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Scientists, Religious Experts, and other Sources of Knowledge: Non-Science Majors' Beliefs about Controversial and Noncontroversial Questions

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ABSTRACT

This study explores the beliefs of non-science majors in an undergraduate biology classroom as part of a larger study on evolution education. Groups of students (n=12) were given fourteen questions, some potentially controversial and some non-controversial, and asked to create categories based on what type of authority students would turn to as a source of knowledge. Examples of questions included "How did all lifeforms come to live on Earth?", "What happens to us after we die?", and "How did the Grand Canyon form?" We coded card sort results to examine how the sources of knowledge categories differed depending on the controversial nature of the question, its science/non-science content, and student groups' evolution acceptance survey scores. Student groups created 35 sources of knowledge ranging from broad sources such as "scientist" to very specific sources such as "God" and "environmental biologist". Results also showed that seven out of 10 controversial questions were placed in categories of questions to be answered by God or religious experts, while non-controversial questions were deemed answerable by scientists. This study shows that students' beliefs about knowledge and authority vary, and that biology educators should be aware that their non-major students often consider non-scientific sources of knowledge when thinking about controversial scientific issues.

Keywords: biology education, epistemology, evolution education, community colleges

Introduction

This study explores non-science majors' beliefs about sources of knowledge in an undergraduate biology classroom. The ability to evaluate sources of knowledge as valid and pertinent is an important part of all students' learning. It is especially important in science education as students are often confronted with science knowledge about topics such as evolution, climate change, or vaccines that can be considered controversial by the public. In this paper, we will examine and describe non-science majors' beliefs about what sources of knowledge should be considered when thinking about both controversial and non-controversial topics.

This data is part of a larger study consisting of community college students (Green & Delgado, 2021). The larger study included a carefully designed intervention based on the cultural border crossing (Aikenhead, 1997) theoretical framework, which posits that some students might experience a figurative border crossing between their home cultures and the science classroom culture. The intervention was also based on the collateral learning theoretical framework, in which Jegede (1995) suggested that students might use collateral learning as a cognitive process that allows them to accommodate possibly conflicting ideas. These two theoretical frameworks were the basis of an intervention designed to allow biology students in the sample to increase understanding and acceptance of evolution without being asked to discard any religious beliefs, or worldviews, that seemingly contradict evolution (Green & Delgado, 2021). The research discussed in this paper is part of that intervention.

Sources of Knowledge and Science Learning

The ability to evaluate knowledge sources, consult multiple sources, and use reliable scientific sources are important goals in science education. The Science and Engineering Practices embedded into the Next Generation Science Standards (NGSS Lead States, 2013) reflect the importance of this epistemological development in Practice eight. Obtaining, Evaluating, and Communicating Information. The Grades 6-8 and 9-12 recommendations highlight the use of multiple sources of knowledge and the assessment of the credibility, accuracy, and bias of sources (NGSS Lead States, 2013). While the AAAS *Vision for Change in Undergraduate Biology* does not specifically address the importance of sources of knowledge, it advocates for student-centered biology core competencies that position undergraduate biology students to take ownership of their learning by *doing* science in terms of generating and testing hypotheses using evidence (Brewer & Smith, 2011). Similarly, Bravo-Torija and Jimenez-Aleixandre (2018) developed a learning progression for the use of evidence in decision making contexts. At the lowest levels, students are able to extract information from sources in response to prompts. At higher levels, students integrate evidence from multiple sources but only support their own position. At the highest levels, students synthesize evidence from multiple sources by supporting their choice and disconfirming other choices (Bravo-Torija & Jimenez-Aleixandre, 2018).

