Students' Engagement in Scientific Practices and Agency During Science Learning: A Social Network Analysis

Abstract

[120 words or fewer for abstract]

Researchers have been paying an increasing amount of attention on agency, with some focusing specifically on agentic engagement. In science instruction, some suggest that engagement may be linked closely to participation in scientific practices, and we examined both of these constructs when learning about socio-scientific topics. Because socio-scientific topics are often controversial and challenging to learn, instructional scaffolds may facilitate students' engagement in the scientific practices and agency. Our study conducted a social network analysis using two types of instructional scaffolding to investigate changes in students' engagement in scientific practices and agency. Results suggest that the more autonomy-supportive instructional scaffold helped promote more collective use of scientific practices and agentic engagement than a less autonomy-supportive scaffold.

Purpose

Learners are discussing socio-scientific topics, such as the current climate crisis and availability of freshwater resources, in the classroom and beyond. While scientific research has made a powerful stance on some of these topics (i.e., the climate crisis is a real and imminent threat and human-induced; NASA, 2021), many of these topics have been deemed "controversial." In fact, even media outlets that are treated as credible sources are not always giving credible information on these topics (Moravec, Minas, & Dennis, 2018) Because of this, students are being exposed to alternate and non-scientific evidence and claims that conflict with consensus from the scientific community. To combat this issue, classroom instruction needs to face this challenge and help students to scientifically think and reason.

Instructional scaffolds that promote students' scientific evaluations may be one way to overcome barriers and facilitate students' learning about socio-scientific issues. Over the past several years, our research team has been developing and testing instructional scaffolds, called the Model-Evidence Link (MEL) activities, to facilitate middle and high school students' evaluation of the connections between lines of scientific evidence and alternative explanatory models (Authors, 2018). Recently, the team has developed an enhanced MEL scaffold, called the build-a-MEL (baMEL), with the hope of increasing students' collective use of scientific practices and agency during the learning process above and beyond the traditional version, which we call the preconstructed MEL (pcMEL). Through increased engagement in scientific practices and agency, students may deepen their scientific knowledge construction in what Pickering (2010) calls a "dance of agency" (p. 21), where individuals and groups are engaged in an intentional practice involving epistemic construction and manipulation of scientific resources (e.g., data in tables and graphs).

The purpose of the present student was to examine differences between these two instructional scaffolds (pcMEL and baMEL; Figures 1 and 2). We specifically compared these when middle school student groups used the scaffolds to learn about socio-scientific geological concepts. In the fracking pcMEL, students are presented with four lines of scientific evidence and two alternative explanatory models about the increased frequency in earthquake activity in the midwestern US (Figure 1; Authors, 2016). In the fossils build-aMEL, students select four lines of scientific evidence from eight possible choices and two alternative explanatory models from three choices about the reliability of fossil evidence for inferring past paleoclimatic and land surface changes (Figure 2; Governor et al., 2020). We were specifically interested about the potential differences between the two scaffolds in facilitating students' engagement in scientific practices and agency using social network analysis (SNA) and specifically asked: *Would SNA reveal a greater degree collective use of scientific practices and agentic engagement when middle school student groups used the fossils build-a-MEL compared to the fracking preconstructed MEL?*

Theoretical Background

The theoretical framework for this study focuses on students' engagement in the scientific practices and agency when learning about socio-scientific topics. Classroom based research has shown that increased student engagement has been associated with science learning and achievement (Lee et al., 2016; Grabau & Ma, 2017). The National Academies of Sciences, Engineering, and Medicine (NASEM, 2020) promotes "student engagement with real-world phenomena and problems" (p. 9) regarding many socio-scientific topics. Student engagement has also shown to build student agency through problem solving (NASEM, 2020). Participation in scientific practices may also facilitate scientific knowledge construction and critique in a way that promotes agency (Authors, 2015). Therefore, agency and the scientific practices go hand-in-hand, but only if instruction effectively integrates ways for students to propose and evaluate ideas that contribute to the community's collective knowledge construction (Miller et al., 2018). Thus, agency may be deepened when students participate in scientific practices that promote discourse where students consider and select appropriate connections between scientific evidence and alternative explanations about phenomena, and evaluate these connections consistent with scientific criteria (Christodoulou & Osborne, 2014). For example, students may examine and select lines of scientific evidence that support or refute alternative models that explain the causes of earthquake swarms in the midwestern US and/or utility of fossils to infer past geological and climatological processes (Authors, 2020), the socio-scientific topics students considered in the present study.

