Fostering Scientific Literacy With Problem Sets That Generate Cognitive Presence and Fulfill Basic Psychological Needs

By Guang Jin, Alicia Wodika, Rebekka Darner, and Jianwei Lai

Guided by self-determination theory to design an authentic learning environment, we attempted repeated engagement in critical evaluation of evidence to foster accuracy-oriented reasoning and critical thinking in an applied science course for non-STEM undergraduates taught completely online during a 6-week summer term and a 16-week fall term. Student outcomes were measured as indicators of the effectiveness of our pedagogical strategies. Results suggest that student engagement in integration and resolution modes of cognitive presence are associated with students’ feelings of autonomy, competence, and relatedness. A positive trend of students moving toward accuracy goals during evidence evaluation was also observed, as students visited both sides of evidence at the same frequency or spent about the same amount of time evaluating both sides of evidence regardless of their voting decision at the end of the course. These findings suggest that scientific literacy among nonscientists may be fostered through repeated, supportive engagement in evidence evaluation.

Most people, including students, do not generally begin evidence evaluation from a neutral position; rather, “evaluation of scientific evidence may be biased by whether people want to believe its conclusions” (Kunda, 1990, p. 490). When students hold directional goals, they are motivated to arrive at their preferred conclusions, despite contradictory evidence, whereas students with accuracy goals are motivated to be accurate in their conclusions (Kunda, 1990). A primary goal of many general science education courses is to foster scientific literacy among students so that they will inform their judgments and choices with evidence. Given this goal, directional reasoning, which may lead a student to disregard sound scientific evidence, is a barrier to fostering scientific literacy among students.

In addition, the emergence of so-called “post-truth” phenomena involves widespread dissemination and acceptance of misinformation in digital media and a prioritization of personal and political ideologies over evidence; these phenomena present a significant challenge for fostering accuracy-oriented reasoning in classrooms (Chinn et al., 2020a; Lewandowsky et al., 2017; Prado, 2018). Profound post-truth challenges occur regarding scientific misinformation on topics such as climate change, genetically modified organisms (GMOs), and pollution, and well-established scientific claims are disputed by various forms of science denial (Lewandowsky et al., 2017; Scheufele & Krause, 2019). Science denial is “the systematic rejection of empirical evidence to avoid undesirable facts or conclusions” (Liu, 2012, p. 129), and a gradual migration of science denial from the periphery toward the center of our society is alarming to the scientific community. Socioscientific issues such as climate change become subject to science denial when they become politicized (Funk et al., 2019; Gauchat, 2012).

The ability to recognize and act on the most accurate claims is vital for personal decision-making as well as the functioning of the democratic society, in which collective, evidence-based decisions are crucial. Hence, education needs to promote dispositions of science acceptance, or “the willingness to engage in critical evidence evaluation, despite potential to contradict one’s preferred conclusion” (Darner, 2019, p. 229), particularly in today’s complex and epistemically “unfriendly” media environments that “present conflicting claims, evidence, and perspectives and that vary in their authorship, quality, reliability, belief consistency, [and] emotional ‘heat’” (Chinn et al., 2020b, p. 55).

Although it is important for students to engage in accuracy-oriented
reasoning while evaluating scientific evidence surrounding politicized socioscientific issues, emotions and basic psychological needs mediate such evidence evaluation (Garcia-Marques & Loureiro, 2016; Jayasinghe & Darner, 2021) and decision-making (Charpentier et al., 2016). Self-determination theory (SDT) attends to the social and cultural factors that foster or undermine motivation (Ryan & Deci, 2000), including motivation to work toward accuracy goals (Darner, 2019), and therefore provides insights in its implication for science instruction. SDT posits three innate psychological needs—competence, autonomy, and relatedness—that determine the regulatory processes that direct goal pursuits (Deci & Ryan, 2000).