Some science education studies have investigated beliefs about sources of knowledge in relation to science learning. When elementary school children were asked to justify their scientific knowledge, most sought justifications for knowledge, other than appeals to authority when possible. These students first justified conclusions with data, than other plausible mechanisms, and only looked to authorities when data lacked conclusiveness (Sandoval & Cam, 2011). In a high school context, high school science students cited several sources of knowledge in their science learning including trials and testing, discipline-based theory, class members, the teacher, parents, and other students outside of class. When presented with open-ended tasks, these high school students tended to draw on more sources of knowledge than during close-ended tasks (Venville et al., 2004). College students who consider and question the authority of sources tend to more often justify conclusions with multiple sources (Braten et al., 2014) and maintain that scientific knowledge is tentative (Liu et al., 2011). Furthermore, secondary students who justified knowledge with research-based authorities like scientists held more adaptive beliefs about Internet information (Cheng et al., 2021). Based on these results, some authors advocate for science instruction that explicitly elicits students' epistemological ideas to identify and address concepts that are justified primarily through teachers' or scientists' authority (Hofer, 2020; Sandoval & Cam, 2011).

Epistemological beliefs are important predictors of other desired outcomes in science education. First, epistemological sophistication is associated with approaches to learning science content. In a study of college science majors, students with less sophisticated epistemological beliefs about sources of knowledge were more likely to rely on memorization of content for tests (Liang & Tsai, 2010) rather than engage in deeper learning strategies employed by their more epistemologically-sophisticated peers (Lin et al., 2012). Second, Fulmer (2014) found that undergraduates had more positive views of science when they believed scientific knowledge is derived from authority, a less sophisticated epistemological view. Fulmer (2014) explained this surprising finding in that the students viewed their science faculty as content experts who derived their authority from their secular academic accomplishments. Additionally, undergraduate students who justified their claims using information from multiple sources demonstrated more comprehensive argumentation when confronting a socioscientific issue (SSI) such as climate change (Braten et al., 2014). Finally, epistemological beliefs such as those about sources of knowledge matter because they influence how people learn, search for information, evaluate claims, apply scientific knowledge, and engage in civic duties. (Hofer, 2020). Clearly, epistemological beliefs about sources of knowledge are important for engagement in science learning, attitudes toward science, and argumentation quality.

Sources of Knowledge and Controversial Science

Scientific knowledge can be controversial for a variety of ways – active science that is controversial within the scientific community, societally-denied science that is widely accepted within the scientific community but contested within society, and SSI (Borgerding & Dagistan, 2018). When reasoning about societally-denied science like evolution, learners often appeal to authorities. The authorities may include scientists, teachers, religious leaders, and parents (Borgerding et al., 2017). In one study of college undergraduates, upperclassmen biology majors appealed to authority less than lower classmen biology majors and nonmajors (Borgerding et al., 2017). Yet, when reasoning about SSI, Liu et al. (2011) found that science majors tended to be less critical of science information about an SSI and more often appealed to scientific authority when compared to their nonmajor counterparts. These findings indicate that background knowledge or identity associated with a college science major may be important as college students consider referencing various authorities.

Researchers have investigated how students confronting SSIs consider and evaluate sources of knowledge. Students examining socioscientific issues often recognize that some sources are more credible than others (Stadtler et al., 2016; Yazici et al., 2016). When preservice social studies teachers examined a nuclear power plant safety SSI, participants readily concluded that scientists working on the issue were most trustworthy, while Parliament officials, nuclear power companies, and television news were the least trustworthy sources of knowledge in that order (Yazici et al., 2016). Students most often attend to the credibility of the source by determining if the source is authoritative/expert versus partisan and/or scientific versus non-scientific (Mason et al., 2010). Other students finding sources for evaluating an SSI about stem cell research used the language of the authors, the authors' statuses within their field, and the content of the source for determining source credibility (Witzig et al., 2013). Previous research has shown that students who evaluate the credibility of sources of knowledge for SSI tend to use multiple sources of knowledge (Braten et al., 2014; Mason et al., 2010). When students are confronted with conflicting evidence about an SSI, they tend to rely more on the quality of the source than their own content knowledge (Bromme et al., 2015) and are more likely to question the motivations of the scientists when the sources differed in terms of their implied trustworthiness (Gottschling et al., 2019). Ultimately, students who attend to the credibility of sources of knowledge about SSI outperform their peers on learning goals (Mason et al., 2010). Importantly, the ability to choose more credible sources of knowledge can improve with training. Training that included awareness of expertise and the importance of source competence when choosing a source of knowledge for issues, such as carbon sequestration or protection of endangered zoo animals, increased vocational students' selection of pertinent expert sources and citation of these sources to justify judgements (Stadtler et al., 2016).