Methods

In the present study, we used SNA as a primary approach to visualize and analyze discourse dynamics during each lesson (fracking with the pcMEL and fossils with the baMEL) between student triad groups. Individual relationships between a trio form the group or network structure in which actors hold structural positions within the network. We overlaid network ties between actors using video observations of classroom discussion to code and map talk segments (Authors, 2015). By diagramming each coded talk segment, we were able to map out how scientific practices, manifested in discourse as epistemic operations, and agentic engagement were distributed across participants (actors), and how individual members of discourse communities shifted in their influence across time. In the present study, we specifically created and analyzed these network visualizations of students' discourse using epistemic operations and their agentic engagement when using the two forms of the MEL scaffold (pcMEL and baMEL) about geology topics.

Participants

Participants ($N = 18$) were situated in a grade 6 Earth science classroom located in the Middle Atlantic US, and specifically in a suburban community flanked on one side with a high density population area of appreciable poverty, and on the other side with a low density population area of appreciable wealth (Census, 2021). The student participants most often identified as Hispanic (of any origin) (n = 8; 44%), with a slight majority identifying as male (n = 10, 56%).

Data Sources and Procedure

We used audio recordings of student groups during two 50-minute lessons, the first featuring the fracking pcMEL and the second featuring the fossils baMEL. The teacher incorporated these lessons into one two week instruction unit, with each lesson spaced a few days apart. Students engaged in the MEL activities following the procedural steps detailed in Authors (2020). The present study focused on the last part of the MEL activity, where groups collectively wrote justifications for two of the four (pcMEL) or eight (baMEL) evidence-to-model evaluations they made on their diagrams. We refer to this activity as the "Explanation Task," where groups discuss, explain, and justify their evaluation of the strength between a particular line of evidence and a particular explanatory model (Authors, 2018). Explanation tasks were scored on an evaluation level scale, where 1 = Erroneous, 2 = Descriptive, 3 = Relational, 4 = Critical. This discussion and writing portion of each lesson constituted the majority of 30 minutes of group activity that we recorded for the present study, with six groups, each with three participants. We specifically constructed line-by-line transcripts of this group discussion and writing phase, which occurred during the last 30 minutes of each lesson. These transcripts were the primary data sources for conducting a qualitative content analysis coding for epistemic operations and agentic engagement (Authors, 2021). Using the content analysis results, we calculated each group member's *centrality* for epistemic operations and agentic engagement. Based on the recommendations of Wagner and González-Howard (2018) for using SNA in examining classroom discourse, we calculated centrality as the average weighted degree (which for this study is the sum of turns--the total number of times a group member uttered an epistemic operation or a type of agentic engagement--and directionality--who spoke to whom). We summed each group to get a total classroom effect, with the three group members identified as Alpha (the participant in the group who had the most turns when doing the pcMEL), Beta (participant with the second most turns), and Gamma (participant with third most turns).

Results

Figures 3 (epistemic operations) and 4 (agentic engagement) show the SNA results obtained via using the Gephi analysis tool (Bastion, Heymann, & Jacomy, 2009). In the figures, the arrows show directionality and turns (relative arrow weight). Group members are shown as circles, with centrality indicated by the side number and proportional size of the circle. We constructed contingency tables of centrality and subsequent analyses showed significant and meaningful differences between the pcMEL and baMEL in both epistemic operations [$\chi^2(2) = 45.2$, $p < .001$, Cramer's $V = 0.40$, a large effect size] and agentic engagement [$\chi^2(2) = 36.5$, $p < .001$, Cramer's $V = 0.33$, a large effect size]. The two graphs also reveal differences in how these two aspects changed, with use of epistemic operations being more collective in the baMEL than the pcMEL, and centrality of agentic engagement switching from Alpha during the pcMEL to Beta during the baMEL.

Discussion and Implications

The aim of this study was to examine if the baMEL would promote greater collective use of scientific practices and agentic engagement in middle school student groups when compared to the pcMEL. Overall, the baMEL scaffold resulted in meaningful changes in group use of epistemic operations and agentic engagement. Specifically, the baMEL resulted in more collective use of epistemic operations compared to the pcMEL, and the baMEL resulted in transfer of agentic engagement from the primary (Alpha) to the secondary (Beta) group members. All in all, this suggests that the baMEL promotes stronger collective group agentic engagement and participation in the secondary and tertiary members compared to the baMEL.