Goal pursuits differ to the extent that they arise from the self or have an internal locus of causality. Intrinsically motivated behaviors are those that are performed for mere pleasure or satisfaction and are entirely self-determined. Even when behaviors are not inherently enjoyable, perhaps such as when a nonscientist engages in evaluation of evidence, individuals may nevertheless fully internalize extrinsic motivators, such as the values shared by a culture (e.g., the valuing of accuracy), so that resulting behaviors arise from an internal locus of causality. Full internalization results in full integration of those values into one’s sense of self, such that the values are fully accepted as one’s own and the behaviors arising from those values constitute self-expression. Internalization of a culture’s values depends on the degree to which the three basic psychological needs are fulfilled by the social milieu afforded by that culture (Deci & Ryan, 2000).

If educators want to motivate students to work toward accuracy goals, we need to cultivate accuracy’s value in the social milieu of our classrooms while supporting fulfillment of students’ feelings of autonomy, competence, and relatedness as they engage in accuracy-oriented reasoning (Darner, 2019). Autonomy-supporting teaching behaviors include offering choices to students and fostering personal agency among students (Hagger et al., 2015). Students’ sense of competence is fostered when learning activities allow the students to apply what they know and understand while simultaneously expanding their abilities; in other words, activities are optimally challenging (Legault, 2017; Niemiec & Ryan, 2009). Competence is further supported when those learning activities are related to students’ personal values and when evaluation downplays evaluation (i.e., grades) while focusing on students’ efficacy in mastering content or solving a problem that they personally value (Niemiec & Ryan, 2009).

Finally, students’ need for relatedness is fulfilled by internalization of the values and practices of the social milieu, through which students accept those values and practices as their own and an expression of their identity (Niemiec & Ryan, 2009). This is likely to happen when students feel like their teacher genuinely likes, respects, and cares about them (Niemiec & Ryan, 2009).

To summarize, the learning environment and its constituent relationships provide support for students’ basic psychological needs, which leads to students perceiving autonomy, competence, and relatedness. This satisfaction of the needs leads to self-determination toward the behaviors and practices that are valued within that social milieu (Legault, 2017).

Thus, as educators, we can structure our classrooms in such ways that they provide the learning environments and relationships that foster self-determination toward engaging in critical evidence evaluation (Darner, 2019). Critical evidence evaluation involves assessing the strength of the connections between evidence (e.g., data, information, theoretical underpinnings) and the alternative, often competing, claims and explanations that can arise from those pieces of evidence (Sinatra & Lombardi, 2020). It is worthwhile to investigate how repeated engagement in critical evaluation of evidence facilitates the sophistication of classroom norms, which in turn influences the basic psychological need fulfillment, the quality of the scientific arguments that students devise, and students’ ability to evaluate their peers’ arguments during classroom interactions (Darner, 2019).

Designing epistemically unfriendly learning environments that include more diverse and authentic information sources and making these pervasive throughout the curriculum are essential instructional strategies to help students engage in critical evaluation of evidence in the post-truth landscape (Chinn et al., 2020b). Students need to be exposed to low-quality information and poor evidence to develop a sense of the epistemic caution and responsibility needed to deal with the unfriendly epistemic climate in the real world. In addition, they can struggle with emotional topics that appeal to the use of directional rather than accuracy goals but that can provide opportunities to consider the value of accuracy goals. Finally, unfriendly yet authentic learning environments offer opportunities to reflect on biased forms of reasoning and to learn to reevaluate them (Britt et al. 2019; Greene et al., 2019; Hobbs, 2017; Journell, 2019).
Addressing critical thinking is important when analyzing the conclusions students develop from course content and the process by which they formed that conclusion. Several models have been utilized to measure critical thinking in an online format (Duffy et al., 1998; Garrison et al., 2000; Gunawardena et al., 1997); however, the practical inquiry model used by Garrison and colleagues (2000) incorporates four phases—triggering event, exploration, integration, and resolution—that assess for critical thinking by measuring the “cognitive presence” of a statement. Cognitive presence is defined as “the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse in a critical community of inquiry” (Garrison et al., 2001, p. 11). In an online platform for discussion, participants’ responses for “triggering events” include engaging with the content without a full understanding of the problem. The second phase of exploration involves a response in which participants are engaging in a discussion of the problem context. A response in the third phase of integration demonstrates that participants are not only identifying the problem complexities but also incorporating support for their understanding. The highest phase of cognitive presence is resolution, in which participants have met the criteria for the previous three phases and can identify potential solutions to the problem and incorporate support to justify their response (Akyol & Garrison, 2011; Garrison, 2003; Garrison et al., 2001). Although critical thinking is based on both a process and a product (Garrison et al., 2001), using discussion-based assignments can be an effective tool for determining individual growth in a specific topic area.