When confronted by societally-denied science topics such as evolution or anthropogenic climate change, sources of knowledge can be particularly important for science learners. Climate change education studies have illustrated the importance of authorities and perceived credibility of sources of knowledge. Wodika and Schoof (2017) identified formal education, the media, and family as sources of college students' climate knowledge. When American college undergraduates evaluated an article about climate change, they perceived trustworthiness of the source and the certainty of the message were better predictors of the plausibility of the message than knowledge of anthropogenic climate change (Lombardi et al., 2014). Additionally, in a study of undergraduates who were provided with a list of scientific authorities and had to choose relevant experts for a climate change scenario, participants largely identified scientists with relevant disciplinary expertise, such as earth scientists, even though the participants had relatively little general science knowledge themselves (Bromme & Thomm, 2015).

Evolution is a particularly complicated example of societally-denied science in terms of credible sources of knowledge. College biology students rely on both religious and scientific authorities to justify their rejection or acceptance of evolution (Borgerding et al., 2017). In that study, students with overall low epistemological sophistication were more likely to rely on authorities and less accepting of evolution in general than their higher epistemological peers. Similarly, Metz et al. (2018) found that evolutionists used empirical evidence and scientific consensus as criteria for their evolution acceptance while Creationists relied on religious authority and "knowledge of the heart" as their justification. Clearly, people rely on and evaluate authorities when identifying sources of knowledge for their positions on societally-denied science.

Importantly for evolution education, learners may view evolution differently than other science subjects because of perceptions of conflict with some religious beliefs (Barnes et al., 2020). Sinatra et al. (2003) examined college learners' understandings, acceptance, and epistemological dispositions surrounding controversial topics (animal evolution and human evolution) and noncontroversial topics (photosynthesis and respiration). As their participants' knowledge of photosynthesis and respiration increased, so did their acceptance of these theories. However, increased knowledge of evolution was not correlated with acceptance of theories about animal or human evolution. Importantly, epistemological sophistication and having an open-minded thinking disposition were correlated with human evolution acceptance, but not acceptance of animal evolution or photosynthesis and respiration. These findings demonstrate that learners view human evolution differently, than less controversial science content such as photosynthesis and respiration. Based on these findings, this study sought to identify participants' sources of knowledge for varying controversial and non-controversial science topics including both animal and human evolution in particular.

This paper focuses on how undergraduates in an introductory biology class for non-majors identify sources of knowledge that could be used to answer scientific and non-scientific questions that vary in terms of their potential controversy. In this research, we aimed to answer the following research questions:

1. What sources of knowledge do community college biology students seek, to answer potentially controversial and noncontroversial questions?
2. To what extent do sources of knowledge differ for potentially controversial and non-controversial science questions?
3. Does evolution acceptance predict the sources of knowledge chosen for potentially controversial and noncontroversial science questions?

Methodology

Sample

Community college students (N=28) taking Biology 110 at a community college in the Southeastern United States participated in this research. All students were earning a non-science degree (Business Administration, Hospitality Management, etc.) and took biology as their only science requirement for a two-year degree. Students could choose between two scientific fields (biology and geology) to satisfy their science requirement. Biology 110 covered cell and molecular biology, genetics, evolution, and ecology with evolution being taught as the penultimate unit of the semester. The course was taught by Mr. Gloucester (a pseudonym), who has Bachelor's and Master's degrees in Biology and has taught at the community college level for nine years. Students were asked to work with their self-selected table mates during this activity. Twelve groups were formed, with the smallest group size as two students and the largest group containing four students. Because the card sort activity was designed as a pedagogical component of the intervention, we asked students to work in pairs/groups rather than independently.

