Frameworks and Methodologies for Epistemic Growth in K-12 Science Classrooms to Address Post-Truth Discourse

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Abstract: Epistemic practices are the goal- and norm-guided actions people use to develop knowledge within a domain, such as analyzing evidence to support scientific claims. Developing sound epistemic practices is critical considering the current rise in post-truth discourse that constrains society's abilities to make informed decisions. Learning scientists have increasingly offered frameworks and methodologies to support improved epistemic performance. However, there is a lack of consensus in the field about what epistemic practices are that students can take up, as well as strategies to best support teachers in this endeavor. This symposium brings together seven teams of researchers who have been working on developing epistemic practices in K-12 classrooms. In conversation with each other and the audience, we aim to understand how epistemic growth is conceptualized in its myriad forms across students and teachers in addition to the design characteristics and indicators of growth of learning environments that promote epistemic performance.

Keywords: epistemic practices, K-12 science education, reasoning and sensemaking, post-truth

Symposium overview

With the recent rise in post-truth discourse, educators have been concerned with how to develop a citizenry capable of appropriately evaluating knowledge claims (Barzilai & Chinn, 2018; McIntyre, 2018). Recent publications have documented challenges in how citizens understand significant scientific issues. For example, Sloman and Fernbach (2017) discussed the tenacity of false beliefs about scientific matters, such as the causes of global warming; in one study, only 12% of respondents were even partially correct. Nichols (2017) revealed issues in the American educational system that do not enforce the habits of critical thinking to enable the evaluation of complex content to make informed decisions. Because many of the consequential issues are in the domain of science learning, such as climate change and vaccines, researchers have noted a pressing need to include a focus on epistemic practices in K-12 science classrooms (Chinn et al., 2021). Epistemic practices (EPs) are the goal- and norm-guided actions people engage in to develop knowledge within a particular domain. Some examples of EPs include constructing, critiquing, and revising models to fit patterns of evidence (Ford, 2008) and engaging in systematic research to develop patterns of evidence. Despite the growing efforts to promote epistemic education–education directed at promoting growth in students' ways of knowing–there is as yet too little clarity of what high-quality epistemic practices look like in classrooms (Rosman et al., 2016). Some research has focused on facets of reasoning practices without providing a more comprehensive picture. For example, research has focused more narrowly on reasoning strategies, such as checking the authenticity of sources or conducting controlled experiments without accounting for the aims or ideals (i.e., the standards) that are critical for establishing scientific knowledge (Chinn et al., 2020). There is a need for more systematic accounts of what high-quality epistemic practices involve. In particular, there is a need for improved theorizing as well as empirical research on the range of useful practices that students can master in classrooms.

In addition to a lack of consensus or clarity on what epistemic practices are that students can take up, we know very little about how best to support teachers in this endeavor. We know that when implemented well in classrooms, pedagogical practices that engage students in epistemic work can disrupt traditional hierarchies of power in science education (Barton & Tan, 2009; Hand, 2012). Epistemic positioning of students also propels a shift in instructional practices from those that engage students in mimicking "correct" canonical science information to adopting strategies that empower students to develop their own ideas (Haverly et al., 2020; Stroupe et al., 2018). Most schools, especially within formal environments, struggle to engage students' epistemic practices (Erikson & Lindberg, 2016). Supporting students' epistemic practices within science classrooms is a challenge for teachers because of the tensions that arise from maintaining authoritative control over the content while attempting to create authentic opportunities for students to engage with and construct knowledge that is meaningful to them (Braaten & Sheth, 2017). This kind of teaching requires tools and processes that are distinctly designed to leverage students' ideas for an active knowledge production process within classrooms while adhering to structural limitations of formal science classrooms (Brown, 2018). Hence, there is a need to investigate innovative professional development (PD) pedagogies and environments that support teachers to engage in epistemic teaching practices. We also need a concentrated effort to understand what PD supports should look like and, importantly, what PD features help to overcome the structural tensions between the epistemic instructional practices and traditional power dynamics between students and teachers.

