again, W.E.I.R.D. societies are defined as Western, Educated, Industrialized, Rich, Democratic societies (Henrich et al., 2010). W.E.I.R.D. societies encompass roughly 96% of the total sample size of people used in human behavioral and psychological research (Henrich et al., 2010). According to Henrich et al. (2010), undergraduate students make up the majority of this 96% which becomes a problem when the data derived from these studies is applied liberally to the rest of the world. The problems are further enhanced by the idea that these students are outliers even among W.E.I.R.D. societies; Henrich et al. (2010) call these students, “a … narrow and potentially peculiar subpopulation”.

There is nothing wrong with studying these W.E.I.R.D. populations; however, Henrich et al. (2010) reveals that these populations vary significantly from non-W.E.I.R.D. populations even on rudimentary processes (i.e. visual illusions, economic decision making, and spatial reasoning); however, it is important to point out that there are similarities between W.E.I.R.D. populations and small scale populations (i.e. color recognition, basic facial expressions, and social relationships; Henrich et al., 2010).

Furthermore, according to the article and Kohlberg’s moral reasoning, there are three levels of basic human reasoning of which W.E.I.R.D. populations express all three and non-W.E.I.R.D. societies express only two (Henrich et al., 2010). This does not mean that developing countries are less able to reason than developed countries, it just shows that the path of reasoning is different between the two societies. These findings about how W.E.I.R.D. populations compare to the rest of the world leads to an area in which little to no research is done – behavioral research on non-W.E.I.R.D. populations, more specifically, research on how non-W.E.I.R.D. populations reason about SHIs.

Developing Countries

As stated above, 96% of behavioral research has been conducted on developed populations and the results from this research has been applied to all different societies with a one-size-fits-all mentality (Henrich et al., 2010). With developed populations representing such a small portion (17.8%) of the world and developing countries representing the majority (82.2%) of Earth’s population, it has become essential to conduct research on this portion of the population in order to have a more thorough understanding of what influences socio-scientific behaviors and reasoning. Being able to better understand how the majority of Earth's population reasons may provide insight for educational experiences for a wider range of students in postsecondary settings and future water-related management and planning strategies.

Research Questions

For this study, I asked two questions:

1. Do students from developed countries differ from those in from developing countries in their priority value identification?
2. If so, are there observable differences in the use of their priority values in their socio-hydrological reasoning? Does the use of those values influence the quality of reasoning between students from developed and developing countries?

Chapter 4 Research Methods

Study Context

This study was conducted in a large-enrollment, required introductory course for all students pursuing an undergraduate degree in the College of Agricultural Sciences and Natural Resources at a large Midwestern university. The course, *Science and Decision-Making for a Complex World*, SCIL 101, was designed specifically to concentrate on providing undergraduate students opportunities to build knowledge of various SSIs and learn to engage in effective decision-making about them. Five to six sections of the course are offered each academic year, each of which typically has 100-120 students enrolled. This study was conducted in one class section during the fall semester of 2016. SCIL 101 lectures met twice a week for ten weeks between the hours of 15:00 to 16:45 on Tuesday/Thursdays. Students were also required to attend an associated hour-long recitation section once a week for fifteen weeks. Each recitation consisted of ~30 students and provided students with a more personal learning experience.

Students represented a variety of different backgrounds, grades (Figure 4:1), and majors (Figure 4:2). Access to students from developing countries was achieved through a four-year university program that provides students with the opportunity to learn about agriculture with the end goal of those students returning home and establishing an advance agricultural system in their home countries.