Data Sources

Card Sort

As previously mentioned, data reported in this manuscript are part of a larger research project focused on an intervention designed to help facilitate evolution understanding and acceptance as needed by community college biology students with religious worldviews. The intervention included daily mini-lessons delivered in Biology 110 guided by the cultural border crossing and collateral learning theoretical frameworks. The mini-lessons were scripted for Mr. Gloucester, and the first author attended all evolution lectures to ensure that the lessons were implemented with fidelity (Green & Delgado, 2021).

In this part of the research, we collected card sort data. Card sorts ask participants to place things into groups; cards can contain pictures or words. They are often used as an exploratory technique when the aim is to collect information on categories people use (Rugg & McGeorge, 1997). Card sorts have been previously used to collect data on various science education topics such as orientations to science teaching (Friedrichsen & Dana, 2003), perceived risks of biotechnology (Gardner & Jones, 2010), and how students think about size and scale (Chesnutt et al., 2018). Card sorts are useful because information organized into categories is an important part of all learners' knowledge (Rugg & McGeorge, 1997).

The first mini-lesson, implemented on the first day of the evolution unit, was titled "Who do you ask?" and focused on different sources of knowledge (for example a science teacher, the Bible, a family member). The lesson plan included the following background information, providing context to the instructor before the lesson:

> Why is this important? We use different sources of information when answering questions. Jegede says that collateral learners can use more than one source of knowledge while studying science. For example, parallel collateral learners might use two different sources of knowledge in two different places. They might answer questions about the beginning of the universe using a scientific source of knowledge while in Biology class, and a religious source of knowledge while in church. This theoretical framework says that students should be able to use multiple sources of knowledge to answer questions about the world, not only one. We should be encouraging students to leverage different sources of knowledge, rather than talking them into believing in only one (science) (Green & Delgado, 2021, p. 492).

The instructor was asked to read the following script aloud to the students before the activity began. This script was created to set up the card sort activity for the students:

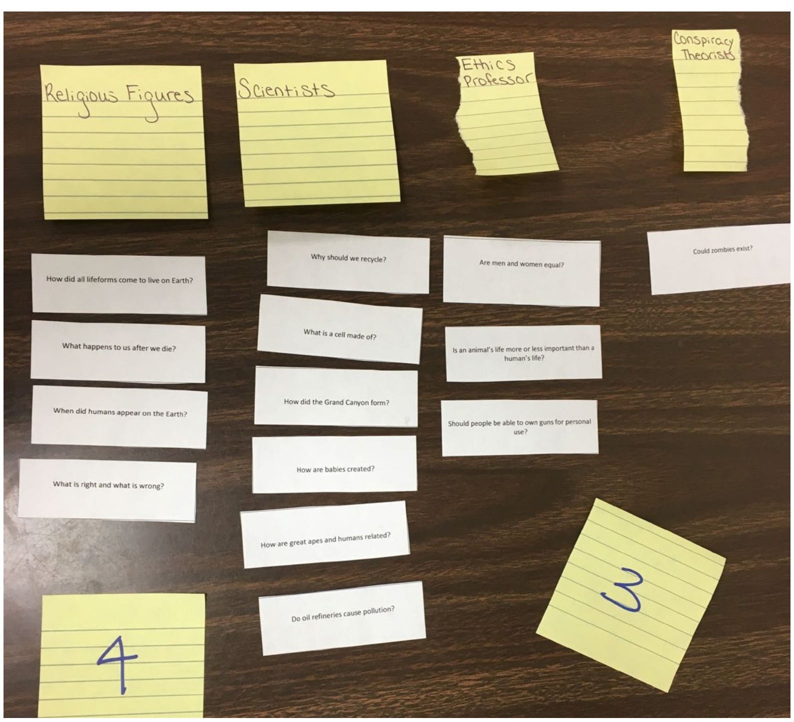
> Some scientific issues are discussed often in places other than science labs and conferences. One of these issues is evolution. You might hear the word "evolution" at school, at a place of worship, or in a doctor's office. If you have questions about evolution, who do you ask?

