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The effect of information source on higher education students' sustainability knowledge

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ABSTRACT

When it comes to what higher education students know about sustainability, where they learn matters. In this study, we explore the extent to which students' level of sustainability knowledge differed according to where they previously learned about the environment. In an online survey administered to undergraduate students enrolled at Michigan State University, a large university in the Midwestern region of the United States, we found a significant relationship between students' level of sustainability knowledge and their environmental learning source. Environmental knowledge gained in the classroom, both at the secondary and postsecondary levels, had the strongest (positive) influence on students' present sustainability knowledge, while there was a significant (negative) relationship between how frequently students gathered knowledge from their parents and their level of knowledge. Results from this study suggest that instructors need to be intentional about the types of prior knowledge they use as a springboard when teaching students about sustainability.

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Sustainability knowledge; informal learning; prior knowledge; information source

In light of the myriad of environmental and sustainability crises facing our world today, increasing students' level of sustainability knowledge should be a top priority of institutions of higher learning. This is especially true given the mounting realities of climate change, environmental degradation, water and food insecurity, biodiversity loss, and mass extinction (Costello et al. 2009; Hoegh-Guldberg et al. 2018; Brauch et al. 2009). 2010–2019 was the hottest decade ever measured on Earth, and 2019 was the second-hottest year recorded (NASA and NOAA Analyses Reveal Second Warmest Year on Record 2020). Inevitably, these environmental problems lead to intensified economic issues (such as inequity and economic volatility; Grubb et al. 2014; Hallegatte and Rozenberg 2017; Jakob and Steckel 2014) and social dilemmas (such as generational poverty and social injustice; Bullard 2018; Lu 2020; Mohai, Pellow, and Roberts 2009). Numerous models predict that these environmental problems (and their economic and social implications) will continue to accelerate, negatively impacting the quality of life on Earth (Costello et al. 2009; Hoegh-Guldberg et al. 2018; Brauch et al. 2009).

Although there is no silver bullet to solving current sustainability-related crises, higher education has been designated by scholars as the single most promising mechanism for preparing future generations to engage in the sustainable living that can save the planet (Dobson 2011; Orr 2005; Sterling 2001). In recent history, though, the support of sustainability education (at both the K-12 and higher education levels) in the United States has been inconsistent, largely

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based upon the political party of the current president. Former President Clinton established the President's Council on Sustainable Development which resulted in *Education for Sustainability (EfS): An Agenda for Action* (1996), and former President Obama touted support of the Sustainable Development Goals (The White House, Office of the Press Secretary 2015). During the United States' 4-year withdrawal from the Paris Climate Agreement under former President Trump, over 400 institutions pledged to remain committed to its goals (We Are Still In, n.d.). While 78% of registered voters support teaching children about climate change in school (Leiserowitz et al. 2021), political leadership on sustainability education remains sparse.

Independent of political efforts, several non-profit organizations have contributed toward infusing sustainability into higher education. For instance, Second Nature's *Presidents' Climate Leadership Commitment* (2009) is the commitment of signatories to lead their institutions to "accelerate research and educational efforts of higher education to equip society to re-stabilize the earth's climate." Resulting is the pledge to make sustainability a part of all students' educational experiences, regardless of their major field of study. However encouraging the infusion of sustainability into higher education may be, it is important to remember that students arrive on campus with their own strong (though not necessarily correct) preconceptions. Most students have heard family, peers, and media discuss climate change (Bulkeley 2000; Dispensa and Brulle 2003), while others have personally endured environmental disasters (Michel 2020a;) (i.e. drought or flood), and have firsthand experience with the changing climate (Leiserowitz 2006; Myers et al. 2013). This direct or indirect experience, along with previous phases of education (Juárez-Nájera, Dieleman, and Turpin-Marion 2006; Wheeler and Byrne 2003), then serve as a springboard, rather than foundation, for their future learning (Gutiérrez and Rogoff 2003; Ladson-Billings 2006). We understand a foundation to signify a base or grounding whereas a springboard is a departure point for change. Given that learning about sustainability entails engaging in cognitive dissonance between prior knowledge and newly acquired knowledge (Michel 2020a; Michel 2020b), we see students' prior knowledge a springboard for higher education level learning.

Absent from the empirical literature is an exploration of the extent to which students' level of sustainability knowledge differs according to where that knowledge was gained. Most of the literature has examined sustainability education in either the higher education context (e.g. Shephard et al. 2014; Zwickle et al. 2014) or in the K-12 context (e.g. Ardoin et al. 2018; DiEnno and Hilton 2005). Few studies have explored the effect of environmental knowledge from K-12, as well as relationships during these formative years (such as parents), on higher education students' sustainability knowledge. Evaluating the effectiveness of these sources is particularly important given that higher education is most effective when it speaks students' language in terms of their own backgrounds (Bransford, Brown, and Cocking 2000; Neumann 2014). Hence, the present study examines if the source of students' prior environmental knowledge influences their present understanding of fundamental concepts of sustainability. Our research was guided by the following question: Does students' level of sustainability knowledge differ according to where that knowledge was gained?