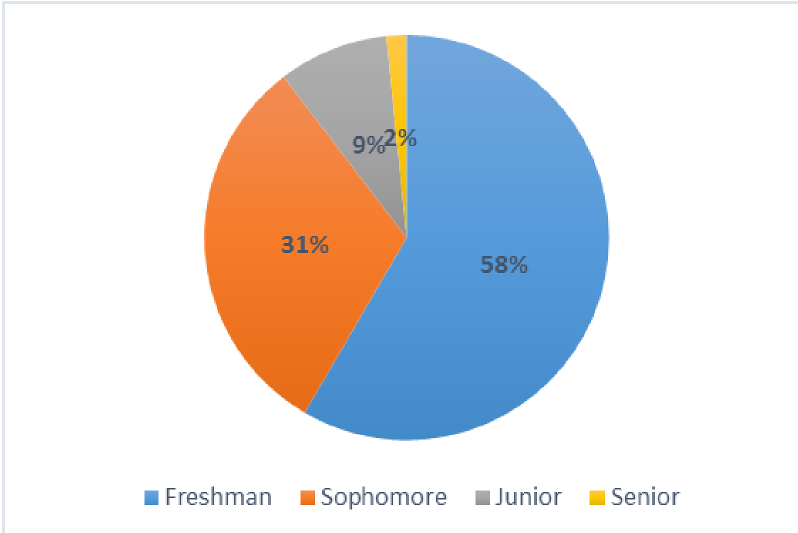

Figure 4:1 Percent of students per grade level

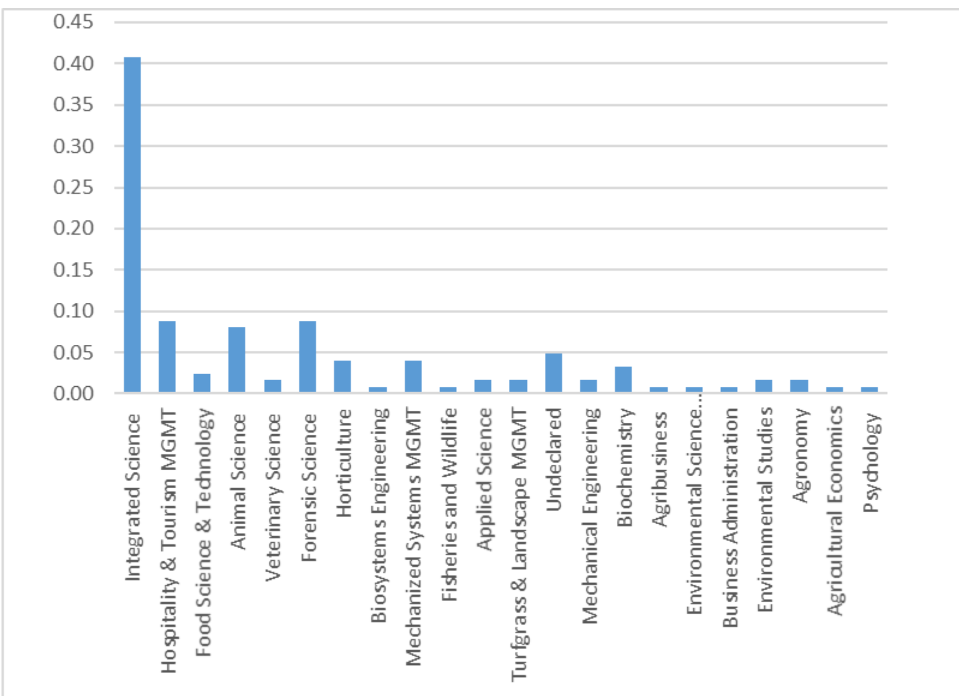

Figure 4:2 Percentage of students per major

During the semester in which the study was conducted, 95 of 125 students enrolled consented for their coursework to be used in educational research. This group consisted of 51 from developed countries and 44 from developing countries. Of the 95 students who consented for their coursework to be used in research, 8 volunteered to be interviewed. This group consisted of 4 from developed countries and 4 from developing countries.

Data Collection

Three sets of data were collected for this research. First, students completed an online values survey (see Appendix 1). Second, students completed a three-part, in-class module assessment in which they are asked to reason through a socio-scientific water-related issue and come to a conclusion (see Appendix 2). Third, students were interviewed using an interview protocol (see Appendix 3). The purpose of the interview was to understand students' reasoning about the SHI in the module assessment. Also, the interviews were essential for designing a rubric with which to analyze the module assessment.

Schwartz Human Values Survey

The Schwartz Human Values Survey (see Appendix 1) is an established instrument for eliciting beliefs, behaviors, and attitudes of diverse populations (Schwartz et al., 2015). An underlying assumption of this survey is that human values are determined by the goals people wish to obtain and the motives behind attaining those goals (Schwartz et al., 2015). Schwartz and others (2015) propose through this survey the idea that there are ten human values that are expressed across all cultures: conformity, tradition, benevolence, universalism, self-direction, stimulation, hedonism, achievement, power, and security. Each value corresponds to a motivational goal (these are shown with examples in Appendix 4). The values survey was presented to the students on Qualtrics at the end of the fall semester and was required for all enrolled students. The survey consisted of 21 questions that were designed for the purposes of assessing diverse populations (Schwartz, 2015). Responses were ranked on a six-point Likert-type scale (1 – Very much like me and 6 – Not like me at all) to determine each group's priority value.

Module Assessment

A module assessment (see Appendix 2) was given to students to work on at the conclusion of the water module in *SCIL 101*. The module assessment was required for all enrolled students and consisted of three parts that were designed to elicit different aspects of students' scientific understanding. Part III of the module assessment was used to obtain students' socio-scientific reasoning around a decision to either restrict or not to restrict the amount of water used for irrigation in the state of Nebraska. This part discretely asked students to reason to a conclusion about the question, "Should we further reduce the amount of water used for irrigation in Nebraska?"

Interviews

One-on-one interviews (Creswell, 2012) were conducted over a four-week period in November and December 2016 (see Appendix 3). These interviews took place after students completed the water module and module assessment. Interviews were held in a private conference room to ensure no interruptions. Interviewers included myself and another graduate student. To avoid conflicts of interest, students were interviewed by the researcher that was not their course instructor. Interviewees were given time to look over their module assessments before the interview started to refresh their memory on the subjects to be discussed. Interview participation was voluntary and was an open call to any interested students (convenience sampling). An outside collaborator announced the research interview and handled student questions and emails to avoid making the students feel pressured into being participants. Those who participated received compensation in the form of a $20 USD gift card.

Interviews consisted of 10 questions that were analyzed for this study (see Appendix 3). Interview questions were constructed following Ajzen's (2013) guide for TPB questioning which provides examples of questions designed to elicit various TPB concepts such as norms and behavior beliefs. However, because these were semistructured interviews (Creswell, 2012), if additional questions arose during the interviews, those were addressed and analyzed in conjunction with the structured questions – all of which were reported in the findings.

Data Analysis

After data was collected, it was brought together and viewed in full to allow for an easier time processing and coding for themes. Quantitative data was analyzed using the steps mentioned under values survey and module assessments. Qualitative data was analyzed using a modified version of the steps suggested by Creswell (2012): (1) prepare and organize data, (2) explore and code data, (3) code for themes, (4) report findings, (5) interpret findings, and (6) validate findings. Following those steps, I was able to take all the collected data and analyze to best answer my research questions.

First, qualitative data was analyzed as a whole to understand what is being said. Second, data was read thoroughly and margin notes were taken to describe what was being said. Third, data was coded by identifying key items that answer the research questions. Open coding was used to ensure full understanding of student responses. I analyzed the module assessments and interviews using these three steps.

Values Survey

The Schwartz Human Values Questionnaire was analyzed via the steps suggested by the instrument's creator (Bilsky, Janik, & Schwartz, 2011; Schwartz, 2015; Schwartz, 2017; Schwartz, personal communication, February, 11, 2017). Analysis was completed to gain an insight into which Schwartz' human values students most identify with: conformity, tradition, benevolence, security, universalism, power, self-direction, self-transcendence, hedonism, achievement (see appendix 4 for values explanation). Using the guides mentioned above, students' responses were: (1) assigned numeric values on a 6-point Likert-type scale (1 – Very much like me and 6 – Not like me at all), (2) means for each value were calculated, (3) means were calculated for each individual over the 21 value items, (4) values were centered to ensure accuracy of results, (5) and t-tests were ran for each of the ten human values. T-tests were used to determine differences between the two study participant groups – developed and developing. Shapiro-Wilk tests for normality were ran on the data and those found to have a non-normal distribution were analyzed using the non-parametric Kruskal-Wallis test.