> In this activity, we'll talk about different sources of knowledge and what questions they answer. For example, if you wanted to know how many planets there are outside of our solar system, who would you ask? [Pause and wait for students to answer. Possible answers might include a scientist, the internet, an astronomer]. What kind of source of knowledge is that? [Pause and wait for students to answer. The intended answer is "scientific".] If you wanted to know what the meaning of life is, who would you ask? [Pause and wait for students to answer. Possible answers might include a philosopher, a religious expert, a friend.] What source of knowledge is that? [Pause and wait for students to answer. Possible answers might include philosophy or religion.]
>
> Think about the different sources of knowledge that you draw from in your own life. I'm going to give you a set of cards. I want you and your table partner to group these cards based on the sources of knowledge you would use to answer each one. You can create as many or as few sources of knowledge as you'd like.

Students were given slips of paper with one question per slip. Some questions were designed to be answered by science, while others were not. In addition, some questions were related to potentially controversial issues (e.g. gun ownership, human origins), while others pertained to noncontroversial topics (e.g. cell composition, zombie existence). For the potentially controversial scientific questions, we used three prompts related to evolution. We classified the questions about evolution as "potentially controversial" because some members of the public may believe that evolution is not the best explanation for the diversity of life on Earth, but there is wide consensus within the scientific community that evolution is a valid theory.

Figure 1

Example of Card Sort Data from One Group



Before the activity began, student groups were asked to place the previously-distributed cards containing their participant number on their desks. Student groups were given post-it notes on which to create sources of knowledge (SoKs) as the researchers wanted students to create their own sources rather than group the questions into prescribed SoKs imposed by the researchers. Student groups were told that they could place a question into more than one source if they felt it was appropriate. Groups arranged the questions into sources of knowledge on their desks. Students were given about 10-15 minutes to complete the activity. After the questions were arranged, a picture of each group's card sort was taken.

Table 1

Questions Given to Student Groups

Question	Can be Answered by Science	Potentially Controversial
What is a cell made of?	X	
How did the Grand Canyon form?	X	
How are babies created?	X	
Could zombies exist?	X	
What happens to us after we die?		X
What is right and what is wrong?		X
Should people be allowed to own guns for personal use?		X
Is an animal's life more or less important than a human's life?		X
Are men and women equal?		X
When did humans appear on Earth?	X	X
Do oil refineries cause pollution?	X	X
Why should we recycle?	X	X
How are great apes and humans related?	X	X
How did all life forms come to live on Earth?	X	X

Quantitative Data Collection (MATE)

We used the Measure of Acceptance of the Theory of Evolution (MATE; Rutledge & Warden, 1999) to collect data regarding students' evolution acceptance. This instrument contains twenty Likert-scale items that can shed light on students' agreement or disagreement with various parts of evolution. Although the instrument was originally designed to assess teachers' acceptance of evolution (Rutledge & Warden, 1999), it has also been successfully used to measure undergraduate students' acceptance of evolution (Borgerding et al., 2017). The MATE is the most widely used evolution acceptance instrument and has been used in over 24 studies since its publication in 1999 (Romine et al., 2017). While other instruments such as the Inventory of Students' Acceptance of Evolution (I-SEA; Nadelson & Southerland, 2012) and Generalized Acceptance of EvolutioN Evaluation (GAENE; Smith et al., 2016) also exist, the MATE was chosen because it is well-validated and accepted (Romine et al., 2017).

Each student in the class took the MATE as a pre-assessment the week prior to the evolution unit and as a post-assessment at the end of the semester. Answers were entered into a Google Sheet and scored according to the scoring guide included with the instrument. Data was identified with a random number previously assigned to the students so learning gains could be measured for the larger study by comparing pre- and post- scores. Because the card sort occurred on the first day of the evolution unit, we used students' pre-instruction MATE scores in our analysis for this paper.