In this study, we attempted to repeatedly engage students in critical evaluation of evidence to foster accuracy-oriented reasoning and critical thinking in an applied science course for non-STEM (science, technology, engineering, and mathematics) undergraduates taught completely online. This course structure was set up in several ways to support students’ basic psychological needs fulfillment, particularly as they engaged in critical evaluation of evidence (Figure 1).

We evaluated the effectiveness of

<table>
<thead>
<tr>
<th>Need</th>
<th>Need support indicated by literature</th>
<th>Course structure</th>
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| Autonomy      | 1. Teacher offers students choices.  
2. Teacher fosters students’ personal agency.                                                        | 1. A variety of learning activities such as reading, watching videos, and engaging in asynchronous discussions can be done at a student’s own pace. Disagreements are encouraged during discussion. Students have options to choose class projects based on their own interests.  
2. Personal agency was attempted to be fostered when socioscientific issues were incorporated into discussions. |
| Competence    | 1. Learning tasks compel students to apply knowledge while also constructing new knowledge.  
2. Feedback downplays evaluation (i.e., grades) and focuses on authentic and relevant problem-solving. | 1. Discussions, problem sets, and self-check practice problems require a student to apply knowledge in new and complex situations with discussion of limitations of the proposed solutions, which often leads to new knowledge to be discussed in the following unit.  
2. Grades on evidence evaluation are based on full participation (i.e., address all aspects of the task), with the instructor’s feedback focused on the complexity of problem-solving in real-life situations. |
| Relatedness   | 1. Teacher conveys respect and concern for students.  
2. Teacher fosters a social milieu that values accuracy-oriented reasoning. | 1 & 2. Class etiquette with an emphasis on respect for facts, validity of evidence, and diversity was introduced at the beginning and students are reminded throughout the semester. During discussions, the instructor focused on guiding students through the mindful process of evidence evaluation (e.g., Is this statement an opinion or a fact? What is the source of this evidence? Is this an independent source? What could be potential bias in this argument? That disagreement seems to be a strong argument; however, what about study X showing a different pattern? Should we look at this through a different lens?). |
our pedagogical strategies by addressing the following questions:
• How do students’ psychological needs fulfillment change as they progress through the course?
• To what extent do students engage in higher levels of critical thinking, as indicated by cognitive presence (Akyol & Garrison, 2011; Garrison, 2003), as they progress through the course?
• How does the pattern of students’ selection of pro and con evidence in relationship to their voting decision change during the public voting scenario in the pre- and posttest, if at all?

The course and pedagogical strategies used
The course is an introductory environmental health course at a large public university in the Midwest. It meets an applied science requirement within the general education curriculum. Students representing every major on campus complete the course, though enrollment tends to be dominated by nonscience majors. The course curriculum addresses several socioscientific topics, including climate change, drinking water cleanliness, food security, and sustainability.

The pedagogical materials specifically developed to promote accuracy-oriented reasoning in this course included a public policy voting scenario, an introductory lecture on “science as a way of knowing,” and three problem sets that prompted evaluation of evidence surrounding three socioscientific issues.

Public policy voting scenario
Before the course, in the orientation module, we presented the public policy voting scenario on a controversial topic, asking, “Should federal government relax the greenhouse gas emission limit for coal-fired power plant?” (See Figure 2.) Students were presented with supporting evidence of pros and cons that included valid evidence (e.g., evidence from peer-reviewed, governmental, or independent sources) and poor evidence (e.g., opinions or evidence from noncredible sources). An equal number of pieces of pro and con evidence was presented. Students were asked to vote on which decision they thought would be best and provide their reasoning. The aim of this assignment was to set the tone for this course as an epistemically unfriendly learning environment that includes realistic, diverse, and authentic information sources like the ones students are likely to encounter in their daily lives. In addition, through this assignment, we intended to demonstrate to students the functioning of a democratic society in which making evidence-based collective decisions is crucial. We tried to make each piece of evidence about the same length and level of readability.