Conceptual framework

The conceptual framework that guides this study is divided into two parts: present sustainability knowledge and prior sustainability knowledge (information source).

Present sustainability knowledge

The first arm of the conceptual framework is *present sustainability knowledge*, or the level of sustainability knowledge students currently possess. In this context, we understand *sustainability* as per the Brundtland Commission's (1987) report entitled *Our Common Future*, wherein

sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (p. 1). We interpret this definition as the act of meeting the environmental, economic, and social needs of today, without compromising the ability of future generations to do so (Zwickle and Jones 2018); something that can only be achieved by citizens who are equipped with enough sustainability knowledge (Cortese 2003; Orr 2004). In particular, according to Miller, Muñoz-Erickson, and Redman (2011), *sustainability knowledge* can be defined as knowledge that: "recognizes the complexity of system dynamics; is socially robust; acknowledged by multiple epistemic cultures; and incorporates normative criteria (several of which will be examined below but may and should change in different contexts)" (p. 179).

To that end, we suggest that students' present sustainability knowledge ought to represent a deep understanding of the environmental, economic, and social domains (Elkington 2013). The environmental domain of sustainability concentrates on human impacts on the ecosystem (Costello et al. 2009; Hoegh-Guldberg et al. 2018; Brauch et al. 2009). The economic domain of sustainability recognizes that the interactions of humans occur within the natural environment, and in particular, use resources to create goods and services that add value to their lives (Edwards 2012; Leal Filho and Pace 2016; Sachs 2005). The social domain of sustainability represents the relationship between human rights, environmental justice, and corporate foresight (Iverson 2016, Merkel and Litten 2007). Although each domain of sustainability is important on its own, together, they offer more complete solutions to current crises. In union, these three domains can allow societies to sustain themselves amid the challenges of environmental limits, economic volatility, social injustice, and political instability (Rowe and Johnston 2013). As such, it is imperative that sustainability balances itself accordingly (Elkington 2013; Iverson 2016). Therefore, we suggest that present sustainability knowledge ought to reflect students' understanding of more than just environmental facts, but the interplay of the environmental, economic, and social domains of sustainability.

Measuring such interdisciplinary, systemic thinking across large populations presents significant challenges. A balance must be struck between the competing goals of theoretical integrity and analytical usefulness. The assessment of sustainability knowledge (ASK; Zwickle and Jones 2018) is a set of multiple-choice questions that measures one's awareness of fundamental concepts of sustainability (see Zwickle et al. 2014 for detailed analysis of the scale creation and validity). While certainly not every aspect of sustainability can be directly measured in such a manner, the items in the scale have been shown to be correlated with undergraduate students' levels of sustainability knowledge overall. In this study, we build off of the past research related to the role of sustainability knowledge in influencing sustainability behaviors (Heeren et al. 2016) to focus on the roots of that knowledge itself.

Information source

The other arm of our conceptual framework is information source, framed by a body of education literature that has stipulated the importance of prior knowledge in students' learning (e.g. Bransford, Brown, and Cocking 2000; Castillo-Montoya 2017; Kolb and Kolb 2017; Neumann 2014; Zull 2002). This scholarship stipulates that students learn better when instructors build on what students already know (their prior knowledge). Prior knowledge can be understood as the knowledge, beliefs, and skills students bring with them to the classroom, which in turn influence how they interpret and organize new information (Bransford, Brown, and Cocking 2000; Castillo-Montoya 2017; Kolb and Kolb 2017). Building from this previous literature (e.g. Bransford, Brown, and Cocking 2000; Zull 2002), we suggest that particular information sources can differ in how they influence students' present understanding of sustainability.

In the context of higher education, Michel (2020a) found that instances of prior knowledge employed by instructors when teaching students about new sustainability ideas include those

from their own personal experiences, high school coursework, college coursework, social roles and culture, family, friends, and media. Therefore, we asked students about four possible sources where they may have obtained information about sustainability issues: academic, personal experience, media, and institutional communication. Demographic characteristics, such as sex, race/ethnicity, major, and class year, due to their role in the formulation of knowledge, were also included.

Academic

Academically derived knowledge consists of subject matter students have learned from their previous formal schooling (Bransford, Brown, and Cocking 2000; Castillo-Montoya 2017). In particular, we consider two types of academic knowledge: secondary and postsecondary. In terms of K-12, many national educational systems, including the U.S., have introduced environmental education at the primary and secondary levels. Although limited, K-12 classrooms are increasingly allocating time to environmental topics (Benavot 2004; Church and Skelton 2010; Wheeler 2013), and textbooks continue to include more information on environmental crises (Bromley et al. 2011). As a result of international standardized testing and policy movements, many students enter higher education with some environmental knowledge from previous phases of education (Juárez-Nájera, Dieleman, and Turpin-Marion 2006; National Research Council 2012; Wheeler and Byrne 2003). In addition to the presence of learning experiences about the environment in high school, prior research has also found that students' level of enjoyment in learning about science and the environment impacts their knowledge and attitudes toward these topics beyond high school (DiEnno and Hilton 2005; Lyons and Quinn 2010). Students' perceptions of scientists (including their science teachers) also influence their knowledge about and engagement with related topics into and throughout their adult lives (Besley 2015; Jones, Howe, and Rua 2000).