Data Analysis

Data analysis of the card sort data employed a constant comparative method approach (Glaser & Strauss, 1967). First, the authors open-coded the various knowledge sources student groups listed on their post-it notes. During this open coding phase, detailed code notes were taken to characterize the dimensions of each emerging code. Through discussion, the authors used these initial codes and dimensions to collapse the existing codes into four categories to describe the sources of knowledge: scientists, religious experts, God, humanities experts, and possibly dubious experts, as shown in Table 2. This coding scheme was then re-applied to all the data to ensure that all sources of knowledge were consistently categorized. This analysis was used to address our first research question about the sources of knowledge community college biology students seek, to answer potentially controversial and noncontroversial questions.

At this point, information about the status of the question (can be answered by science, can be considered controversial) was used to sort the sources of knowledge categories. In this way, data were sorted to develop axial codes that highlight the conditions/contexts in which the categories occurred and possible relationships between sub-codes. These findings were used to address the second research question regarding the extent to which sources of knowledge differ for potentially controversial and non-controversial science questions.

Finally, to address the third research question targeting the extent to which evolution acceptance predicted the sources of knowledge chosen for potentially controversial and noncontroversial science questions, we merged the MATE evolution acceptance data with category data. We scored the MATE according to Rutledge and Warden's (1999) recommendations to generate numerical scores for each participant. Because students worked in groups for the card-sorting task, we averaged the MATE scores for the members of each group to get a group MATE score and group MATE score range. We then developed a cross-tabulation of average MATE score and categories for each group in order to identify any trends relating evolution acceptance with types of knowledge sources. We were unable to perform any additional statistical analysis due to the small sample size and the fact that the MATE was scored on an individual level while the card sort was performed in pairs.

Results

Source of Knowledge Categories

The first research question was "What sources of knowledge do community college biology students seek, to answer controversial and noncontroversial questions? Student groups created 35 distinct sources of knowledge in this study. An SoK was considered distinct if the difference between it and another SoK was more than simply the difference between singular and plural. For instance, "scientist" and "scientists" would not be distinct sources of knowledge but "science" and "scientists" would be distinct.

Since many SoKs were similar, we grouped them into four categories. Table 2 lists, describes, and exemplifies these categories.

Table 2

Sources of Knowledge Categories

Categories	Code Description	Participant Exemplars
Scientists	Any individual whose professional responsibilities pertain to science	"Scientists," "Biologist," "Environmental Scientist," "Geologist/Ecologist/Toxicologist"
Religious experts and God	Any individual whose professional responsibilities pertain to religion; also God	"God," "Religious Expert," "Priests, Preachers, etc."
Humanities experts	Any individual whose professional responsibilities pertain to human culture or society	"Ethics professor," "Political Scientist," "Law," "Humanities," "Psychologist," "Sociologist," "Political/Ethical experts," "Economist"
Possibly Dubious experts	Lay people and sources with questionable credibility	"Parent," "Activists on both sides," "Internet"

Controversial and Noncontroversial Questions

To answer the second research question, "To what extent do sources of knowledge differ for controversial and non-controversial science questions?", the authors compared the source of knowledge categories for the different types of questions. See Table 3 to explore which questions were placed in which category.

As the data show, different types of questions elicited different sources of knowledge. First, students almost always placed the questions we considered non-controversial and answerable by science questions ("solidly science"), including the questions about cells, the Grand Canyon, recycling, how babies are created, oil refineries, and how humans are related to apes in the scientist SoK category. One group placed the question about babies in the possibly dubious experts category (specifically placing the question in a "parents" SoK). One group placed the question about humans and apes in a religious category and one group thought that question could be answered by humanities experts. We