With an international group of scholars, in this session we seek to investigate frameworks and methodologies that support students' and teachers' epistemic performance by asking the following questions: 1) How is epistemic growth conceptualized in its myriad forms across students and teachers? 2) What are the design characteristics of the processes, tools, and learning environments that promote epistemic performance in science classrooms? and 3) How are epistemic learning gains measured and what can be agreed upon as successful indicators of epistemic growth?

Structure of symposium

To demonstrate the range of applications, symposium presenters will present both theoretical and empirical research and early and late-stage work that addresses post-truth issues. The symposium will be structured to allow conversations between presenters and the audience about the collective emerging scholarly work, with the ultimate goal of mapping current and future possibilities for advancing the field of educational epistemic performance. We will begin with a 5-minute introduction from each of the 7 posters followed by 40 minutes of participant rotations to each poster. Our discussant Dr, Toshio Mochizuki will offer 10 minutes of remarks on the collective scholarship and then we will open up the discussion to both presenters and participants.

Designing for growth in apt source evaluation performance

Sarit Barzilai, Shiri Mor-Hagani, Fayez Abed, & Danna Tal-Savir

Being able to evaluate the trustworthiness of information providers is vital for navigating "post-truth" information landscapes. Current approaches to source evaluation instruction often focus on teaching students how to apply a set of heuristics or a criteria checklist. There are several limitations to such conceptions of sourcing instruction. First, instruction is often divorced from students' science learning and inquiry. Consequently, the importance of source evaluation for reaching sound conclusions can be under-appreciated (Paul et al., 2017). Second, simple sourcing rules underestimate the complexity of evaluating sources. This requires discerning and evaluating multiple epistemic criteria that students can find hard to grasp (Allchin, 2021). Third, students may have little agency to evaluate sources and determine who *they* trust. Consequently, disagreements about who to trust between students from different social and cultural backgrounds, and between students and teachers, are usually ignored. We use the Apt-AIR framework (Barzilai & Chinn, 2018) to inform our efforts to design instruction that addresses some of these challenges. The Apt-AIR framework posits that epistemic growth means increasing competence to successfully achieve epistemic aims. Further, epistemic growth involves five intertwined aspects: (1) increased practical abilities to employ reliable processes and apply appropriate ideals in order to achieve epistemic aims (2) in an adaptive manner across diverse tasks and contexts; as well as increased (3) metacognitive understanding and regulation of epistemic aims, criteria, and processes, (4) dispositions to value and pursue these, and (5) grasp of their fundamentally social nature and uses.

Through ongoing collaborations with teachers, we developed several principles for designing learning environments to support growth in apt source evaluation performance. One principle is *making sources meaningful*. This means integrating sources with diverse trustworthiness levels in engaging inquiry activities, so that students have opportunities to grapple with diverse sources [Apt-AIR aspects 1&2] and experience the risks of relying on unreliable sources [aspect 4]. A second principle is *making sources visible.* We have developed a scaffold for visualizing sources and mapping how sources relate to competing claims (Barzilai et al., 2020, 2021). We found that visualization helps support growth in practical abilities to evaluate sources [aspect 1]; and that it facilitates individual and collaborative regulation of sourcing as well as understanding of the impact of sources on knowledge construction and evaluation [aspects 3&5]. A third principle is providing *meta-epistemic discourse prompts* that encourage students to explain their source evaluations, describe their criteria, and discuss their disagreements about source trustworthiness [aspects 3&5]. Such discussions become meaningful when students have *epistemic agency to decide who to trust* [aspects 4&5]. We will illustrate the affordances and challenges of implementing these principles using examples and artifacts from inquiry units in which Israeli ninth grade students conducted investigations using diverse authentic information sources. These findings contribute to the design of learning environments that can prepare students for reasoning in a “post-truth” world.