Agentic engagement has been shown to help promote scientific learning (Lee et al., 2016; Grabau & Ma, 2017), therefore developing appropriate instructional scaffolds can help dissipate false information that may be running rampant through schools and students. Socio-scientific topics have become more prevalent and are being discussed beyond educational and professional settings. Instructional scaffolds are one way to help students to appropriately evaluate information to determine what is scientifically supported and what has been scientifically disputed (Author, 2018, 2020)

The relations between agentic engagement and scientific learning have been proposed theoretically in the scientific literature, with emerging empirical support. The transition from a theoretical basis to practical use, however, is complex and requires additional design and testing. This present study is one step in the process of helping develop scaffolds that promote collective agency and students' critical evaluation skills when considering scientific and non-scientific claims on important socio-scientific issues, a critical component of scientific literacy.

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Figure 1

Student Example of a Pre-Constructed Model-Evidence Link (pcMEL) Diagram.

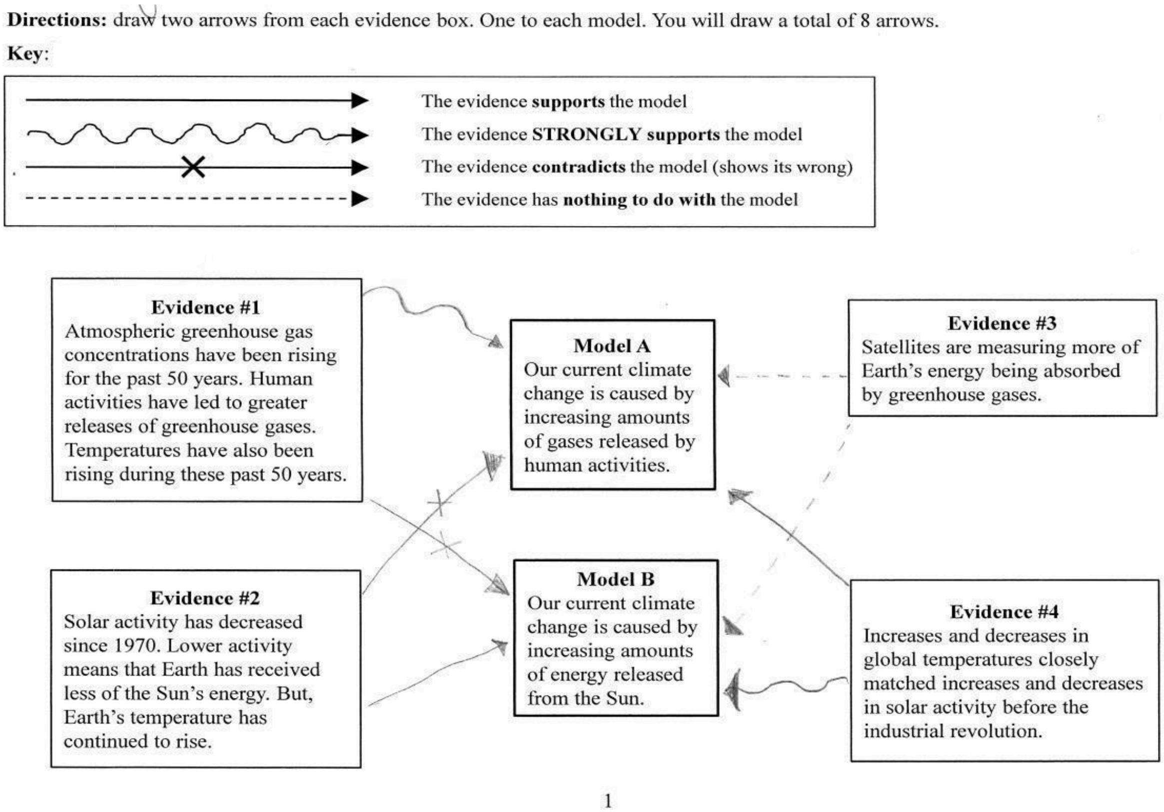

Figure 2

Student Example of a build-a Model-Evidence Link (baMEL) diagram

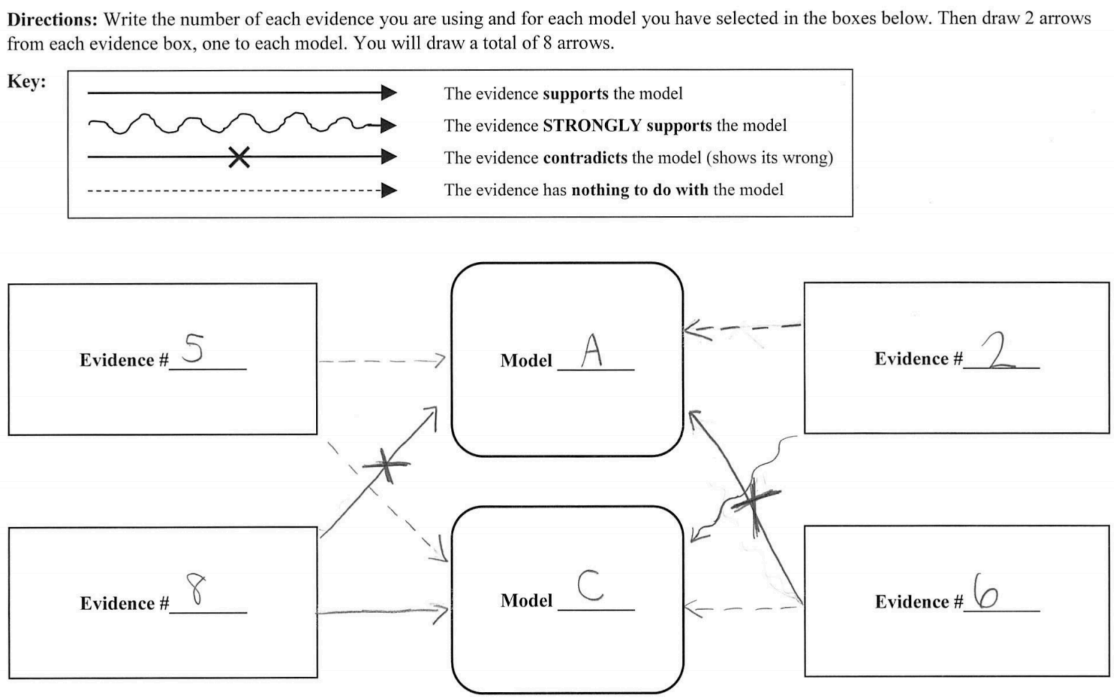

Figure 3

Social Network Analysis of epistemic approaches (a) and agentic engagement (b) for pcMEL

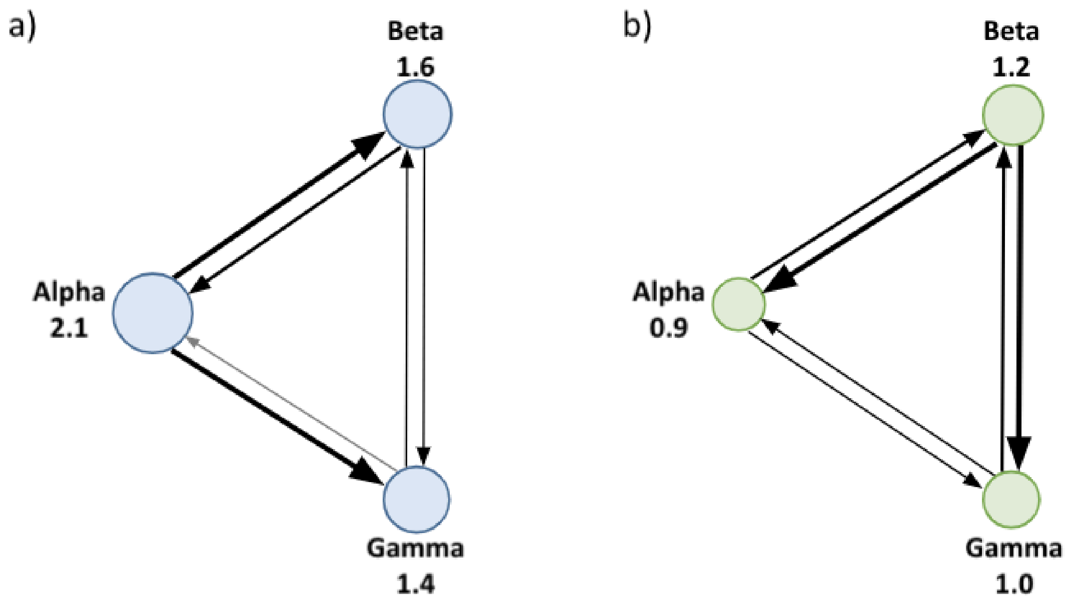

Figure 4

Social Network Analysis of epistemic approaches (a) and agentic engagement (b) for baMEL