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Navigating Epistemological Borders: Considerations for Team Teaching at the Intersection of Humanities and STEM

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WIP: Navigating Epistemological Borders: Considerations for Team Teaching at the Intersection of Humanities and STEM

This paper is a part of a larger project designed to better equip engineering students with empathetic attitudes. While our larger project focuses on the student experience and measuring empathy levels, this paper focuses on the teaching of such a course. Specifically, this paper examines what we are terming two humanities-driven STEM (HDSTEM) courses taught at two different institutions (Texas Tech University and Rochester Institute of Technology). These courses are unique because they are co-taught by an engineering professor and a history professor who regularly collaborate to develop the syllabus and lessons within the classroom. Both iterations of the course are titled "War, Machine, Culture, and Society: History and Engineering in the Second World War," and focus on teaching students the social and political foundations of World War II while discussing technical issues, design thinking, and problem-solving skills associated with the war. As we describe in the review below, there are various reasons to develop an interdisciplinary model in STEM courses, integrating the humanities into engineering coursework. However, it is often difficult for STEM faculty to integrate their lessons with non-STEM faculty (Al Salami et al., 2017). Moreover, it can be difficult for faculty from any single discipline to understand how knowledge is constructed, valued, and/or transmitted across different disciplines, given that disciplines often vary from one another in these beliefs (Demarest & Sugimoto, 2015; Osbeck and Nersessian, 2017). Thus, we use a case study approach to answer three research questions:

1. What implicit epistemologies can be discerned when professors describe their approach to design and develop the HDSTEM courses that are a synthesis of history and engineering?
2. How do professors' personal beliefs and epistemological alignments inform the way that they teach HDSTEM courses?
3. How do instructors across disparate disciplines navigate epistemological differences when co-teaching?

We hope that by answering such questions, we may develop better insight into the dispositions, attitudes, and epistemological orientations that instructors from disparate disciplines hold when teaching with one another. This information may be used by engineering faculty when collaborating with other instructors to develop curricula and lesson plans that integrate disciplinary knowledge beyond STEM.

Literature review

Disciplinary Knowledge

Each discipline has its unique view of reality with distinct phenomena, epistemology, assumptions, concepts, theories, and methods, so a singular disciplinary focus cannot, by its nature, be comprehensive or holistic (Demarest & Sugimoto, 2015; Repko & Szostak, 2017). Challenges that are inherent in discipline-specific education also exist in science, technology, engineering, and mathematics (STEM) education. Based on the literature, three challenges seem to emerge. First, globally, improving STEM education has become a concern. In recent years, there has been a decline in the motivation and interest of learners, particularly in Western countries and more affluent nations in Asia, to pursue STEM fields (Thomas & Watters, 2015). However, the demand for STEM skills is on the rise as we face increasingly complex global challenges (Kelley & Knowles, 2016). This poses a challenge as there is a disconnect between learners' waning interest in STEM and the growing need for these skills. In addition, disciplinarily, the misalignment between humanities and STEM education is another challenge. The humanities play a critical role in STEM since they provide the ground for science and technology innovation from human needs (Carrell et al., 2023), and problem-solving in STEM to serve society better. Taking engineering as an example, serving society and meeting the needs of society is the ultimate goal of engineers to build things (Crawley et al., 2014). However, it is ironic that engineering courses rarely incorporate humanities (Wisnioski, 2015), which contributes to the failure to cultivate more comprehensive crtical thinking skills for learners. Lastly, from an individual perspective, more soft skills are needed for STEM professionals. In reality, STEM professionals usually work in a team to solve complex problems together. Without more human-centered skills, like communication, teamwork mindsets, and empathy, it would be demanding to accomplish tasks efficiently and effectively as a team. Unfortunately, the emphasis on technical knowledge in STEM education has often overshadowed the importance of personal and interpersonal skills (Crawley et al., 2014). Regrettably, STEM professionals are sometimes stereotyped as having poor social skills (Cheryan et al., 2013; Ehrlinger et al., 2018; Starr, 2018). We argue that the neglect of humanities in current STEM education contributes to this stereotype.

One potential solution to the challenges faced in STEM education is the integration of humanities. In the past, there have been some examples of blending humanities in STEM courses to foster innovation, creativity, and communication skills among STEM learners (Bequette & Bequette, 2012; Henriksen, 2014). Also, integrating humanities into STEM courses can broaden students' perspectives and enable them to consider multiple factors and viewpoints when solving problems. Specifically, the humanities can provide contextual information for problem-solving, such as social challenges (Carrell et al., 2023), which encourage students to look beyond the problem itself and examine the broader context and contributing factors. This could facilitate STEM professionals to have system thinking skills and better meet the needs of society. Furthermore, incorporating humanities into STEM education can help learners understand the social implications of their discipline when compared to traditional STEM courses (Foutz, et al., 2015). Humanities provide good opportunities for STEM specialists to solve technical issues through social, cultural, and historical perspectives, which could assist in growing their personal and interpersonal skills, like empathy.