Toward “truth”: Scientific sensemaking through epistemic and social negotiations

Emily Adah & Leema Berland

To address the call for equity, science teachers position students to collaboratively make sense of a phenomenon by using scientific practices and applying science ideas in small groups. Simultaneously, they must negotiate implicit understandings about whose scientific ideas are valued, what scientific ideas count, and how they should be communicated—they must negotiate multiple epistemological perspectives (Bang & Medin, 2006). These epistemic judgments are part of the sense they make of the scientific phenomenon under study—the “truth” they discern. Thus, students must practice addressing and evaluating implicit and embedded claims about the identities of the speaker and the audience, the students’ relationships to science and to knowledge, and bids for what language, culture, and norms belong in science discourse, all while making sense of a scientific phenomenon (Brown, 2004). In this study, we view epistemic growth as change in epistemic practices and ideas (Herrenkohl, 2006), from traditional and fixed, exclusionary understandings and ideas, to flexible and responsive to the situation (Berland & Crucet, 2015). We present our analyses of instances in which students engage in sensemaking as a complex and multi-layered negotiation where the “truth” encompasses more than resolution of scientific ideas.

As part of a larger design-based research project, we gathered data from videotaped transcriptions of 3 small groups’ interactions during an 8-week project-based unit on animal adaptations. We reviewed video and transcripts to identify moments in which students made bids to introduce different ways of engaging in the collaborative sensemaking work. We employed discourse analysis to describe the decision-making criteria being employed, how bids to change it were made and responded to, power dynamics associated with these moments, and finally, the “truth” students constructed (i.e., the sense they made). Through these analyses, we explore the growth of scientific sensemaking as epistemic and relational negotiations. For example, consider an interaction between two Latine, 4th graders making sense of a bird’s life cycle. One student began the discussion in formal English and affected posture, suggesting that science ideas should be communicated in ways that align with historical and institutional scientific norms. With unsuccessful take-up by others, the student introduced alternative epistemic criteria (i.e., he spoke conspiratorially in Spanish, using an informal posture suggesting that science ideas come from non-privileged sources). This stance was curtailed by the partner as non-credible. However, when the same student switched modalities and offered ideas with informal English and a gesture for center stage, the partner attended. Hence, scientific sensemaking enabled and coordinated, and was enabled and coordinated by, epistemic negotiations.

This brief interaction underscores the epistemic negotiations that determine "truth" during sensemaking. In our poster, we explore the claim that a key aspect of growth in epistemic practice in the post-truth era is this multilayered negotiation.

Tools to support thinking and regulating scientific inquiry

M. Anne Britt, Steven McGee, Randi McGee-Tekula, Kathryn Rupp, Karyn Higgs, Kathleen Easley, & Amanda M. Durik

The scientific practices students are expected to learn from inquiry units in science classes are the same ones that students need to develop to evaluate scientific claims outside the classroom. Many students, however, struggle to coordinate these skills to create a scientific argument (Osborne et al., 2004). Some challenges for middle school students are: including providing reasoning to demonstrate why the evidence supports a claim and/or why the evidence refutes an opposing claim. Previous research with middle school students has found that students place less emphasis on engaging in scientific practices, as compared to understanding specific scientific phenomena (Rupp et al., 2020). One potential support for students is to help teachers support students' reflection on and development of these scientific practices (Herrenkohl et al., 2011) to improve epistemic competence (Chinn et al., 2014). Our team approaches epistemic cognition as the development of a regulatory task model which includes understanding the goal state (purpose) of each subtask, understanding how to accomplish each subtask (subgoals, tools, and strategies), and valuing the goals of the primary task and the subgoals of each subtask (Britt et al., 2018). A discipline-appropriate task model instantiates epistemic aims and value, epistemic ideals or criteria, and epistemic processes to achieve those aims.