In a postsecondary setting, college and university students are increasingly being exposed to sustainability subject matter throughout their studies. Many institutions have explicitly made room for sustainability in the academic space by initiating sustainability specific coursework, infusing the subject into the general education core requirements, and even creating sustainability majors and minors (Liu 2011; Rowe and Johnston 2013). The result is students who are likely to be exposed to sustainability in their coursework even if their major may be in a traditionally unrelated field (Cohen 2007; Reid and Petocz 2006).

Personal connections

The second information source we included was knowledge acquired by way of personal connections. Students are influenced by their family and friends in many ways, including how they think about highly controversial as well as political topics (Jennings and Niemi 2015), like sustainability. A recent study found that when adults converse about climate change with family and friends, in return they seek to learn related facts (like the scientific consensus that climate change is happening as a result of human behaviors). As such, discussing climate change with personal connections like family and friends leads to increased knowledge and concerns about the environment (Goldberg et al. 2019).

Additionally, today, most students have heard family and peers discuss climate change. For instance, prior research has found that the most important predictors of climate change skepticism among adolescents were the perceived skepticism among their parents and peers (Ojala 2012; Stevenson, Peterson, and Bondell 2019). In addition to absorbing what their family and peers say, students have also witnessed their behaviors (Mead et al. 2012; Ojala 2012) either in pro-environmental (like recycling or choosing organic foods) or unsustainable (like driving fuel inefficient vehicles or careless use of plastic). Exposure to unsustainable behaviors and anti-climate science messages from trusted sources like family members will consequently impact students'

sustainability attitudes. Given this strong influence of social norms from their personal community, students' personal connections are an important source of prior sustainability knowledge.

Media

Next, we looked at knowledge gained from two different kinds of media sources: traditional and social. In terms of traditional media, as a result of the increasing (and polarizing) coverage of climate change, students now arrive on higher education campuses with varying beliefs and opinions about sustainability (Jennings and Niemi 2015). Although on the decline among consumption from college-aged students (Hirst 2020), television, radio, and newspaper reporting remain a powerful force in providing citizens with vital information to consider the social, political, and environmental conditions nationally and internationally (Boyce and Lewis 2009; Dispensa and Brulle 2003; Smith 2005).

Additionally, people increasingly consume media information via social media in a manner that is user—rather than network—controlled. College students regularly use, communicate, and consume information with peers and other media sources by way of social networks, whether it is hearsay or credulous journalism (Clark and Marchi 2017; Sponcil and Gitimu 2013; Wang, Chen, and Liang 2011). Social media has the potential to influence students' perceptions. For example, McKenzie-Mohr (2011) shared examples of sustainable behaviors that have been influenced by social diffusion (in ways such as their social networks) such as installing programmable thermostats and solar panels. To date, the literature does not unanimously agree on the impact of media (both traditional and social) on sustainability knowledge. Given the barrage of information on all sides of the issue, and the tendency of social media sources to provide content oriented toward user preferences, we posit that either type of media can serve primarily as a source of confirmation.

Institutional communication

Institutions offer many pathways to communicate with students. One way is through instructors imparting knowledge upon students in the traditional context of the classroom. But classroom time is only a fraction of students' full college experience—and institutions also convey knowledge through channeling communications via university websites and printed materials (Chapleo, Carrillo Durán, and Castillo Díaz 2011; Jevons 2006). For example, in the dining hall, an institution may hang a poster asking students to compost their food waste, explaining why this is important. Such less traditional forms of "teaching" are also useful methods for institutions to communicate about sustainability with students. Since such communications can have an ancillary impact on the establishing of a social norm surrounding sustainability knowledge, attitudes and behaviors, we included it in our framework.

Demographic characteristics

The final component of our information source framework is identity, as prior knowledge is considerably affected by students' demographic characteristics (González, Moll, and Amanti 2006; Ladson-Billings 2006, 1995). Since students develop knowledge and internalize concepts from everyday life (González, Moll, and Amanti 2006), along with social and cultural interactions (Bernal 2002), their knowledge is rooted deeply within their identity, such as race, ethnicity, socio-economic status, and religion. These identities reflect larger social, cultural, and historical realities that are not explicitly covered in the other information sources (Castillo-Montoya 2017). In particular, we measured four expressions of identity that prior literature has shown important in understanding sustainability: sex (Gough and Whitehouse 2020; Luchs and Mooradian 2012; Yates et al. 2015), race/ethnicity (Brainard, Jones, and Purvis 2009; Bullard et al. 2008), class year (as a proxy for age) (Wiernik, Dilchert, and Ones 2016), and major field of study (Lang 2011).

