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Opinion: Lessons from the 'Misinformation Age': Proposing a Socially-Embedded Approach to Foster Conceptual Change

ABSTRACT

Engineering educators strive to help students understand concepts that may be difficult and counterintuitive. This often entails helping students bring their understanding of how a phenomenon works into alignment with the scientifically-accepted explanation. For the most part, fostering conceptual change has been thought of as a process of logically convincing students of the validity of the scientifically-accepted explanation. This piece introduces a socially-embedded view of conceptual change that takes into account the impact of the group affiliation of the learner. It is suggested that conceptual change is not a wholly cognitive process, but rather one that is also social in nature.

INTRODUCTION

We live in an age when different groups of people hold opposing views about a variety of important issues. What one group asserts as a "fact", an opposing group labels as "misinformation" and vice versa. Both groups tenaciously hold on to their own views of reality and remain unmoved by any of the opposing side's arguments, and we have seen (at least virtually) confrontations escalating into violence. We are left wondering: "What is going on here? Why are these beliefs so deeply and strongly held? And why are they so difficult to change?" Educators have posed similar questions about students' understanding of difficult STEM concepts. "Why", educators ask, "are some conceptions about STEM concepts so difficult to change?" Education researchers, when posing this question, call their efforts "fostering conceptual change".

I propose that we consider our current information-misinformation divide as a case study of conceptual change "in the wild". How might what we are learning from conceptual change in the wild be applied to conceptual change in the classroom? In this Opinion piece, I will share my speculations about this question. It is meant as a way to begin to share my ideas, and should not be perceived as a thorough thesis about the topic. Nonetheless, these early speculations could spur a useful discussion about classroom practices.

I begin this piece with a brief summary of conceptual change research, then draw parallels to explanations about the spread of alternate beliefs, and end with implications for educators.

CONCEPTUAL CHANGE RESEARCH

The discussion of conceptual change research should begin, I feel, with Thomas Kuhn's classic work *The Structure of Scientific Revolutions* (Kuhn, 1962). Here, Kuhn used examples from the history of science to present a framework for how scientific revolutions occur – switching from "normal science" – where progress is incremental, to a "revolution" where a paradigm shift within the community brings about a new understanding of a phenomenon. Kuhn posited that a shift in community understanding comes about when new data could no longer be explained by current theory and a new theory was accepted if it was deemed intelligible (or understandable), plausible, and fruitful (or suggesting new lines of research). In the early 1980's Posner and colleagues posited that conceptual change for an individual learner also follows a similar progression. Posner et al. (1981) argued that to undergo conceptual change, a learner comes to a logical conclusion that a new theory or concept is intelligible, plausible, and fruitful. "Our central commitment ... is that learning is a rational activity. That is, learning is fundamentally coming to comprehend and accept ideas because they are seen as intelligible and rational." (Posner et al., 1981, p. 212) Therefore, the job of the instructor was to clearly present a new theory/concept and provide solid evidence of its veracity. The learner would then use this evidence to accept the new theory or concept.

Chi added to the conversation about conceptual change by looking at the nature of the concept that one is trying to change. She proposed three kinds of conceptual change: belief revision, mental model transformation, and categorical shift (Chi, 2008). And each kind of conceptual change required a different instructional strategy. Chi argued that bringing about a categorical shift is the most difficult of the three kinds of conceptual change because the learners must be instructed in a new way of thinking about the nature of the concept itself. For example, a learner may think of "heat" as a property of an object, rather than as the result of ongoing, random, interactions among collections of molecules. Chi and colleagues have argued this is an example of learners viewing heat as a material substance (one kind of ontological category) rather than the result of an emergent process (another kind of ontological category) (Reiner, Slotta, Chi & Resnick, 2000). To encourage an ontological shift, an educational intervention called ontology training was developed (Slotta & Chi, 2006) where a new way of categorizing concepts is explicitly taught. Chi has continued to refine her thinking about ontology training (Chi, 2005, 2021; Chi et al., 2012) and ontology training has been applied in engineering education with mixed results. Sometimes the ontology training has seemed to "work" and sometimes not (Yang et al., 2020).