We will describe the development of two tools designed to help teachers guide students through a multi-session inquiry unit that required engagement in and reflection on epistemic practices within the discipline of science. The first tool, *Investigation Steps Chart*, is a class-level regulatory structure to help students develop epistemic practice of figuring out how the unit and lesson investigation questions will be explored through scientific inquiry, what was found, and what still needs to be done to answer each of the questions. This is intended to help students develop a task model to organize multiple days of inquiry to support writing of a unit culminating with a scientific argument. The *Investigation Steps Chart* uses key NGSS storyline routines (i.e., exploration, navigation, investigation, problematization, "putting the pieces together") to guide inquiry (Reiser, 2017). The second tool, *The Evidence Sorter*, supports student synthesizing notes taken across the multi-day inquiry to help students construct argumentation by: (a) organizing all evidence collected during the unit, (b) determining which claim is best supported, (c) engaging in reasoning to connect evidence to the chosen claim. These tools were improved upon over the course of two academic years in the context of middle-school science classes in the Chicago Public Schools. Iterations were informed systematically by: teacher feedback provided during workshops, analysis of student written work, classroom observations (pre-pandemic only), and analysis of teacher and student surveys. The key changes to the *Investigation Steps Chart* included reordering the questions so that students did not consider materials not available, improved emphasis on the student's role in scientific practices as they consider how the material that is provided will be used, encouraging separately the connections with the overall goal (unit question) and subgoals (investigation question), and including a prompt for making deliberative connections to the key concepts as a scaffold or a lens for creating reasoning statements. The key change in the *Evidence Sorter* was a revision to decrease cognitive load. Through the use of tools that bring students into the discussion about the process of scientific inquiry, students should develop appropriate epistemic cognition and practices that can be used when they encounter scientific claims.

It did not fly but it would outside: Pushback and purpose in investigation practice

Eve Manz & Chris Georgen

We conceptualize science practice, including empirical investigation, as model alignment, involving representational practice, model-based reasoning, and pushback from people, representations, and the world (Manz et al., 2020; Nersessian, 2008; 2012; Rouse, 2015). We ask how children can engage in iterative investigative work where they seek to make progress on understanding some aspect of the world by modeling it: representing it, playing the model out, making sense of the implications, and then refining their understanding and, sometimes, the investigative model itself. In doing so, we seek to shift current instructional approaches and pedagogical strategies for classroom investigations, which rely on investigations demonstrating general principles (plants need light; water can shape earth, a magnet's force decreases with distance) and, almost invariably, lead to materials dictating investigation procedures and teachers stepping in to correct children's ways of measuring, interpreting, or making connections so that they will conclude what they need to. These approaches oversimplify scientific activity, omit opportunities for children to engage in critical evaluation of models and their relations, and introduce investigation as a school game that involves following rules, letting go of what you know of the more complex world, and trusting the teacher's authority.

We engaged in co-design and design-based research with teachers to develop, implement, collect video data on, analyze, and revise investigations into seed travel. Second grade (7 and 8 year-old) students plan, conduct, and make sense of how well particular seeds travel by water, wind, and sticking, using the wind tests as a focal case. In the first instantiation, the team focused on children's choice and agency in designing their investigations, providing an array of materials to use (paper fans, straws, an electric fan). We experienced substantial difficulty helping students reason about the results of the investigation and make connections to the form/function and ecological relationships involved in seed travel. In the redesigned investigation, students (1) examined video of seeds travel by wind, beginning to focus on particular mechanisms, (2) argued over what counted as "flying," (3) conducted a shared test and collected data, (4) rejected the test as providing useful information about the maple seed, which needs to be dropped from a high enough height that it will twirl, and (4) re-tested the maple seed by dropping it from a window.

We highlight several design features and aspects of young children's thinking across these two instantiations, using it as a case to invite discussion. First, we found that children's framing of the purpose of their investigative work including, and often laminated, frames for *representing the world, making something happen, and figuring out.* These were dynamic and context-dependent, and further were consequential for the conceptual resources that were called on and refined and children's evaluative and iterative practices. Bringing together representational and figuring-out frames appeared important for allowing children to develop and iterate tests that allowed them to make and evaluate claims about seed travel. Features of the environment that supported these framings included shared experiences with the phenomenon, support to play out and evaluate the implications of investigation choices, focusing uncertainty and discussion on choices that have conceptual import (here the height of the maple seed), and designing pushback into children's work with investigations. We will further share the assessment foci and practices we and our teacher partners are building to consider epistemic growth in children's framings and related practices for evaluating investigative choices.