Table 3

Questions and Participants' Proposed Sources of Knowledge

Question	Question Type	Scientists	Religious experts	Humanities experts	Possibly Dubious experts
What is a cell made of?	S, NC	12	0	0	0
How did the Grand Canyon form?	S, NC	12	0	0	0
How are babies created?	S, NC	11	0	0	1
Could zombies exist?	S, NC	10	0	0	3
What happens to us after we die?	NS, PC	1	6	5	1
What is right and what is wrong?	NS, PC	0	4	7	3
Should people be allowed to own guns for personal use?	NS, PC	0	1	8	4
Is an animal's life more or less important than a human's life?	NS, PC	0	2	8	3
Are men and women equal?	NS, PC	1	2	8	1
When did humans appear on Earth?	S, PC	7	2	2	1
Do oil refineries cause pollution?	S, NC	11	0	1	0
Why should we recycle?	S, NC	11	0	1	0
How are great apes and humans related?	S, PC	10	1	1	0
How did all life forms come to live on Earth?	S, PC	6	5	2	1

Note. (s=science, ns=science, c=controversial, nc=non-controversial, pc=potentially controversial)

placed the question about zombies in this category although three groups out of thirteen thought it could be answered by possibly dubious experts such as "conspiracy theorists."

Another set of questions ("beyond science"), we considered both potentially controversial and beyond the scope of science included the questions about the afterlife, what is right/wrong, gun ownership, animal rights, and gender equality. None of the groups placed these questions in a scientist category, with the exception of one group who placed the gender equality question there. All "beyond science" questions were placed in a religious experts category by at least one group, with what is right/wrong appearing in the religious experts category most frequently. At least one group placed all questions in the possibly dubious experts category, with the question about gun ownership being placed there by four groups.

Most of the mixed results were found with the questions pertaining to evolution, "How did all life forms come to live on Earth?" and "When did humans appear on Earth?" For the lifeforms question, the majority of the groups placed the question in a scientist or religious experts SoK. Two groups placed the question in a humanities SoK, and one group would turn to a possibly dubious expert--in this case, the internet.

Evolution Acceptance and Sources of Knowledge

Our final research question examined whether evolution acceptance predicts the sources of knowledge chosen for controversial and noncontroversial science questions. We used the MATE scores as the measure of acceptance of evolution. The smallest range in MATE scores between group members was 2 points, with the largest difference being 53 and a mean difference of 23.2 points between group members.

Further analysis of the data showed no consistent patterns. For example, Group eight had MATE scores of 75 and 80 (moderate to high acceptance), yet placed four questions in a religious SoK, while Group nine had MATE scores of 81 and 85 (high acceptance) and did not create a religious SoK. Group 11 had a 35-point difference between scores (ranging from high to low acceptance) and placed the question about what happens after humans die in a religious SoK and the question about lifeforms appearing on Earth in a scientific SoK. Group 12 had one very low accepter, one low accepter, one moderate accepter, and one high accepter yet created no religious SoK. After analyzing the data, we did not see any alignment between acceptance of evolution and SoK chosen for science questions.

Discussion

Different Questions Elicited Different Sources of Knowledge

Different questions clearly elicited different sources of knowledge. Participants distinguished between SoKs for non-controversial and potentially controversial science-related questions. The noncontroversial science-related questions primarily elicited SoKs in the scientist category while only a few instances of humanities experts and possibly dubious experts were seen in the data. Participants never sought religious experts for noncontroversial science-related questions. However, all three of the controversial science-related questions elicited religious experts as sources of knowledge. The questions pertaining to humans' first appearance on earth and how all life forms came to live on Earth elicited the most SoKs by far. These findings are consistent with previous literature in which college biology students sought scientific and religious authorities for evolution-related questions (Borgerding et al., 2017; Metz et al., 2018) when compared to less controversial science topics (Sinatra et al., 2003).

Some groups used very few sources of knowledge across all the different types of questions. Two of these groups relied exclusively on either religious experts or scientific experts across the questions. This binary may be very important for students' science learning experiences, especially when learning about biological evolution. In a German study, evolution acceptance was found to be related to students' perception of the conflict between science and religion (Konnemann et al., 2016). In an investigation of Christian university students, many religious students entered college with the perception that religion and biology are in conflict and that the biology community is not sympathetic to religion (Barnes et al., 2017a). These religious students had negative biology learning experiences when their instructors did not acknowledge religion or religious viewpoints in their teaching and emphasized conflicts between religion and biology (Barnes et al., 2017a). For student groups that identify science-religion binaries when expressing sources of knowledge, an instructor can help students understand questions that science can and cannot address by helping them understand the bounded nature of science (Southerland et al., 2012).