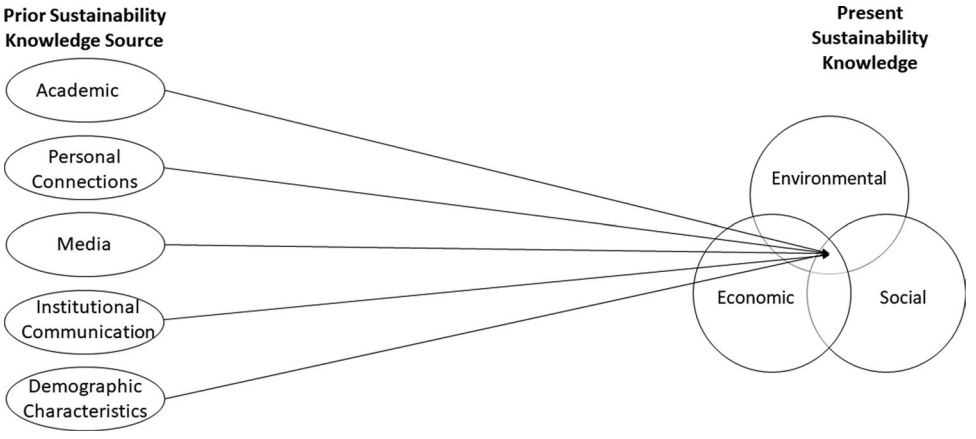

Figure 1. Conceptual model.

Influence of previous information source on measured knowledge

In this study, we explored the relationship between where students previously learned about sustainability and their current level of sustainability knowledge. We suggest that each information source can differentially influence the comprehensive state of students' present sustainability knowledge (Figure 1).

Procedures

Site

The present study used data from a survey conducted at Michigan State University (MSU), a large, public, four-year, research intensive university. MSU is visibly active in a variety of sustainability initiatives, holding a silver Association for the Advancement of Sustainability in Higher Education (AASHE) Sustainability Tracking, Assessment & Rating System (STARS) rating ("About MSU Sustainability," n.d.) and publicly indicating its commitment to supporting climate action to meet the Paris Agreement ("We Are Still In," n.d.) under the United States' withdrawal.

Sample

The data for this study was collected through the 2015 iteration of the annual MSU sustainability survey. Students were sent an email invitation at the beginning of the spring 2015 semester and three follow-up reminders asking them to participate in the electronic survey. To capture a wide range of undergraduate students, 25,000 undergraduate students, approximately 60% of total undergraduate enrollment, were randomly chosen to participate in the study, with 2,841 (11.3%) students completing the entire survey. A chi-square test was conducted to compare the sample to the overall student population, showing that females (60.4%) and students who identified as Asian (16.3%) were statistically overrepresented, while Black or African American students (4.7%), Hispanic, Latino/a/x or of other Spanish origin (3.0%), and White students (72.5%) were statistically underrepresented. For a complete picture, the representativeness of the study sample compared with the overall student population can be seen in Table 1.

Instrument

Students' level of sustainability knowledge was measured using the revised Assessment of Sustainability Knowledge (ASK; Zwickle and Jones 2018), which assessed students' knowledge

Table 1. Representativeness of student sample ($N = 2,841$) compared with student population ($N = 39,090$).

	Student sample		Student population	
Demographic characteristics	N	%	N	%
Sex				
Female	1642	60.4	19,778	50.6
Male	1078	40.6	19,312	49.4
Race/Ethnicity				
Asian	463	16.3	1946	5.8
Black or African American	134	4.7	2742	8.1
Hispanic, Latino/a/x or of Spanish Origin	86	3.0	1629	4.8
White	2061	72.5	26169	77.7
Other	97	3.4	1191	3.5

Note: Inconsistencies in numbers are due to missing data.

of fundamental sustainability concepts. The revised ASK was adapted from a previous version (Zwickle et al. 2014) to include items with a blend of questions of varying difficulty covering the environmental, economic, and social domains. Each item was presented in a multiple-choice format with one correct option, three incorrect options, and an "I don't know" option to reduce guessing. ASK survey questions, response options, and percentage of student results can be found in Table 2.

We then questioned participants about where they had learned about environmental-related information. Students were asked to respond to each item on a 7 point scale as to how often they gathered environmental knowledge from a specific source with values ranging from 1 = never to 7 = daily from each of the sources. Finally, we asked how good or bad their high school environmental studies coursework experiences were, from 1= very bad experience to 7= very good experience. These items can be found in Table 3.

Analyses

We ran ordinary Least Square (OLS) regression with Stata 14 software to test for a relationship between students' level of sustainability knowledge and information source. Our dependent variable was a sum of the revised ASK questions that students answered correctly. Our independent variables were how positive or negative student participants reported their experiences with high school environmental studies classes, and how often students gathered environmental knowledge from the sources specified in our prior knowledge framework (academic, personal connections, institutional communication, and media), as well as demographic characteristics.