“Science as a way of knowing” introductory lecture
The “science as a way of knowing” topic was presented during the first lesson. We used an environmental controversy (endangered spotted owls and their habitat destruction) to model how science processes enhance understanding and problem-solving. Students first saw how the arguments and evidence from both sides were identified and presented, followed by an evaluation of the evidence. Students examined data on total area covered by forests in the United States; the importance of the critical point of differentiating old-growth forests from second-growth forests; and how the old-growth forests’ ecosystem provides a habitat suitable for spotted owls and other wildlife, whereas second-growth forests do not support such biodiversity. Characteristics of the evidence that strengthen its validity were also presented and discussed, including peer review (the extent to which the evidence has undergone a peer-review process), independence (the extent...
to which the source of evidence is free of personal gain or loss related to the outcome of the evidence), and consistency (evidence that is based on multiple independent sources of evidence and addresses and explains evidence that conflicts with the explanation). Finally, we presented policy implications of this controversy to help students decide whether to preserve old-growth forests or allow timber harvesting.

Socioscientific issue problem sets

We developed three problem sets that addressed immigration and its effects on the U.S. economy, safety of GMOs for human health and the environment, and the quality of bottled water versus tap water quality. These topics were chosen because of their controversial nature, common misconceptions surrounding them, and their relevance to the course content. Students were prompted to work through a series of tasks that involved stating preconceptions on the issue in response to open-ended questions, analyzing biased websites on the issue while being reminded of media literacy strategies, discussing evidence regarding the issue with peers in an asynchronous discussion board, and revisiting one’s preconceptions in open-ended questions (Figure 3).

In addition to the asynchronous discussions embedded in the problem sets, the course also engaged students in discussion on five additional topics to promote critical thinking; these discussions were evenly distributed throughout the course and included human footprint (#1); world hunger, agriculture sustainability, and GMOs (#2); e-waste and consumer responsibilities (#3); carbon capture and storage (#4); and sustainability (#5). The discussions were open-ended to give students more opportunities to share their knowledge of the topic and to apply concepts they had previously learned from problem sets.

For these activities, the instructor focused on guiding students through the mindful process of evidence evaluation and arguments, with an emphasis on source and the quality and validity of evidence; questioning potential bias in arguments; reminding students of media literacy; and supporting disagreements. These activities were required for all students.

METHOD

Study sample

Students enrolled in the course were recruited to participate in the study following the Institutional Review Board.

FIGURE 3

Three-phase structure of socioscientific issue problem sets.

Phase 3
- What are your thoughts on ___?
- How have your ideas changed?
- If they haven’t changed, how are you now more informed?

Phase 2
- Presented with evidence on the issue
- Discussion with peers
- Classroom norms – justify claims with evidence, mistakes are ok, dissension leads to better understanding

Phase 1
- What are your thoughts on ___?
- Reminder to practice media literacy
- Analysis of biased websites related to the issue

Note. In this structure, students are prompted to share their initial ideas about an issue, receive instruction on media literacy strategies, analyze biased positions on the issue, discuss evidence on the issue with peers, and then revisit their initial ideas and discuss how they have changed.
Board–approved protocol. Research tasks involved completion of course assignments. All students were asked to provide consent for having their work included in the study. Two online sections of this course offered in 2019, one in the summer (6 weeks) and another in the fall (16 weeks), participated in this study.