Looking at the nature of the concept is a welcome addition to conceptual change research. But it is an elaboration on the basic premise that learning is a rational, logical process and that conceptual change can be brought about by presenting clear evidence for a new way of viewing a concept. But,

as instructors have experienced, presenting more and better evidence has limited results. Learners might parrot back what they know is the desired response on an exam, but when asked what they really believed was happening with a phenomenon, they would return to their former way of thinking. "Convincing through logic" didn't seem to bring about conceptual change in the classroom any more than it has among the general public.

EMOTIONAL COHERENCE

So, if people don't change their views because of evidence what does work? Here, the work of Nobel Laureate Daniel Kahneman can supply an answer (Kahneman, 2011). Kahneman, along with his close collaborator, the late Amos Tversky, spent decades studying the processes people use when making judgments and decisions. [A narrative account of their collaboration may be found in Lewis, 2016]. These processes often differed radically from the then-accepted theories of economic decision-making that asserted that humans make logical decisions based on their best interests. Instead, Tversky and Kahneman found "decisions were often based on feelings of liking or disliking, with little deliberation or reasoning." (Kahneman, 2011, p.12) When changing one's beliefs, Kahneman writes,

> "The amount of evidence and its quality do not count for much.... For some of our most important beliefs we have no evidence at all, except that people we love and trust hold these beliefs." (Kahneman, 2011, p. 209)

Kahneman points out that our beliefs are *emotionally coherent* (Kahneman, 2011, p. 82) in that we believe people we already love and trust. [A video of Kahneman explaining emotional coherence can be found at https://www.youtube.com/watch?v=-Txt7ZWDMYc] It is emotional coherence, not rational argumentation, that is more likely to change people's views.

A SOCIALLY-EMBEDDED APPROACH TO CONCEPTUAL CHANGE

How does emotional coherence connect to group identity and conceptual change? To explain this connection, I turn to evolutionary biology and the social sciences. The late evolutionary biologist, E.O. Wilson (2019) argued that humans can survive only as a member of a group. In the struggle for survival, it is the unit of the group that is acted upon by natural selection, as groups compete with each other for resources. Groups whose members cooperate are more successful in terms of

their survival than are groups whose members compete with each other. Thus, there is a strong evolutionary impetus for humans to identify with and cooperate within their group, and to mistrust and compete with other groups.

As part of their cultural experience and heritage, different groups create and enforce cultural norms around learning and may have a distinct cultural epistemology (Tasaki, 2001). The human brain is highly attuned to social cues (Lieberman, 2013), and we are also sensitive to social markers of group membership (Moffet, 2019). Beliefs or ways of knowing are also ways to distinguish people as members of a group. Thus, what you believe can be seen as an indicator of your group membership. Again, current events make this point very evident.

Groups are not stagnant. They can merge or split. Groups also compete and jockey with each other for power, complicating our feelings about our own and other groups. Sometimes we aspire to become part of a dominant group. Sometimes we act to keep subordinate groups "in their place." Sometimes we battle to replace the dominant group with our own group. In contrast, there are also times when the boundaries between our group and "others" dissolve and our desire to nurture and cooperate override our urge to compete. At those moments humans are capable of extraordinary measures of empathy and altruism.

Group members trust members of their group and distrust members of other groups, and groups can have their own knowledge and way of viewing the world. Therefore, when making the decision to accept a new concept, instead of asking "is this intelligible, plausible?" as Posner posited, we probably first (unconsciously) ask ourselves – "Is this something my group believes?" And, if it is not my group's belief, "what are my feelings toward the group that does believe this?"

What might this process look like with regards to conceptual change? Here, a framework by Chinn and Brewer (1993) may provide a useful model. Chinn and Brewer laid out a framework describing seven ways one may respond to anomalous data – in other words, what happens when we are presented with data that does not fit our expectations. We might (1) ignore the new data, (2) reject it, (3) exclude it from our thinking, (4) hold it in abeyance, (5) reinterpret it, (6) make peripheral changes to our thinking, or (7) actually change our thinking. Notice that six of the seven ways we may react to anomalous data do not bring about conceptual change. Chinn and Brewer asserted that all seven responses were logical processes. However, I would argue that a social process is also at work here. Whether or not we ignore, reject, exclude, or reinterpret the data may be more greatly impacted by our assessment of the *group* that generated or disseminated that data, rather than on the logic of the data itself.