Results

Descriptive results

Descriptive statistics of variables employed in our study are reported in Table 3. In terms of area of study, just under half the sample majored in natural science disciplines. Student participants were spread across the four traditional class year categories. On average, students got 7.57/12 (or 63.1%) ASK questions correct on the assessment. Overall, the student sample noted very good experiences with environmental studies classes in high school.

Students reported gathering environmental knowledge most frequently from social networks, then from higher education coursework, then from TV/Radio, followed by campus posters, friends, printed news, printed materials, and university websites. The least frequent source of environmental knowledge was parents/guardians, as illustrated in Figure 2.

Table 2. Revised assessment of sustainability knowledge (ASK) questions and answers.

Question	Response Options	Percentage of student results
What is the most common cause of pollution of streams and rivers?		
	Dumping of garbage by cities	8.3%
	Surface water running off yards, city streets, paved lots, and farm fields	55.8%
	Litter near streams and rivers	4.4%
	Waste dumped by factories	25.0%
	Don't know	6.5%
Ozone forms a protective layer in the earth's upper atmosphere. What does ozone protect us from?		
	Acid rain	2.5%
	Climate change	3.8%
	Sudden changes in temperature	3.1%
	Harmful UV rays	88.1%
	Don't know	2.5%
Which of the following is an example of sustainable forest management?		
	Setting aside forests to be off limits to the public	11.5%
	Never harvesting more than what the forest produces in new growth	75.6%
	Producing lumber for nearby communities to build affordable housing	3.2%
	Putting the local communities in charge of forest resources	4.1%
	Don't know	5.6%
Of the following, which would be considered living in the most environmentally sustainable way?		
	Recycling all recyclable packaging	35.4%
	Reducing consumption of all products	50.4%
	Buying products labeled "eco" or "green"	10.6%
	Buying the newest products available	0.5%
	Don't know	3.1%
Which of the following is the most commonly used definition of sustainable development?		
	Creating a government welfare system that ensures universal access to education, health care, and social services	8.5%
	Setting aside resources for preservation, never to be used	6.6%
	Meeting the needs of the present without compromising the ability of future generations to meet their own needs	72.5%
	Building a neighborhood that is both socio-demographically and economically diverse	3.3%
	Don't know	9.1%
Over the past 3 decades, what has happened to the difference between the wealth of the richest and poorest Americans?		
	The difference has increased	87.3%
	The difference has stayed about the same	4.6%
	The difference has decreased	3.6%
	Don't know	4.4%
Many economists argue that electricity prices in the U.S. are too low because…		
	They do not reflect the costs of pollution from generating the electricity	60.3%
	Too many suppliers go out of business	2.3%
	Electric companies have a monopoly in their service area	17.7%
	Consumers spend only a small part of their income on energy	5.1%

	Don't know	14.6%
Which of the following is the most commonly used definition of economic sustainability?		
	Maximizing the share price of a company's stock	4.6%
	Long term profitability	50.2%
	When costs equal revenue	22.6%
	Continually expanding market share	8.1%
	Don't know	14.5%
Which of the following countries has now passed the U.S. as the biggest emitter of the greenhouse gas carbon dioxide?		
	China	81.6%
	Sweden	1.8%
	Brazil	2.0%
	Japan	4.2%
	Don't know	10.5%
Which of the following is a leading cause of the depletion of fish stocks in the Atlantic Ocean?		
	Fishermen seeking to maximize their catch	35.5%
	Reduced fish fertility due to genetic hybridization	4.5%
	Ocean pollution	33.0%
	Global climate change	16.8%
	Don't know	10.1%
Which of the following is the best example of environmental justice?		
	Urban citizens win a bill to have toxic wastes taken to rural communities	6.7%
	The government dams a river, flooding Native American tribal lands to create hydro-power for large cities	5.4%
	All stakeholders from an indigenous community are involved in setting a quota for the amount of wood they can take from a protected forest next to their village	68.8%
	Multi-national corporations build factories in developing countries where environmental laws are less strict.	4.5%
	Don't know	14.6%
Put the following list in order of the activities with the largest environmental impact to those with the smallest environmental impact: A. Keeping a cell phone charger plugged into an electrical outlet for 12 hours B. Producing one McDonald's quarter-pound hamburger C. Producing one McDonald's chicken sandwich D. Flying in a commercial airplane from Washington, D.C. to China		
	A, C, B, D	7.2%
	D, A, B, C	44.1%
	D, C, B, A	8.1%
	D, B, C, A	34.6%
	Don't know	6.0%

Note: Correct answers are in bold.

Univariate results

Results of the OLS regression revealed that where students gained their environmental knowledge in the past significantly influenced their current level of sustainability knowledge, as seen in Table 4. Students who reported learning about environmental issues from formal coursework, both at the secondary and postsecondary levels, had significantly better sustainability knowledge. More specifically, there was a significant positive relationship between how frequently

Table 3. Descriptive statistics and coding ($N = 2{,}720$).