Of the three possibly-controversial, evolution-related questions, participants sought far more religious sources of knowledge for the questions addressing humans' first appearance on Earth and how all life forms came to appear on Earth. However, the other possibly-controversial, evolution-related question about how great apes and humans are related mostly elicited scientific sources of knowledge. This difference may reflect college biology learners' distinction between evolutionary origins and evolutionary processes (Smith, 2010). Future card sort research that includes more questions about evolutionary origins and processes could examine this possibility.

Evolution Acceptance Did Not Predict Categories

The range of evolution acceptance did not predict types of SoK created. Since groups were composed of table partners/groups (and seats were not assigned), researchers did not intentionally group students based on evolution acceptance or rejection. When examining the groups' SoKs, it was evident that some groups were composed of students with similar MATE scores while others showed a wide range of scores between group members. Since no patterns emerged linking average MATE score to SoK categories, we wondered how students navigated differences in evolution acceptance when creating their categories. For instance, two groups had similar differences in MATE scores between the members, but one group (Group seven) created a religion SoK and placed four questions in it while the other group (Group eight) did not create a religion SoK. We wondered who posited the idea of a religious source of knowledge in Group seven and whether Group eight members discussed a possible religious SoK. A limitation of the present study is that field notes and audio recordings during the activity were not taken. In future research, audio recordings of student discussions during this type of activity would help elucidate student discourse around sources of knowledge, and examine the extent to which group dynamics are important for identifying sources of knowledge for potentially controversial science subjects.

Understandings About Scientific Expertise Were Diverse

Participants in this study had a range of understandings related to scientific expertise. While the majority of groups used a generic "scientist" source of knowledge, several other groups were aware of specialization within scientific fields. This awareness of specialization signifies greater epistemological sophistication by recognizing that experts have specific training and are at the cutting edges of their fields (Hofer, 2004). The ability to choose more credible sources of knowledge can improve with training (Stadtler et al., 2016). In the context of evolution learning, the ability to identify the most credible experts may be particularly important. Despite the fact that evolution is overwhelmingly supported within the scientific community, the United States public is much less accepting of evolution in public polls (Wiles, 2010). Students seeking information about evolution must navigate their way through various purported scientific documents developed by Creationists and supporters of Intelligent Design. Compared to evolution research documents that advance evolutionary claims supported by empirical evidence, Creationist and Intelligent design documents rely less on empirical support and on a myriad of other justifications including appeals to authority and the absence of evidence, among others (Barnes et al., 2017b). Clearly, students must be able to evaluate the expertise of sources of knowledge regarding evolutionary questions. Students may hold different ideas of what constitutes "expertise" or "expert sources" and may need to operationally define the idea of what an "expert" is.

Conclusion

This study investigated the sources of knowledge sought by community college biology students for various science/non-science and controversial/non-controversial questions. The main contributions of this study are centered around college students' choices of sources of knowledge. First, college biology students clearly sought different SoKs for science and non-science questions, with science questions largely evoking scientific experts. Second, among the science-related questions, the potentially controversial ones were connected to religious and other SoKs when compared to the noncontroversial questions. Third, these community college students never considered themselves a source of knowledge for any of the questions. Fourth, some students were aware of conflicts between SoKs and recognized a range of expertise among scientific SoKs.

Implications for science educators center around students' epistemologies. In general, it is important for science educators to be aware of students' wide-ranging depth of epistemological ideas about science and scientific evidence. Based on these findings, efforts to promote epistemological sophistication, especially in science education, among college students are warranted. Careful, non-threatening discussions about students' beliefs about evidence, expertise, and reasoning could lead to higher epistemological sophistication. Specifically, efforts should address the status of various evolution experts within the scientific community, the nature and development of scientific expertise, and strategies for assessing the relative credibility of competing sources of knowledge.

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