Module Assessments

Module assessments were initially analyzed using a quantitative, open coding approach (Creswell, 2012). Additionally, modules were analyzed using Christenson and Rundgren's (2015) reasoning framework in conjunction with Creswell's (2012) six steps mentioned above. Christenson and Rundgren's (2015) framework aided in the process of understanding how students reason. Students who, during coding, mentioned more of the framework's items were considered to have higher quality reasoning than those who mentioned fewer (Christenson & Rundgren, 2015). That is, students who mentioned several of the different items had higher quality reasoning than those who mentioned the same items several times; furthermore, students who mentioned both pros and cons to their reasoning claims were considered to have higher quality reasoning (Christenson & Rundgren, 2015). Numerical values, described in the following paragraph, were assigned to each of the student's responses to quantify their reasoning. Students received different points depending on which items of the framework they mentioned (Figure 4:3).

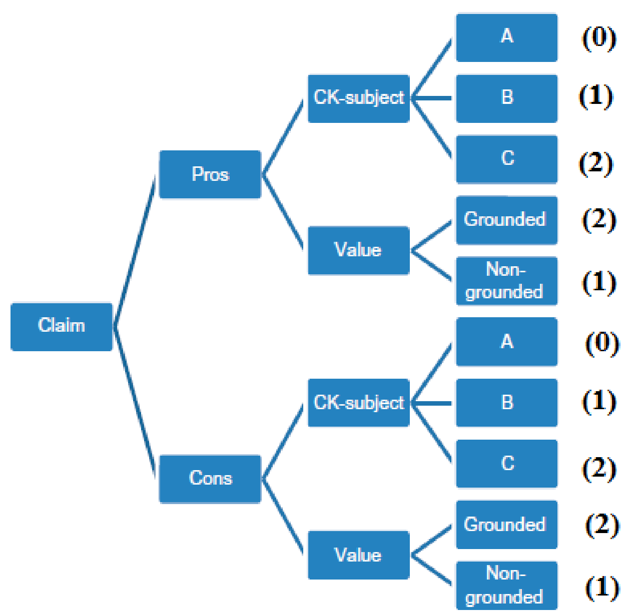

Figure 4:3 Modified framework for analyzing module assessments

Points were assigned to each item based on the type of information presented (see Table 4:1 for examples of coded student responses). Item A was assigned a point value of zero because the information provided in this category was incorrect or the expression of a misconception. Item B was assigned a value of one because information provided was non-specific or not directly related to the argument. However, the expression of this item was weighted heavier than item A because it did not consist of misconceptions but rather generalized truths. Item C was assigned a value of two; this item received the highest value because it was the expression of relevant and correct knowledge.

Table 4:1 Examples of coded student pros/cons responses

Coded Item	A	B	C
	Pros		
Student		BC5	AD45
	N/A	(Care for others personal health) "everyone needs water to survive and without clean/fresh water our population would die out."	(Care for othes not having to work to get their water) "They would have to go out and get their water, which is unfair in my opinion. Water should be a right to anyone and no one should have to work to get their water."
	Cons		
Student		BC53	BC53
	N/A	(Security for farmers having healthy crops) "The higher irrigated area with different irrigation practices, the better the yields except diseases disruption"	(Security for PRESENT people) "the essential is to use what you have resources you have today so that it can produce another something important to be used in future. All possible natural resources must be used anytime it is available especially water which is source of life."

Furthermore, item non-Grounded was assigned a value of one because this item was the expression of feeling. In other words, this item was the expression of a student's group's priority value that was not based on fact or common knowledge, but instead was based on personal beliefs or feelings, thus having less support than item Grounded. Item Grounded was assigned a value of two because it represented the expression of the priority value that was backed by facts or common knowledge. It is important to note that for values, only a student's group's most identified value, their priority value, was quantified. That is, students from developed and developing countries were scored based on the use of her group's priority value and not all ten human values; developed students were scored for their use of the value benevolence while developing students were scored for security (Table 4:2). Furthermore, I coded for each groups' priority values by looking at implicit or explicit statements of those values. Values that were not explicitly stated were uncovered via careful reading and minimal interpretation.

Table 4:2 Examples of coded student priority value responses

Student	Values Use	
	Developed	
AD48	(Care for others personal health) "everyone needs water to survive and without clean/fresh water our population would die out."	(Care for othes not having to work to get their water) "They would have to go out and get their water, which is unfair in my opinion. Water should be a right to anyone and no one should have to work to get their water."
	Developing	
BC53	(Security for farmers having healthy crops) "The higher irrigated area with different irrigation practices, the better the yields except diseases disruption"	(Security for PRESENT people) "the essential is to use what you have resources you have today so that it can produce another something important to be used in future. All possible natural resources must be used anytime it is available especially water which is source of life."

Additionally, it is important to note that in order for each statement (pros, cons, and value statements) to be included in the overall reasoning score, the statement had to be unique and not a reiteration of a previously mentioned idea or concept. This approach was intended to emphasize that the multifarious use of ideas and concepts represents higher-quality reasoning (Table 4:3). That is, higher-quality reasoning is exemplified by the use of different, deeper perspectives, while lower-quality reasoning is the expression of redundant, shallow perspectives. Reasoning scores were observed to have a range of zero to 38 points.

Table 4:3 Examples of coded student redundant and diverse responses

Student	Redundant		Student	Diverse	
BD82	"Taking into account the climate /weather/ seasonal changes. restrictions will take into account seasonal changes and farming seasons and type of crop planted which will enable the effective use of irrigation water"	"Restrictions will take into account seasonal changes and farming seasons and type of crop planted which will enable the effective use of irrigation water"	AC75	"If things continue the way they are, we will be facing a serious problem in the future, it may not be our generation but we will leave a crisis for future generations to try to fix"	"While the farmers do have a right to access the water, they should not just get free reign to do whatever they want because their actions don't just affect themselves, they have the potential to affect the whole world"
AC42	"The sooner we start restricting the longer the aquifer is going to be there in the future."	"Be more aware of the water that I am using and not waste as much. If everyone did this, it could potentially decrease the amount of pumping out of the aquifer."	AD38	"To have good health I am going to need good clean drinking water, and if the aquifer goes dry, then that is going to make it a lot harder to find"	"It is important that we fix this now so that future generations have enough water to support themselves also"
AC49	"By limiting the amount of water we can pump out of it allows us to keep the aquifer around much longer to fulfill the needs we have."	"Everyone rely on the aquifer so we should try to keep it for as long as possible."	BC107	"As most studies have shown depletion rate now it is high so that the water would become a problem in future"	"We can use less water to achieve more productivity by increasing efficiency and apply plant science technology to achieve good result"

Interviews

Interviews were analyzed using a qualitative approach following Creswell's (2012) six, previously mentioned steps in conjunction with Christenson and Rundgren's framework (Figure 4:3; 2015). Interviews were coded following the same steps as the module assessments. Pros, cons, subject knowledge, and values were all coded for and reported in findings. Findings from these interviews were used to reinforce and validate findings from the module assessments. However, these interview findings were not used in the overall reasoning quantification score as not all students participated in interviews.