Variable	Coding/ Frequency	Mean	SD
Number of correct responses on the ASK	1–12	7.57	2.68
How good or bad students' experiences with environmental studies classes were in high school	1 = very bad experience 2 3 4 5 6 7 = very good experience	6.36	1.71
How often students gather environmental knowledge	1 = never 2 3 4 5 6 7 = daily		
Higher education coursework		4.07	1.73
Parents/guardians		3.23	1.72
Friends		3.56	1.73
Social networks		4.46	1.74
University websites		3.32	1.71
Campus posters		3.73	1.72
Printed materials		3.46	1.71
TV/Radio		3.77	1.73
Printed News		3.46	1.72
Sex	Female: 60.4% Male: 40.6%		
Race/Ethnicity	Asian: 16.3% Black or African American: 4.7% Hispanic, Latino/a/x, or of Spanish Origin: 3.0% White: 72.5% Other: 3.4%		
Major Discipline	Natural science: 45.8% Not natural science: 54.2%		
Class Year	First Year: 20.9% Sophomore: 20.1% Junior: 28.5% Senior: 30.5%		

students gathered environmental knowledge from higher education courses (by way of in-class discussions and readings) and their current level of sustainability knowledge (β=.148, $p \leq .001$). Classroom learning, at the postsecondary level, had the strongest (positive) influence on students' present sustainability knowledge. Closely related, how much students enjoyed their high school classroom experiences with environmental studies, was also a powerful a factor in sustainability knowledge. There was a significant positive relationship between students' experience with environmental studies classes in high school and current level of sustainability knowledge (β=.141, $p \leq .001$).

Next, we examined the relationship between the frequency with which students learned from personal connections and their present sustainability knowledge. There was a significant negative relationship between how frequently students gathered environmental knowledge from their parents/guardians and their current level of sustainability knowledge (β=–.146, $p \leq .001$). In other words, the more students received environmental information from their parents, the less they knew about fundamental concepts of sustainability. There was no significant relationship between the frequency of learning about the environment from friends and present level of sustainability knowledge ($p \geq .05$).

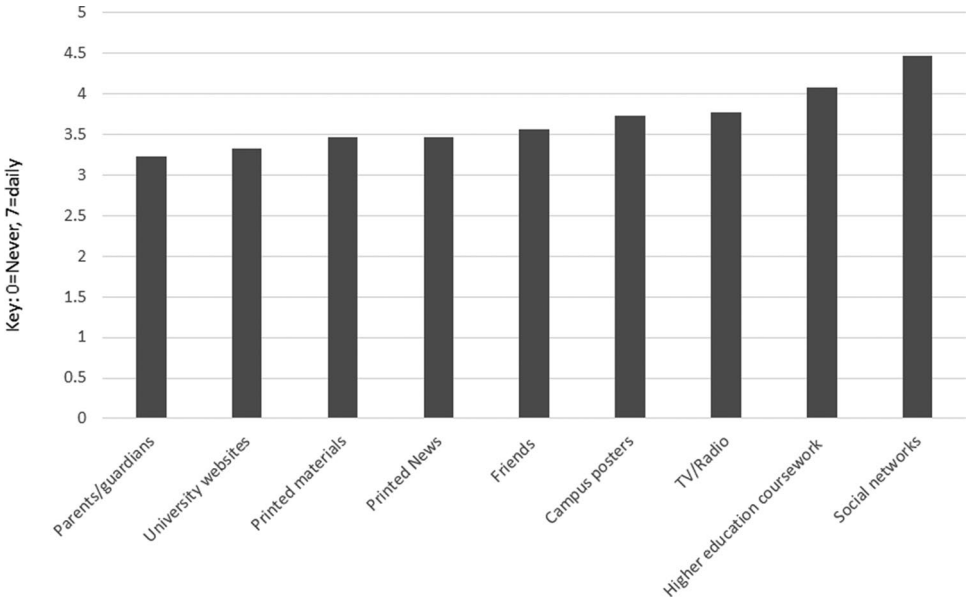

Figure 2. Frequencies for often students gain sustainability knowledge from different sources.

Table 4. Standardized coefficients of predictor and control variables on number of correct responses on the ASK ($N = 2{,}720$).

	Number of Correct Responses on the ASK
How good or bad students' experiences with environmental studies classes were in high school	.141***
How often students gather environmental knowledge from	
Higher education coursework	.148***
Parents/guardians	−.146***
Friends	.020
TV/Radio	−.018
Printed News	.015
Social networks	.091***
University websites	−.114***
Campus posters	.011
Printed materials	−.059*
Sex (female is the reference group)	.123***
Race (not identifying as this race is the reference group)	
Asian	−.113***
Black or African American	−.071***
Hispanic, Latino/a/x or of Spanish Origin	.002
White	.224
Other Race	−.003
Senior Class Standing	.077***
Natural science major	.052***
adj. R^2	.271

Notes: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

In terms of the influence of media on sustainability knowledge, we investigated both traditional types of media as well as social media. With regard to traditional media sources, neither gathering environmental news from TV/radio ($p \geq .05$), nor printed news ($p \geq .05$) influenced students' present level of sustainability knowledge ($p \geq .05$). There was, however, a

significant positive relationship between how frequently students gathered environmental knowledge from their social networks (such as Facebook and Twitter) and their current level of sustainability knowledge (β=.091, $p\leq$.001).