Data collection and analysis

Socioscientific issue problem sets and additional discussions

Each problem set involved a discussion using the asynchronous discussion board, and students completed five additional discussions throughout the course. Students’ discussions served as data, which were queried using Administrative Technologies’ SQL Server Reporting Services. Students’ critical thinking expressed in discussions was assessed by a practical inquiry model for critical thinking (Akyol & Garrison, 2011; Garrison, 2003; Garrison et al., 2000). Students’ responses were measured by three coders who applied a cognitive presence indicator (1 = triggering, 2 = exploration, 3 = integration, 4 = resolution, 5 = not accurate/on task). Cognitive presence indicators were then analyzed to determine percentages and compared via a chi-square test. Interrater reliability was assessed using Cohen’s kappa among the three coders (k = > 0.7). Qualitative data from discussion boards and problem sets were also analyzed to identify common themes using ATLAS.ti.

Pre-/post-assessment using public voting scenario

We presented the public policy voting scenario that had been presented during the orientation to students again at the end of the course as a pre-/post-assessment. This assessment was presented to students on a website developed with PHP (Hypertext Preprocessor), HTML, CSS, JavaScript, and jQuery. Students’ interaction data, such as when a piece of evidence was clicked and how long a student stayed on a particular piece of evidence, were captured with JavaScript. The pieces of evidence clicked and the time spent on each were used to evaluate whether students were moving toward accuracy goals, as evidenced by students visiting sites that included both sides of the evidence at the same frequency or spending about same amount of time evaluating both sides of evidence, regardless of their voting decision.

Assessing psychological needs fulfillment

To evaluate whether the course fostered accuracy-oriented reasoning via basic psychological needs fulfillment, needs fulfillment was measured while students engaged in problem sets, both at the beginning and close to the end of the course, using the following three items, to which students responded on a 5-point Likert agree or disagree scale:

- “In this class, when discussing a controversial topic with others, I feel a sense of autonomy or that I have free will to speak and think as I please.” (autonomy)
- “In this class, when discussing a controversial topic with others, I feel I am competent, in that I am capable of evaluating the available information and coming to a logical conclusion based on the information.” (competence)
- “In this class, when discussing a controversial topic with others, I feel that I have unique contributions to make to the group discussion and that my contributions are valued by others.” (relatedness)

Although the validated 21-item Basic Psychological Need Satisfaction Scale (Deci & Ryan, 2000; Johnston & Finney, 2010) is an option for measuring basic psychological fulfillment, we chose to use these three items to focus participants specifically on their needs fulfillment while discussing the often-contentious socioscientific issues addressed in the course. Furthermore, these items were embedded in the course’s problem sets, and we feel that embedding a 21-item instrument would have distracted from the learning activity. We acknowledge that not using a previously validated instrument is a limitation of our pilot study, but we also felt that measuring students’ perceived needs fulfillment during engagement in the learning activities was necessary to capture fulfillment more proximally to critical evidence evaluation. Therefore, even though asking a single item per construct cannot have reliability, doing so has practical value, given that this study is a pilot study aimed at exploring pedagogical methods. Responses to these items at the beginning of the course and close to the end of the course were compared using Wilcoxon signed-rank tests. Quantitative data were analyzed using IBM SPSS version 26.

Results and discussion

Because the 6-week summer session is much shorter and more intense than the 16-week fall session, it is likely that students’ learning behaviors differed over the course of the terms. In addition, we have observed that students enrolled in summer sessions have, on average, higher course grades than students in
the fall sessions. Therefore, we cautiously compare these two sessions, due to the numerous factors in which they differ that are unrelated to the variables of interest.

How does students’ psychological needs fulfillment change as they progress through the course?

Wilcoxon signed-rank tests revealed no changes in basic psychological needs fulfillment over the course of the sessions (Table 1).

During the summer session, students’ basic psychological needs fulfillment was high at the beginning of the course and remained unchanged, indicating that a social milieu that developed within the course might have supported students’ autonomy, competence, and relatedness as they were called upon to engage in accuracy-oriented reasoning regarding controversial topics. In the fall, however, students’ basic psychological needs fulfillment was lower at the beginning of the course and remained low. A Mann-Whitney nonparametric test revealed that differences between summer and fall sessions in terms of pre-psychological needs and post-psychological needs were statistically significant (all p values < 0.0005). It is heartening that psychological needs fulfillment did not significantly decrease throughout the course in either section. Because the course content, delivery method, and instructor were all identical for the two sessions, this difference observed in basic psychological needs fulfillment between summer and fall might be due to (i) students who took the intensive 6-week summer session being more academically motivated and prepared overall than those who took the 16-week fall session or (ii) the fall session enrolling significantly more first-year students than the summer session. First-year students might feel homesick and stressed about adjustment to college, whereas students in summer sessions may have acclimated to college. These differences in psychological needs fulfillment between the two sessions provide an opportunity to examine whether needs fulfillment was related to student engagement in critical thinking (as we discuss in the following section).