Chapter 5 Results & Findings

RQ1 – Do students identify with different priority values?

In research question 1, I asked, “Do students from developed countries differ from those from developing countries in their priority value identification?” Taken as a whole, students most identified with the value benevolence (*Mean* = -0.36, *Standard Deviation* = 0.55) while they least identified with the value power (*M* = 0.57, *SD* = 0.79) (Figure 5:1). Looking at the student groups separately, students from developing countries most identified with the value security (*M* = -0.38, *SD* = 0.56) and least identified with the value power (*M* = 0.71, *SD* = 0.88). Students from developed countries most identified with the value benevolence (*M* = -0.43, *SD* = 0.56) and least identified with the value power (*M* = 0.44, *SD* = 0.67). Results from a Wilcoxon-Mann-Whitney test indicate that there was a statistically significant difference in identification with the value security between the two groups of students ($W = 2008$, $p < 0.01$; Table 5:1); security was a key value to students from developing countries (*Mdn* = -0.29) while not essential to students from developed countries (*Mdn* = 0.02) (Figure 5:2). Findings suggest that students from developing countries identify with at least one different value than students from developed countries. It is important to note that, following the analysis instructions from the instruments creator (Schwartz, 2017), the values representing “more like me” are smaller, and thus negative once centered.

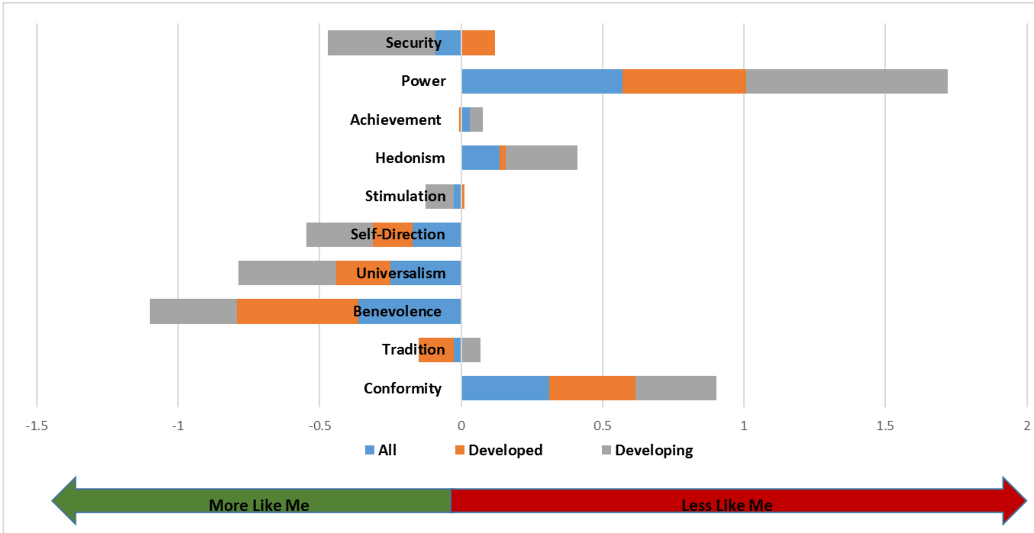

Figure 5:1 Ten human values across study participants

Table 5:1 Results from Wilcoxon tests comparing the two study groups value identification

Conformity		Tradition		Benevolence		Universalism		Self-direction	
W score	*p* -value	*W* score	*p* -value	*W* score	*p* -value	*W* score	*p* -value	*W* score	*p* -value
1411	0.97	1170	0.12	1237	0.26	1626	0.18	1603	0.24
Self-transcendence		**Hedonism**		**Achievement**		**Power**		**Security**	
W score	*p* -value	*W* score	*p* -value	*W* score	*p* -value	*W* score	*p* -value	*W* score	*p* -value
1532	0.46	1167	0.11	1381	0.82	1239	0.27	2008	0.002

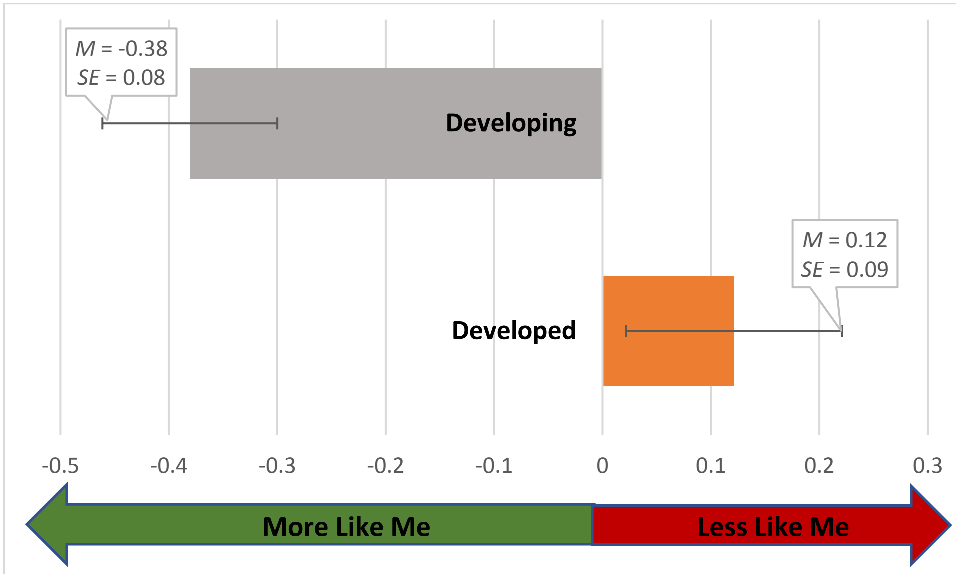

Figure 5:2 Mean identification with the value of security with error bars

RQ2 – Are there differences in the use of values in their reasoning and does use of those values influence quality of reasoning?