Two sources of institutional communication had significant negative relationships with current sustainability knowledge. Students who reported more frequently gaining environmental knowledge from university websites (β=–.114, $p\leq$.001) and university-produced printed materials (β=–.059, $p\leq$.05) had lower knowledge scores. There was no significant relationship between the frequency of learning about the environment from campus posters and present level of sustainability knowledge ($p\geq$.05).

Finally, we explored the relationship between student demographics and sustainability knowledge. Our results showed that students' sex was related to their sustainability knowledge (β=.123, $p\leq$.001), with males on average scoring 7.88/12 on the sustainability knowledge assessment, while females scored 7.30/12. In terms of race, students identifying as white had significantly higher sustainability knowledge (β=.224, $p\leq$.001; = 8.16), while students who identified as Asian (β=–.113, $p\leq$.001; = 5.46) or Black or African American (β=–.071, $p\leq$.001; = 5.80) had lower sustainability knowledge scores. Race was not significantly related to sustainability knowledge for those students who identified as Hispanic, Latino/a/x or of Spanish Origin (6.81/12) or of another race (6.85/12; $p\geq$.05). Furthermore, students with senior class standing had higher levels of sustainability knowledge than their first-year, sophomore, and junior-year counterparts (β=.077; $p\leq$.001). Seniors had a mean score of 8.09/12, while the average of first-year students was 6.60/12; sophomores averaged 7.25/12, and juniors 7.87/12. Natural science majors had significantly greater levels of sustainability knowledge than non-natural science majors (β=.052; $p\leq$.001). On average, those majors scored 7.92/12 on the sustainability knowledge assessment, while their non-science counterparts earned 7.26/12.

We employed nested F tests in order to explore possible interactions between information sources and demographics (race, gender, major, and class year). None of these tests were significant and thus results presented here only focus on the main effects (and not interactions).

Discussion

In this study, we explored the extent to which students' current knowledge of fundamental concepts of sustainability was related to where they obtained information in the past. As using past knowledge as a springboard for learning has been proven to be an effective teaching technique (Bransford, Brown, and Cocking 2000; Kolb and Kolb 2017; Zull 2002), we tested whether all prior information sources were equally beneficial. Our results were mixed, showing that some sources of information were connected to greater levels of sustainability knowledge, some were associated with lower levels of knowledge, and others had no effect. Formal education in both secondary and postsecondary classroom settings had the strongest positive relationships with knowledge, closely followed by how much students enjoyed those classes. On the other hand, environmental information gained from parents was found to be associated with lower levels of knowledge. These results can provide instructors with insight on how to use students' prior knowledge to help them learn new sustainability-related concepts.

Formal classroom learning

It comes as no surprise that students who reported learning about environmental issues from formal coursework, both at the secondary and postsecondary levels, had significantly higher sustainability knowledge scores. Our findings support prior literature that bridges K-12 and higher education learning (instead of looking at them separately; Kirst and Venezia 2001; Kuh et al. 2007) as our results show that K-12 learning influences higher education level-sustainability knowledge. The present study also demonstrates the effectiveness of implementing sustainability

across the higher education curriculum (Azar, Holmberg, and Lindgren 1996; Hopkinson and James 2010; Michel 2020b), as students who learned about sustainability in their previous college coursework demonstrated higher levels of sustainability knowledge. It should be noted that it is possible that the effect of academic interventions may be exaggerated by the fact that our measure of sustainability knowledge is academic in nature.

Additionally, students who enjoyed their environmental science courses in high school demonstrated higher levels of knowledge than those who did not, reinforcing the notion that an enjoyable learning environment translates to better learning and retention (DiEnno and Hilton 2005; Lyons and Quinn 2010). This also supports prior literature that advocates for transitioning away from rote lecture and employing more innovative and engaging pedagogies (Campbell et al. 2017; Carini, Kuh, and Klein 2006; Pascarella and Terenzini 2005) when teaching about sustainability (Christie et al. 2013; Rouhiainen and Vuorisalo 2019; Walshe 2017; Michel 2020a).

Media

None of the sources of traditional media significantly influenced students' sustainability scores (neither TV/radio nor printed news). On the contrary, the more frequently students gained environmental news from their social networks, the higher their sustainability knowledge scores. This finding reflects a broader trend, as younger generations are increasingly getting their news from social rather than traditional media outlets (Gangadharbatla, Bright, and Logan 2014; Rosengard, Tucker-McLaughlin, and Brown 2014). Additionally, social media algorithms are configured to show people content that interests them, meaning students who report getting environmental news from social media represent a subset of the population that is likely more interested in sustainability issues. Finally, the distinction between traditional and social media is largely artificial, as much of the filtered information students receive from social media actually comes from "traditional" news organizations.