Students' understanding and caring about placing trust in the time of corona

Jessica Shuk Ching Leung

In a world increasingly shaped by science, there is a pressing need for citizens to be able to make informed judgment about knowledge claims in socioscientific issues. These are ill-structured problems that are inextricably linked with science and require both scientific and ethical reasoning for decision-making. Laypeople's limited understanding of science often predisposes them to placing trust on science experts about these issues. To avoid misplacing trust, students need to learn the nature of science (NOS) – How does science work? What happens when scientists disagree? When should we be skeptical about science? (Höttecke & Allchin, 2020). This is not merely about understanding NOS. It is also about the use of such understanding (Ford, 2008). This may include: (1) identifying whether recognition from peer reviewers has been obtained; (2) examining the credentials of those who claim expertise; (3) determining the level of expert consensus; and (4) identifying possible sources of bias (Leung & Cheng, 2021). Developing students' understanding of NOS as a form of practice, rather than strictly a form of knowledge, has been shown to play a productive role in their evaluation of socioscientific issues (Leung, 2020). This practice-oriented approach to learning NOS was informed by the Apt-AIR framework of epistemic growth (Barzilai & Chinn, 2018), which conceives epistemic growth as increasing competence to successfully achieve epistemic aims. Developing such competence does not only involve the practical abilities of employing reliable epistemic processes and epistemic ideals to achieve epistemic aims, but also entails students' metacognitive understanding and regulation as well as their motivation-affective disposition to value and pursue epistemic aims.

Contextualized within the Covid-19 pandemic, this qualitative case study examines students' growth in understanding and caring about placing trust in a lesson unit guided by a practice-oriented approach to NOS. Seventy-three undergraduate students enrolled in a general education course on making sense of socioscientific issues participated in this study. Reflective journals were used to capture participants' growth in epistemic performance. Findings revealed: (1) an increased awareness on the need and reasons for laypeople to place informed trust on knowledge claims; (2) consideration of a broader range of reliable epistemic processes; (3)

increased consciousness about these epistemic processes; and (4) increased concern, inclination and self-efficacy in assigning epistemic trust. Participants expressing increased understanding about reliable epistemic processes often showed appreciation for these processes. This suggests an association between participants' understanding and caring about reliable epistemic processes, offering empirical support for the intertwining of aspects in the Apt-AIR framework.

Supporting students' development of a "grasp of modeling"

Na'ama Av-Shalom, Ravit Golan Duncan, Clark Chinn, Joshua Danish, Cindy Hmelo-Silver, Danielle Murphy, Christina Stiso, Zachary Ryan & Jinzhi Zhou

Science is a social knowledge-building process, in which scientists collaborate to construct knowledge and ratify it through a process of social critique (Ford, 2008). For example, scientists refine their ideas through a social process of receiving critique from the scientific community (e.g., through peer review or at conferences) and refining their ideas based on these critiques with the aim that the knowledge will eventually be taken up by the community. Often, these knowledge building practices are foregrounded in science instruction with little attention to social critique (Ford, 2008). But, to navigate information in an epistemically complicated post-truth world, students need to develop a robust understanding not only of how science is done, but also how these practices lead to reliable knowledge. For this, students need opportunities to engage in evaluation and critique (Ford, 2008). One context for knowledge construction and critique is modeling (NRC, 2013). An important aspect of modeling practice are the norms that scientists use as they engage in modeling--particularly reliable epistemic processes and epistemic ideals (see AIR framework: Chinn & Rinehart, 2016). Reliable epistemic processes are practices involved in doing modeling, such as defining components and processes in a mechanism. Epistemic ideals are the criteria that scientists use to evaluate models, such as "models are good when they explain a mechanism." A key ideal, fit with evidence, and the associated reliable evidentiary processes (e.g., integrating bodies of evidence; see Duncan et al., 2018) form the foundation for establishing the veracity of models in science (NRC, 2013). Extending work by Ford (2008) and Duncan et al. (2018), we suggest that a "grasp of modeling" involves understanding how models are constructed and critiqued, and how the norms guiding this process are themselves constructed and ratified through social critique processes.