In research question 2, I asked, "Does the use of those values influence the quality of reasoning between students from developed and developing countries? And if so, are there observable differences in the use of their most identified values in their socio-hydrological reasoning?" Results from a Wilcoxon test show that there is a statistically significant difference between the overall quality of reasoning of students from developing (*Mdn* = 14) and developed (*Mdn* = 10) countries ($W = 584$, $p < 0.001$). Students from developing countries exhibited more sophisticated reasoning than did students from developed countries.

Results from a Kolmogorov-Smirnov test show that the two populations significantly differ in their distributions ($D = 0.43$, $p < 0.001$), with those distributions from developing (*skewedness* = 1.89, *Standard Error* = 1.01) and developed (*sk* = 0.74, *SE* = 0.83) countries being positively skewed as is seen in Figure 5:3. Additionally, results of an independent t-test show that there is a significant effect of priority value use ($t(75) = -7.01$, $p < 0.001$) with developing students ($M = 4.35$, $SD = 1.56$) using their priority value more than their developed ($M = 1.92$, $SD = 0.22$) counterparts (Figure 5:4).

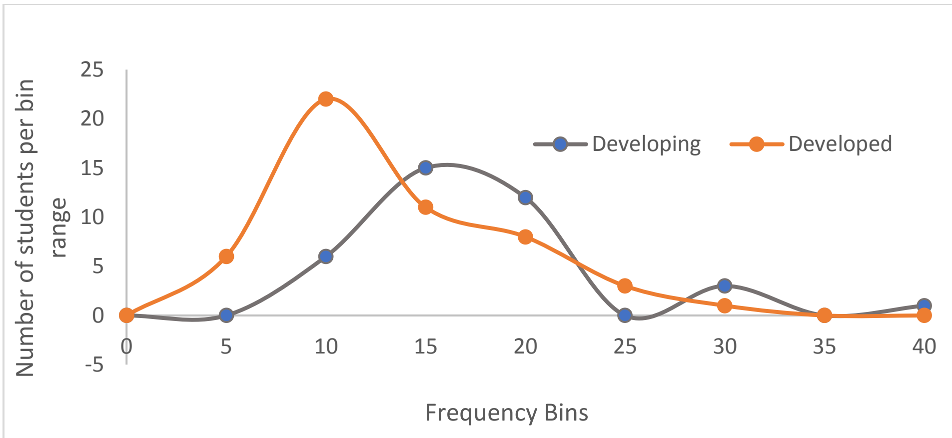

Figure 5:3 Frequency distribution of reasoning scores from students from developing and developed countries

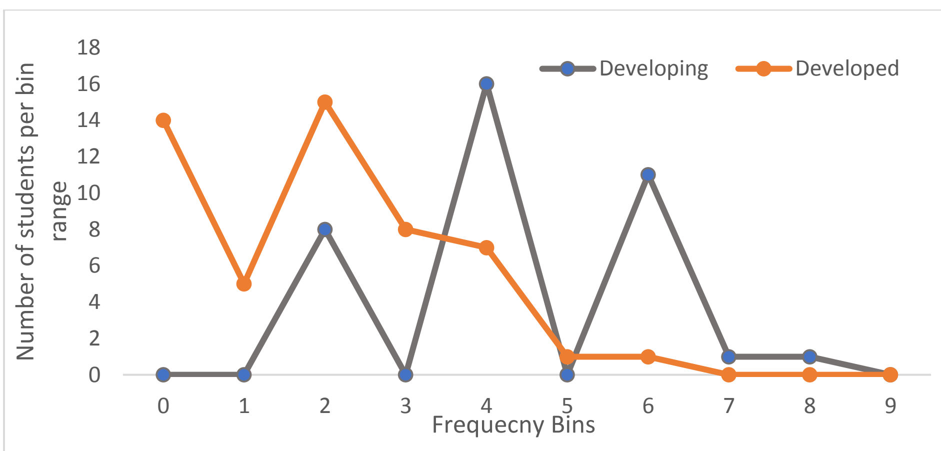

Figure 5:4 Frequency distribution of the use of priority values by students from developing and developed countries

Differences in the quality of reasoning between the two groups can be further expanded by examining qualitative evidence for students' low and high quality reasoning.

Examples of low quality reasoning include few to no mentions of their groups' priority value (security for developing students; benevolence for developed students). Furthermore, trends in low quality reasoning include the use of unrelated knowledge and the inability to express both pros and cons of the overall reasoning claim (Table 5:2). Conversely, higher quality reasoning included instances where students mentioned their groups' priority value in multiple different contexts. Additionally, high quality reasoning exhibits the expression of both pros and cons of the overall reasoning claim (Table 5:3). These concepts are expanded upon in following paragraphs.

Table 5:2 Examples of low quality student reasoning

		Pros		Cons	
Student	**Claim**	**Content Knowledge**	**Value**	**Content Knowledge**	**Value**
AC62	No	Although irrigation does use a lot of water, that water doesn't get wasted	[Care for farmers being able to continue] Econimic development	N/A	N/A
AD74	Yes	N/A	N/A	Farmers are the main reason for our agriculture and what helps our state	N/A

Table 5:3 Examples of high quality student reasoning

Student	Claim	Pros: Content Knowledge	Pros: Value	Cons: Content Knowledge	Cons: Value
BD8	Yes	Without adaptions that take time and trial, farmers would really be at a loss without new strategies to continue with less water and water to continue current practices.	I would like to make some sacrifices now, to be able to use our water sources far into the future. Especially with a growing human population, preserving water is important in keeping as many people as possible economically successful and properly fed.	Farmers need to make a living too and crops need water	Restrictions makes their job nearly impossible and they are facing economic loss now
		Most of our indirect water use comes from our diet. Beef production uses a large amount of water, so really limiting my consumption will help save water. Also, switching to less water dependent fruits and vegetables, such as blueberries, will help to reduce water use			
AD32	No	Groundwater is a public resource that is connected to more than just the land a farmer owns. Drain it in one spot, and it disappears from others	Without water, there are no crops, and without crops, the country's breadbasket won't be able to feed a growing population or support the massive ethanol business.	Restrictions on water may cause economic harm in the short term but might present a state-wide economic calamity in the future	Depletingtheaquifer may cost me and my family our whole water supply.
		[NRD's] seem to be doing a fairly good job with their water policies. [Nebraska's] water levels are staying rather stable		Farmers should have the right to use the water under their land	

Developing Students

As shown in the quantitative findings, students from developing countries utilized their priority value to a greater extent than did students from developed countries. Results of interview and module assessment analyses show that students from developing countries frequently mentioned security (safety and stability of society) such as: "…the

Ogallala aquifer water is useful for this time but also for the future time. so we have to be serious on the issue to live well in this time but also prepare a good life for future generation" (Water Student BD_6). This statement is an example of a common trend throughout the student work of security for future generations. Students also mentioned security for the environment and for providing enough water for future agricultural use.