Do students engage in higher levels of critical thinking as they progress through the course?

Students’ critical thinking shifted toward higher levels of cognitive presence as they progressed through the course for both summer and fall sessions (Table 2). Comparing the first discussion with the final discussion, the percentage of students engaged in a level of integration and resolution in the fall session increased from 10.1% to 14.9% and from 0% to 2.3%, respectively. A similar trend was observed in the summer session, in which the percentage of students who engaged in the levels of integration and resolution increased from 14.3% to 19.2% and from 0% to 7.7%, respectively.

Students’ critical thinking appeared to be different between summer and fall. A Pearson chi-square test was used to compare thinking between summer and fall for each topic. Only discussion topic #4 showed a statistically significant difference between summer and fall ($X^2 (3, n = 114) = 8.567, p = 0.036$).

How does the pattern of students’ selection of pro and con evidence in relation to their voting decision change during the public voting scenario between pre- and posttest?

We analyzed the students’ selection of pro and con evidence in terms of both number of visits as well as time spent on each piece of evidence (Table 3).

If a student was not biased in evidence evaluation, then the student

<table>
<thead>
<tr>
<th>Basic psychological need</th>
<th>Summer session ($n = 26$)</th>
<th>Fall session ($n = 86$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Competence</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Relatedness</td>
<td>4.1</td>
<td>4.4</td>
</tr>
<tr>
<td>Autonomy</td>
<td>4.2</td>
<td>4.5</td>
</tr>
</tbody>
</table>
would visit both sides of evidence at the same frequency or spend about the same amount of time evaluating both sides of the evidence (i.e., same time spent on pro and con), regardless of their voting decision, under the assumption that cognitive demand to process both sides is about the same.

In the summer pretest data, the percentage of visits to pro evidence for students who voted “yes” was 87.3%, whereas only 12.7% of visits were to evidence against a student’s decision (i.e., con evidence). These percentages changed to 59.9% and 40.1% during the posttest, much closer to 50%, signaling a positive trend toward accuracy goals during evidence evaluation. The same trend was also observed for fall.

We also looked at the average time (median) that students spent on evidence for different cognitive presences (median from all discussion topics; Table 4). Overall, students whose median cognitive presence score was integration or resolution spent significantly more time evaluating evidence than those whose median cognitive presence score was integration or resolution.

**Limitations of the study**

Our pilot study has several limitations and thus indicates avenues for future research. We observed deeper critical thinking in the summer session, where psychological needs fulfillment as measured in this study was higher than in the fall session. Due to the limitation of our measurement of psychological needs fulfillment, it is hard to know whether this obser-

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### TABLE 2

**Students’ critical thinking in general discussion topics.**

<table>
<thead>
<tr>
<th>Cognitive presence</th>
<th>Discussion #1</th>
<th>Discussion #2</th>
<th>Discussion #3</th>
<th>Discussion #4</th>
<th>Discussion #5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer (%; k = 0.75)</td>
<td>Fall (%; k = 0.93)</td>
<td>Summer (%; k = 0.89)</td>
<td>Fall (%; k = 0.79)</td>
<td>Summer (%; k = 0.93)</td>
</tr>
<tr>
<td>Triggering</td>
<td>28.6, 39.3</td>
<td>11.1, 41.6</td>
<td>10.7, 20.2</td>
<td>44.4, 48.3</td>
<td>23.1, 24.2</td>
</tr>
<tr>
<td>Exploration</td>
<td>57.1, 50.5</td>
<td>66.7, 48.3</td>
<td>57.1, 63.1</td>
<td>37.0, 46.0</td>
<td>50.0, 58.6</td>
</tr>
<tr>
<td>Integration</td>
<td>14.3, 10.1</td>
<td>14.8, 10.1</td>
<td>28.6, 14.3</td>
<td>11.1, 3.4</td>
<td>19.2, 14.9</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.0, 0.0</td>
<td>7.4, 0.0</td>
<td>3.6, 2.4</td>
<td>7.4, 2.3</td>
<td>7.7, 2.3</td>
</tr>
</tbody>
</table>