In the Scaffolding Explanations and Epistemic Development for Systems (SEEDS) project, we explore how students develop such a grasp of modeling practice. We designed a fifth-grade model-based science intervention focused on constructing and critiquing models using epistemic criteria. Classes collaboratively developed and revised criteria for evaluating models. Students worked together in small groups using the computer-based Model and Evidence Mapping Environment (MEME) to construct and critique evidence-based models of a phenomenon using different kinds of evidence. In prior and ongoing analyses of written artifacts, pair interviews, and classroom videos of groups, we focused on students' use and metacognitive understanding of reliable processes and ideals for modeling. For instance, in interviews students were asked to rank the importance of each of their class criteria. In their justifications for their ranking, students were able to reason about the nature of different criteria (e.g., redundancies) and their relationships to the aims of the model (e.g., communicating ideas) (Murphy et al., 2021). Although the students did not consistently prioritize evidentiary criteria, they did offer justifications regarding the role of evidence (e.g., supporting accuracy), showing a growing metaepistemic understanding of the relationship of evidentiary norms to modeling. Our analysis indicates that supporting students in developing a sophisticated grasp of modeling—a central aspect of scientific knowledge-building—can equip them to engage with science as they encounter it in the post-truth world.

Epistemic practices that advance learning of complex scientific models

Noora F. Noushad, Amanda Cottone, Huma Hussain-Abidi, Clark Chinn & Susan A. Yoon

With the recent rise in post-truth discourse, educators have been concerned with how to develop a citizenry capable of critically evaluating knowledge claims (Barzilai & Chinn, 2018; McIntyre, 2018). Since many of the issues are consequential to the domain of science learning, such as climate change and vaccines, researchers have noted pressing needs to include a focus on epistemic practices in K12 science classrooms (Chinn et al., 2020). Our project addresses the implications for designing for post-truth reasoning by examining productive epistemic practices (the practices used to establish, critique, and use knowledge within a domain) that occur when students reason with biological models in science classrooms. With the eventual goal of using these practices when evaluating science-related real-world issues, in this poster, we articulate efforts in the first phase of the project, which was to establish a baseline understanding of what epistemic practices students already use. We were also interested in identifying those epistemic practices that are most appropriate for establishing knowledge claims with our complex systems biology curricula. To address these research goals, we use the AIR framework found in Barzilai and Chinn (2018), who argue that the goal of epistemic education is *apt epistemic performance,* which refers to successfully achieving epistemic goals (such as accurate beliefs or a good understanding) through competence. Epistemic competence involves use of: 1) *Epistemic **A**ims and values*: the goals that people have, such as developing explanations, and the value that people place on these aims; 2) *Epistemic **I**deals*: the criteria that are used to evaluate whether the epistemic aims have been met (e.g., fit with evidence) and 3) ***R**eliable epistemic processes*: the procedures, strategies, and methods that have a high probability of achieving epistemic aims (e.g., selecting representative samples in a study).

We analyzed an archived video dataset of students interacting with the biological models from a previous research project that occurred between 2012 and 2014. The curriculum requires students to run the models, collect and analyze data, and make inferences about the scientific phenomena, e.g., how to create a sustainable ecological system. Using Interactional Analysis (Jordan & Henderson, 1995) to analyze the five videos of student pairs, we identified ten AIR codes related to our modeling curriculum. They comprised six epistemic processes and four epistemic ideals. We inferred that the observed processes were typically governed by an ideal that students were applying in the background. For example, the process, *Inferencing,* was always coded together with the ideal, *Fit with Evidence,* because all instances of making inferences involved students citing evidence from the simulation to fit their mental model. The categories of processes and ideals that emerged with the greatest frequencies were: *Run and Observe* (process), *Describe Trends* (process), and *Fit with Evidence* (ideal). However, we noted that students often drew conclusions based on insufficient evidence (such as single runs of the model rather than averaging multiple runs). Furthermore, we found that there were a number of other processes and ideals not present in student reasoning, such as *Planning an Experiment* (process), *Making Data-Informed Revisions* (process), *Check Plausibility* (process), *Making Sense* (ideal), and *Having a Mechanism* (ideal). We used these findings to modify the curriculum to develop greater epistemic performance in the subsequent summer PD workshop. We also worked with teachers to relate these EPs to issues that are current in the public domain to demonstrate adaptive epistemic practices, e.g., the complexity of global warming. We are currently collecting data to see how the modified curricula worked in classrooms. We further report on these experiences in the poster.

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