Additionally, some students reasoned that preserving water today would provide prolonged agricultural productivity, thus, leading to prolonged profits and the ability to decrease poverty in their home country, "restricting water used in agricultural education would promote economic development of the country at large, and the wealth of the citizens can be achieved" (Water Student BC_89). Furthermore, others reasoned that, "[not restricting water]…encourages every single people to practice irrigation in order to become wealthy through having more yields from his or her agriculture irrigation methods" (Water Student BC_53).

Moreover, students also mentioned that it was the duty of "…the government to intervene in order to conserve future agriculture activities" (Water Student BC_15). Further examples of this reasoning include, "…the government also might come up with solutions to fight against it" (Water Student BD_22), and "[restriction] is concerned with the ability of the country to provide security of food to its population, maintaining the agriculture sector as productive as possible, employment opportunities for farmers and their families" (Water Student BD_21). Together, these statements are representative of how students from developing countries draw upon their priority value of security to reason about the socio-hydrological issue at hand.

Developed Students

It is important to reemphasize that there is a statistically significant difference in the use of values in reasoning between the two groups. That is, developed students did not reason with their priority values at the same frequency as developing students (Figure 5:2). However, results of interview and module assessment analyses showed that students from developed countries did mention their priority value of benevolence (care for, and preservation of, people one knows, likes, and is in contact with) multiple times such as, "It is important to make some changes even on a small scale to preserve agriculture in the Midwest" (Water Student AC_27) and, "I could…raise awareness in my community for this issue and reach out to the communities that it is directly affecting to help" (Water Student AC_33).

Additionally, the idea of doing what is considered fair for all people was a common occurrence such as, "... I believe that everyone should be allotted the amount of water that is fair for him or her and that they need to live comfortably" (Water Student AC_33), "It is very important because homeowners don't want [their] wells to go dry and be without water so there needs to be a mutual agreement between the homeowners and farmers" (Water Student AC_34), "make it equal and allow for the maximization of gross product now" (Water Student AC_56) and, "Everyone must limit their water use if farmers have it. Like communities with pools, golf courses, and watering their lawns. It is not fair to just limit the farmers, when they are feeding America" (Water Student AD_20).

Furthermore, students frequently used their priority value with the context of caring for others personal health. Students made statements such as, "get enough water to drink and food to eat and both drinking water and food growth are affected by this issue (Water Student AC_63), "if we do not have enough water, it is bad for our personal health. Because water is important for humans" (Water Student AD_12), and "living things need to be nourished in order to sustain life" (Water Student AD_19). Additional examples of care for others personal health include, "[without the ability] to supply households with water, people won't be able to bathe and that can lead to serious health issues" and, "everyone needs water to survive and without clean/fresh water our population would die out" (Water Student AD_48).

Moreover, many students had no mentions of their priority value in any context. Students also used their values redundantly making statements such as, "…living things need to be nourished in order to sustain life" and "there are other[s]… that need water in order to survive" (Water Student AD_19). Additional examples of redundant values use includes, "Without water, we would be dehydrated, causing health problems, and we could also not grow crops, which is needed for a food resource, which would lead to death" and "Without water, our society would decline, people would die, and we would have to find another way to live" (Water Student AC_72). It is shown through these statements that students from developed countries reason about socio-hydrological issues by drawing upon their shared priority value of benevolence.

Students from developed countries tended to have lower quality reasoning than developing students for several reasons. Although developed students did mention their priority value of benevolence in their reasoning, they mentioned their priority value less frequently and in fewer contexts than their developing country counterparts. Moreover, students scored lower due to a lack of mentioning both pros and cons to their overall claim. In other words, developed students tended to mention their priority value less frequently and more redundantly in combination with not mentioning the pros and cons to their claim, thus leading them to score lower on overall reasoning quality than their developing country counterparts.

Chapter 6 Discussions, Implications, and Conclusion

Discussion

As populations increase, so too does the demand placed on water resources which is predicted to cause an increase in competition for those resources (FAO, 2015). Now is a critical time to understand how growing populations reason about their water resources. This study is essential as water resources tend to cut across many natural, cultural, and religious boundaries. With this intimate connection, it is imperative to better understand how various stakeholders reason about water resource with hopes to help decrease predicted future conflict. Building upon these ideas, this study aims to become the foundation of research on how values differ based on diverse background factors (Lam, 1999), and how those differing values are used to reason about socio-hydrological issues.

First, this study provides evidence that, much like recognized in the TPB (de Leeuw et al., 2015), students from developed and developing countries have different values with which they identify. These different values are exemplified throughout their reasoning and thus should be acknowledged by educators. Values must be acknowledged, respected, and molded in ways that push students to be environmentally conscious. Additionally, if values are acknowledged, pro-environmental behaviors could become more consistent with a reduction in the number of tradeoffs that occur due to all stakeholders having a say in an issue’s resolution (Wilson & Arvai, 2006). Providing students with additional SHIs that challenge their values may allow educators the opportunity to better understand students’ reasoning. Moreover, understanding the role that values play in reasoning could afford decision-makers and plan-implementers the ability to include stakeholders' values in the decision which would provide a higher probability of successful implementation and continuation.

Second, evidence supports the idea that students from developed and developing countries reason differently, perhaps based on their exposure to differing background factors (Ajzen, 2013; de Leeuw et al., 2015). Students from developing countries tended to mention security while their developed country counterparts tended to mention benevolence. These differences are further expanded by the diversity of use of each groups' priority value. Understanding these differences could provide educators with insight into how to encourage students to reason through complex SHIs in pro-environmental ways. Additionally, understanding reasoning differences could afford educators with the insight into which students need additional help and guidance. Moreover, understanding that different populations identify with different values affords better insight into what those populations prioritize. This insight could help struggling water resource managers see that water-related solutions, although scientifically accurate, are not always one-size-fits-all. Combining the input of stakeholders, backed by awareness of their values, with the facts and knowledge of science will allow for a higher probability of successful water management (Gregory, 2000; Wilson & Arvai, 2006).