Personal connections

While there was no association between friends and peers as an information source on students' sustainability knowledge, there was a negative relationship between parents as an information source and students' sustainability knowledge. In other words, the more environmental knowledge a student obtained from their parents, the more likely that knowledge was to be incorrect. This negative association provides an opportunity for instructors to use what students' learned from parents as a pathway to teaching about sustainability.

Neumann's (2014) cognitively responsive teaching framework suggests that good instructors support students both emotionally and cognitively when the subject matter being taught leads them to question long-held beliefs within the process of reconciling prior knowledge with what they are learning. Instructors should provide opportunities for students to express being challenged by comparing of old (prior) and new ideas, as learning happens when a student negotiates differences between prior views and new subject matter ideas from the course (Bransford, Brown, and Cocking 2000; Shulman 2004). It is important to surface prior knowledge learned from parents, and if incorrect, support students through the tension between the prior knowledge they learned from parents and the new knowledge to change and correct it.

Demographic characteristics

The final component of information source that we examined was identity, as prior knowledge is considerably affected by students' demographic characteristics (González, Moll, and Amanti 2006; Ladson-Billings 2006, 1995). The male students in our sample had higher knowledge scores than female students, reinforcing Gough and Whitehouse (2020) challenge to reframe

climate change education though an ecofeminist lens. White students scored higher than other racial and ethnic groups. A possible explanation for this common trend is that minoritized racial students, although disproportionately affected by climate change (Brainard, Jones, and Purvis 2009; Bullard et al. 2008) enroll with lesser frequency in sustainability coursework (Garibay, Ong, and Vincent 2016), and thus have had fewer opportunities to learn about sustainability and the environment. Given that, we advocate for initiatives to recruit and support racially minoritized students in natural science majors. Students with senior-class standing had higher knowledge scores than their lower class standing peers. Prior research has shown that sustainability learning increases when students are exposed to this topic in higher education classrooms (Ryu and Brody 2006; Wolfe 2001), and therefore, results from the present study reinforce the notion that more exposure to learning (as evidenced by more time in college) results in higher knowledge.

Conclusion

The present study examined if the source of students' prior environmental knowledge influenced their present understanding of fundamental concepts of sustainability. We found that students come to higher education with different levels of knowledge on sustainability, and not all prior knowledge is created equal. Knowledge gained from certain sources, especially academic experiences at both the secondary and postsecondary levels, better influence students' present knowledge.

While sustainability faculty may know that students bring a swath of information and levels of knowledge with them to the classroom, implications from this study shed light upon the benefits of engaging in teaching practices to support students in bridging their prior knowledge with new classroom knowledge. Prior literature has stipulated that faculty (particularly natural science faculty) typically do not receive pedagogical training during their doctoral careers (Austin 2002; Gardner and Jones 2011). As such, practice oriented implications from our study are that sustainability faculty ought to intentionally call upon students' formal classroom learning experiences, informal learning experiences from parents, friends, and the media, and their social and cultural roles to assist them in more deeply learning about sustainability. And, given that there have been limited efforts to provide faculty with the professional development to equip them with the pedagogical tools essential to teach sustainability subject matter (Michel 2020a), we suggest that policymakers advocate for pedagogical training for instructors teaching about politically charged and complex subject matter, like sustainability.

Limitations

This study has important limitations which should be kept in mind when considering the generalizability of the findings. The first is our operationalization of prior sustainability knowledge. We chose to ask students about their source of information about *environmental* issues, while we measured sustainability knowledge across three domains. We chose this as a proxy measure as many students equate environmental issues with sustainability, they likely would discuss environmental issues without using the term "sustainability," and may have been confused about what exactly the term "sustainability information" meant.

Additionally, our study only measured the source of prior information, and not the quality or accuracy of it. From that perspective, although we found that students who learned about environmental issues from their parents/guardians demonstrated lower levels of sustainability knowledge, we were unable to conclude that what they learned from their parents was necessarily incorrect. Perhaps knowledge gained this way is simply insufficient, or focused on specific, localized events. Future research should investigate this negative relationship more fully to better understand these important interactions between parents and children.

Finally, the use of multiple-choice questions to measure an expansive concept such as sustainability is inherently limiting. Such a measure requires simple correct/incorrect responses, making it impossible to gauge partial knowledge or contextual nuances. The necessary creation of one succinct correct answer likewise complicates a systems-thinking approach to sustainability. It is important to state that the ASK should not serve as a definitive measure of the entirety of an individual's sustainability knowledge. Rather, its usefulness lies in its ability to compare scores in the aggregate across large populations.

Disclosure statement

No potential conflict of interest was provided by the author(s).

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