**Note.** Percentages represent proportion of the discussion text coded as different modes of cognitive presence. Interrater reliability was assessed using Cohen’s Kappa (k) among the coders.

### TABLE 3

**Average percentage of visits of evidence and percentage of time spent on evidence evaluation.**

<table>
<thead>
<tr>
<th>Voting decision</th>
<th>Pre (% of visits, % of time)</th>
<th>Post (% of visits, % of time)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Pro evidence</td>
<td>Con evidence</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voted “Yes”</td>
<td>87.3, 83.8</td>
<td>12.7, 16.2</td>
</tr>
<tr>
<td>Voted “No”</td>
<td>30.8, 32.5</td>
<td>69.2, 67.5</td>
</tr>
<tr>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voted “Yes”</td>
<td>81.6, 80.8</td>
<td>18.4, 19.2</td>
</tr>
<tr>
<td>Voted “No”</td>
<td>38.6, 36.3</td>
<td>61.4, 63.7</td>
</tr>
</tbody>
</table>

**Note.** “Pre” and “post” refer to before and after the activity.
vation was because higher psychological needs fulfillment is leading to deeper critical thinking or is simply associated with such thinking. It seems that students’ needs fulfillment is generally high, so there may be too little variation to account for the more substantial variation in cognitive presence. A future study exploring the nature of the relationship between cognitive presence and psychological needs fulfillment with a correlational analysis would be informative.

At the posttest for the policy voting scenario, we observed a decreased number of clicks on evidence as well as decreased time spent viewing evidence. This might be because by the end of the semester, students on average know the background information much better than at the beginning of the semester, but it may also be due to course fatigue and lack of engagement. In the future, we will seek to identify ways to better measure the constructs related to motivated reasoning.

**Conclusion**

Repeated engagement in critical evaluation of evidence through asynchronous discussion boards appeared to be effective in helping students engage in critical thinking about controversial topics for which there are common misconceptions. Students’ basic psychological needs fulfillment was unchanged for both summer and fall sessions; however, needs fulfillment was higher in the summer session than in the fall session, which is also when higher levels of critical thinking were observed. For both summer and fall, students’ critical thinking showed a general trend of shifting to higher levels as they progressed through the course. However, during the summer session, when basic psychological needs fulfillment was high, students came to engage in more sophisticated modes of cognitive presence than they did in the fall, when basic psychological needs fulfillment was low. Students in the fall session continued to engage in triggering and exploration at the end of the course, whereas students in the summer session progressed toward integration and resolution by the end of the course. Resolution, however, was the least likely to be demonstrated in summer or fall; this finding was also evident with Akyol and Garrison’s (2011) findings, in which they state the importance of course design and time for enabling students to progress through higher levels of thinking. When considering the skills needed for scientific literacy, we argue that integration and resolution are more important indicators than others because it is insufficient to only recognize or explore the socioscientific problem; rather, sophisticated scientific literacy involves identifying solutions, testing them, critiquing them, and taking actions, all skills captured by the integration and resolution modes of cognitive presence.

A positive trend of students moving toward accuracy goals during evidence evaluation was also observed, as demonstrated by them visiting both sides of the evidence at the same frequency or spending about the same amount of time evaluating both sides of evidence, regardless of their voting decision at the end of the course.

In the future, we seek to identify ways to better measure the constructs related to motivated reasoning, such as accuracy orientation and directional reasoning. Observation of in-person problem-set discussions and evidence evaluations will be necessary to better understand when and how students shift their reasoning.

**References**


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