Third, data shows that reasoning quality is higher and is expressed by a larger percent of students from developing countries than their developed country counterparts. This is directly in line with the TPB ideas explained by de Leeuw et al. (2015), and the assumption that these populations would have different reasoning. Understanding students' quality of reasoning affords educators the opportunity to guide students with additional pathways of reasoning which would provide students with the support needed to have high quality reasoning, thus better preparing them to become tomorrow's global citizens. The skills needed to reason through SHIs at high levels are beneficial not only for being a successful student, but also an involved stakeholder in the global water system.

Implications

This study addresses the need to better understand students' reasoning, as well as appreciating possible differences in the reasoning of citizens from developing and developed countries. This study contributes to research on students' use of SSIs (Kolosto, 2001), students' reasoning (Sadler, 2004), the use of values in reasoning (Zurek, 2016), and differences in how people from developing and developed countries reason (Nilsson, Baxter, Butler, and McAlpine, 2016). Additionally, this study has implications for the fields of education, human dimensions of natural resources, and science literacy.

This study has implications for better understanding how post-secondary students reason about SHIs, thus providing educators with the ability to tailor lessons in a way that challenges students while also providing students support with ways to include their values in reasoning. Understanding students reasoning could provide educators with a guide on what should be the focus of those lessons to better challenge the students and help them become more scientifically minded and thus molding future scientifically literate global citizens.

Additionally, this study has implications for better understanding the human dimensions component of value usage. Understanding the role that values play in natural resources, particularly water management, and including stakeholder inputs in decision-making will allow for a higher probability of successful water management (Gregory, 2000; Wilson & Arvai, 2006). Furthermore, this study provides evidence that values are a critical component that should be included in natural resource management. That is, as populations continue to grow, understanding and including the human-dimension of values in water management plans is essential for the sustainability of water resources.

Finally, this study has implications for providing insight into how students reason and how that reasoning, with the use of their values, either strengthens or weakens students' science literacy. In an attempt to create buy-in, teachers and decision-makers must propose SHIs in a way that students and citizens can understand and in such a way that the stakeholders can see how their values can be used in reasoning about the issue. Lederman (2007) explains that a person's background, and the interactions that they have been involved in, influence how they view science. With this knowledge, educators can use SHIs for instruction and help students express their values while also being environmentally conscious. That is, if educators are able to understand that students' values are different and they are able to propose SHIs in a way that students' values can be used in the solution, then students will be more engaged, thus working to increase their overall science literacy. Again, in order to strengthen student science literacy, students must be presented with SHIs that create buy-in and encourage those students to use their unique values in the issues solution. This should be a goal of educators, for when personal values are used in the resolution of SHIs, those resolutions have fewer tradeoffs (Wilson & Arvai, 2006) which may lead to an increased probability of success.

Limitations and Future Studies

This study was conducted on undergraduate students at a large Midwestern university. Undergraduate students, from developed countries, are typically seen as outliers when compared to populations from developed countries (Henrich et al., 2010). Furthermore, students attending universities are typically affluent or the top of their K-12 classes. The latter is especially true for the developing country undergraduate students this research was conducted on. Those students had to undergo extensive academic testing to be considered for the program and were ranked the best-of-the-best out of a large pool of applicants from their home country. Researching affluent and high academically achieving students is a limitation to this study as they may not provide as holistic a view of that society as research on everyday citizens would. Keeping these limitations in mind, future studies would be best served by focusing on everyday citizens in both developing and developed countries. This will allow for a more holistic view of those populations.

Another limitation of this study could be sample size. While this research was conducted in a large-enrollment class and 95 students participated (51 from developed countries and 44 from developing countries), this is far less than even one percent of the population of each of those country types. Being such a small subset of those populations, the holistic view might not be as accurate as if there were more participants. Keeping this limitation in mind, this study would be best served by expanding the number of participants as much as possible to get a more accurate, all-inclusive understanding of those populations.

This study, while being conducted in part on students from developing countries, is not an accurate representation of all developing countries. That is because not all developing countries have the same set of cultures, religions, and traditions which may lead them to having different values. Therefore, research should be conducted on all countries and societies and should be done frequently as cultures and societies are always shifting.

Future studies could also incorporate the TPB in different ways. Perhaps designing the module assessment following the same guidelines as the interview could provide a more cohesive look at students' reasoning with regards to the items mentioned in that framework. Conducting an extra survey item that provides insight into the students' socio-economic status could also be important. This would afford researchers the opportunity to see what specific factors, other than region of residence, influence socio-hydrological reasoning. Additionally, future studies could look into the pathways of reasoning, uncovering the steps that connect the various elements of reasoning that students mentioned.

Conclusion

Earth has been called the Blue Planet due to the abundance of water found on its surface. However, only 3% of that water is usable for human consumption, and further yet, only 1% is considered easily accessible. With current trends in population growth coupled with increasing strain on this invaluable natural resource, now is the time to act to ensure the longevity of water resources. Educators, plan-implementers, water managers, and everyday citizens must work together to assure that everyone has access to the water they need, as well as providing global stakeholders with an education that shows them the importance of water and how its protection is intimately tied to their cultures, religions, regions of residence, and personal values. Moreover, the UN's 2030 goals (UN, 2015a) can be achieved by working hard and striving to better understand how stakeholders' values differ and how those stakeholders draw upon their values to reason about SHIs. A water literate and secure world is what we should be diligently working to achieve.

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APPENDIX

APPENDIX 1. VALUES SURVEY

Here we briefly describe some people. Please read each description and think about how each person is or is not like you.