I am proposing a socially-embedded approach for conceptual change that does not assume that learning is socially neutral. In a socially-embedded approach, some kinds of knowledge are associated with certain social groups, and the learner's feelings of trust in and belonging to that group is an important first step in being open to conceptual change. Without trust and belonging,

the new information may be ignored, rejected, excluded, or reinterpreted before any further logical processing is begun.

Is there evidence for a socially-embedded approach in engineering? A socially-embedded outlook would predict that our feeling of belonging in a learning setting, and our identity as part of the group, would be important factors for learning. And there indeed is engineering education research that is consistent with this prediction. Denise Wilson and colleagues found feelings of belonging (especially belonging in a particular course) were associated with positive emotional and behavioral engagement in STEM college students (Wilson et al., 2015). And feeling that engineers do things that "people like me do" was a powerful motivation to choose, and complete an engineering major (Matusovich et al., 2010).

IMPLICATIONS FOR EDUCATORS

What Would A Socially-Embedded Approach To Conceptual Change Mean For Educators?

First, educators need to recognize that when they teach, they are representatives of a particular group. For example, engineering has a strong association with maleness and whiteness (Holly Jr., 2020b) and anyone who teaches engineering automatically inherits this association. Learning can be impacted by learners' feelings about the group their instructor represents. If learners already identify with the group their instructor represents (for example, maleness and whiteness), then they are more likely to be persuaded to undergo conceptual change. If learners are not part of this group, they may ignore or reject the information. Educators hoping to foster conceptual change might not simply be asking learners to logically follow the evidence. They might also be asking learners to accept a belief that is foreign knowledge for the learner's own group.

How has holding a socially-embedded approach personally impacted my own teaching philosophy? I now see one of my primary duties as a professor as helping learners *feel they belong in my class*. How does one do that? One long-term term solution is to have diverse learners in the class, which increases the likelihood that learners can identify with other classmates. But what about in the short term? What can I do tomorrow? My answer to this is to recognize that trust is essential for learning to occur. Of course, some level of trust is earned by my position as a "professor" within my institution and I hope that my students trust in my expertise. (Though we have seen that for faculty who are women or people of color, trust may not come so automatically. And this too is related to group dynamics). I can reinforce this trust by being knowledgeable and clear. There is nothing unusual in this advice so far. But trust is also engendered, at a very deep level, when learners sense their professor is a person who cares about their learning, who is fair and thoughtful in their assessment, and who values their worth as human beings. Culturally relevant (Gay, 2002) and culturally-sustaining (Paris

& Alim, 2017) teaching principles point out the need for learners' cultures to not only be tolerated but celebrated. Some particularly good examples of culturally sustaining principles in action help us to visualize what this might look like in engineering. For example, Shawn Jordan's work with Diné children in Arizona has incorporated fact-based story-telling about Navajo STEM professionals into engineering design (Jordan, 2015; Jordan et al. 2017, 2018). And James Holly Jr. (2020a) used his personal experience and cultural knowledge growing up as a Black male in Detroit, including sharing his love of basketball, as a way to bring engineering to urban Black youth. In both cases, something familiar and important to the children's respective cultures was woven into "instruction" about engineering. They were made to feel that engineering was not foreign to their way of life.

In conclusion, I have proposed a socially-embedded approach to conceptual change. In a socially-embedded approach, conceptual change is more than a logical analysis of evidence. A socially-embedded approach to conceptual begins with instructors being caring and welcoming human beings who help learners feel they belong in their classrooms.

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Ruth A. Streveler (she, her) is a Professor of Engineering Education at Purdue University and has been researching conceptual change for over 25 years. She has been motivated by the question: Why are some concepts so difficult to learn? Her answers to that question have expanded from a strictly cognitive to an embodied approach and she is now fascinated by the role of culture and membership in social groups in conceptual change. Professor Streveler is the creator and host of the podcast Engineering Education Research Briefs which is entering its 6th season. Upcoming episodes will feature engineering educators who use culturally sustaining pedagogy in their classrooms.