	Very much like me	Like me	Somewhat like me	A little like me	Not like me	Not like me at all
Thinking up new ideas and being creative is important to him/her. He/she likes to do things in his/her own original way.	○	○	○	○	○	○
It is important to him/her to be rich. He/she wants to have a lot of money and expensive things.	○	○	○	○	○	○
He/she thinks it is important that every person in the world should be treated equally. He/she believes everyone should have equal opportunities in life.	○	○	○	○	○	○
It's important to him/her to show his/her abilities. He/she wants people to admire what he/she does.	○	○	○	○	○	○
It is important to him/her to live in secure surroundings. He/she avoids anything that might endanger his/her safety.	○	○	○	○	○	○
He/she likes surprises and is always looking for new things to do. He/she thinks it is important to do lots of different things in life	○	○	○	○	○	○
He/she believes that people should do what they're told. He/she thinks people should follow rules at all times, even when no-one is watching.	○	○	○	○	○	○
It is important to him/her to listen to people who are different from him/her. Even when he/she disagrees with them, he/she still wants to understand them.	○	○	○	○	○	○
It is important to him/her to be humble and modest. He/she tries not to draw attention to himself/herself.	○	○	○	○	○	○
Having a good time is important to him/her. He/she likes to "spoil" himself/herself.	○	○	○	○	○	○
It is important to him/her to make his/her own decisions about what he/she does. He/she likes to be free and not depend11 on others.	○	○	○	○	○	○
It's very important to him/her to help the people around him/her. He/she wants to care for their well-being.	○	○	○	○	○	○
Being very successful is important to him/her. He/she hopes people will recognise his/her achievements.	○	○	○	○	○	○
It is important to him/her that the government ensures13 his/her safety against all threats. He/she wants the state to be strong so it can defend its citizens	○	○	○	○	○	○
He/she looks for adventures and likes to take risks. He/she wants to have an exciting life.	○	○	○	○	○	○
It is important to him/her always to behave properly. He/she wants to avoid doing anything people would say is wrong.	○	○	○	○	○	○
It is important to him/her to get15 respect from others. He/she wants people to do what he/she says.	○	○	○	○	○	○
It is important to him/her to be loyal to his/her friends. He/she wants to devote16 himself/herself to people close to him/her.	○	○	○	○	○	○
He/she strongly believes that people should care for nature. Looking after the environment is important to him/her.	○	○	○	○	○	○
Tradition is important to him/her. He/she tries to follow the customs handed down by his/her religion or his/her family.	○	○	○	○	○	○
He/she seeks every chance he/she can to have fun. It is important to him/her to do things that give him/her pleasure.	○	○	○	○	○	○

APPENDIX 2. MODULE ASSESSMENT

Part III (24 points): What do YOU think?
Should we further restrict the amount of water used for irrigation in Nebraska?

Now that you've evaluated a few arguments related to this socioscientific issue, stop to think about your own opinion about what's going on. Write down your own personal ideas about the questions below.

1. (4 points) What other questions or information are important to the issue that weren't captured in the articles you read for this assignment? Why are these questions important?

2. (4 points) Write a one-sentence statement of what you value that is relevant to this issue (for example, economic development, personal freedom, environmental health, personal health etc). Explain how it is relevant.

3. (4 points) Using both your statement of value and the scientific information in the articles you've read or we've discussed in class, answer the following: What is your opinion about whether or not we should restrict the amount of water used for agricultural irrigation in Nebraska? Why?

4. Consider the arguments of those who are on the opposing side of the issue.
   A. (2 points) What would someone who disagrees with you say about whether or not we should restrict the amount of water used for agricultural irrigation in Nebraska?

   B. (2 points) How would you address these arguments? Identify the best counter-argument.

5. (4 points) Is there anything you could do to impact this issue? What are some things you could do and how might they impact the issue?

6. (2 points) a) How important do you think this issue is to you personally?

b) Rank the issue on a scale of 1 (not at all important) to 10 (one of the most important issues. _______

7. (2 points) a) How important do you think this issue is to society?

b) Rank the issue on a scale of 1 (not at all important) to 10 (one of the most important issues. ________

APPENDIX 3. INTERVIEW PROTOCOL

I am interviewing Student AA on November xx, 2016, at xxpm.

Again, as a reminder, these questions are about the issue of whether or not we should reduce the amount of irrigation in Nebraska.

1. Do you think that science information helps form your opinion about the issue?
2. Do you think that your opinion about irrigation might change in the future?
3. How important is the issue of irrigation and water to you personally? On a scale of one to ten, **where ten is the most important issue and one is not important at all**, where would you place yourself on this issue? Why did you choose that number? Be as specific as possible.
4. When it comes to this issue of irrigation, what would your family and friends say you ought to, or should do?
   - Put yourself in their mindset.
5. On a scale of one to ten, **where ten is doing what is suggested, by family and friends, and one is not doing what is suggested**, where would you place yourself? Why did you choose that number? Be as specific as possible.
   - Do you value their opinions or not?
6. When it comes to this issue, what would your family and friends do?
   - This is what they would actually do given their circumstances.
7. On a scale of one to ten, **where ten is being like your family and friends and one is not,** where would you place yourself? Why did you choose that number? Be as specific as possible.
8. When it comes to this issue, do you believe that you will have an easy or difficult time performing your decision?
9. On a scale of one to ten, **where ten is having extreme difficulty and one is having no difficulty**, how would you rank your ability to perform your decision? Why did you choose that number? Be as specific as possible.
10. How frequently have you talked with family or friends about irrigation and water use before the start of this class?
11. After taking the class, how likely is it that you'll talk more with family or friends about irrigation?

APPENDIX 4. VALUES EXPLAINED

Values	Goals	Example
Conformity	Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms.	People should do what they're told and follow rules at all times
Tradition	Respect, commitment and acceptance of the customs and ideas that traditional culture or religion provide the self.	Do things the way learned from one's family, follow customs and traditions
Benevolence	Preservation and enhancement of the welfare of people with whom one is in frequent personal contact.	Help and care for the people you know and like
Universalism	Understanding, appreciation, tolerance and protection for the welfare of all people and for nature.	Every person in the world should be treated equally, justice for everybody
Self-Direction	Independent thought and action-choosing, creating, exploring	Be interested in things, being curious, trying to understand everything
Stimulation	Excitement, novelty, and challenge in life	Looking for an exciting life with adventures and risks
Hedonism	Pleasure and sensuous gratification for oneself.	Enjoy life, having a good time
Achievement	Personal success through demonstrating competence according to social standards	Be very successful, stand out, impress other people
Power	Control or dominance over people and resources.	Be in charge, tell others what to do and wanting them to do it
Security	Safety, harmony and stability of society, of relationships, and of self.	safety of one's country from its enemies is very important

Note: Table adapted from Schwartz *et al*., 2015.