Team-teaching

Embedding humanities modules into STEM education is regarded as a common practice (Cohen, Rossmann, & Bernhardt, 2014). The formats of embedding can be classified into two types: one is an individual instructor possessing basic humanities knowledge, and the other is collaborative team teaching (JRST, Cruz). For team teaching, we would like to borrow the concept of a team from Armstrong (1980) in the context of interdisciplinary faculty development efforts. Team teaching is defined as faculties from different disciplines working towards the same mental endeavor, like course design and teaching.

Different models of team teaching mean that the interactions and cooperation among faculties in a team may take different forms. Armstrong's (1980) four levels of integration provide a perspective to understand these different interactions among faculty. Armstrong argued that there were four levels of cognitive integration and synthesis of knowledge among disciplines, from the easiest to the most challenging level. For level one and level two, there is no faculty collaboration. Learners take the main responsibility for synthesizing knowledge through taking courses outside their majors or through a capstone seminar; Level three was called "serial teaching." It is distinct from levels one and two by having at least two faculty or more involved in the process of teaching, but there are no prescriptions for the ways that the information across disciplines is synthesized. Faculty from different disciplines simply take turns bringing their specialties and expertise to a course within the course framework. Armstrong suggests that the fourth level is the most challenging to implement, and it requires that faculty from distinct disciplines work together to integrate discipline knowledge into a new "coherent entity" (Armstrong, 1980, p.54). They work together to conceptualize the course, design the syllabus, and class presentations. This would require faculty actively and deeply involved in knowledge integration by meeting the requirements of understanding and respecting other disciplines' epistemology and methodologies, so it is the most challenging level, but the most beneficial for learners. Armstrong called this level "true" team teaching. In this paper, team teaching focuses on level 4 integration, as faculty members in our study collaborate to give engineering and the humanities equal weight in the classroom and to ensure that their lessons dovetail with one another.

Theoretical framework

Given the interdisciplinary nature of this project, we use a theoretical framework of epistemological identity. Epistemology, broadly, is one's way of knowing the world (Bhattacharya, 2017). More specifically, it is one's theory of knowledge: what counts as knowledge, how one gains and comes to understand knowledge, and what knowledge is valuable or lacking in value. Demerath (2006) suggests that individuals build an identity around their respective epistemologies. Certain narratives from others will either reinforce or threaten our epistemological identities: he states that "the more meaningful something is to an individual, the more gratified she is when her knowledge of it is reinforced, and the more upset she is when that knowledge is contradicted" (Demerath, 2006, p. 493). As Demerath argues, individuals are motivated to pursue that which is familiar and meaningful to them; he further develops this argument to suggest that certain ways of speaking about and understanding the world become familiar to us (Demerath, 2012). We identify with our ways of understanding and knowing, so much so that these epistemological understandings become a priori judgments about the information we receive (Alcoff, 2010). This can lead to judgments about the credibility and characters of others who adopt different epistemological standpoints than ourselves, especially related to those who might adopt radically different viewpoints from those to which we are used. In this case, we often feel the need to defend our identities by relying on viewpoints of knowledge that are most familiar and comfortable to us (Byrd, 2021). Demerath (2012) further suggests that when we are surrounded by those who think differently from ourselves, we may feel alienated and retreat inward. In this way, identity, and one's epistemological norms, are tied to motivation and personal affect (Demerath, 2006; Osbeck & Nersessian, 2017).

Interdisciplinary work, especially the kind that we highlight in this study, has a high probability of mixing individuals who identify differently from one another epistemologically.

Osbeck and Nersessian (2017) discuss the ways that disciplinary norms promote epistemological identities: disciplines provide us with "descriptive accounts of ways identity is shaped and negotiated through discipline-specific communicative practices" (p. 227) which are fundamentally rooted in a discipline's epistemological assumptions. When multiple disciplines come together to perform unified work, this can lead to a translation problem, where not only is it difficult for those from across disciplinary backgrounds to express the value of their ideas and research to one another, but the very language they use may not cross disciplinary gaps (Demarest & Sugimoto, 2015). While this may create a divide among faculty members attempting to perform research with one another, we also see this affecting students as coursework in the sciences becomes more and more interdisciplinary. As Cruz et al. (2021) note, students within interdisciplinary tracks may have difficulty navigating the epistemological assumptions and expectations of their professors.

Conceptual framework

In our study, we adopt a modified typology of epistemologies expressed in Cruz et al.'s (2021) work on student epistemologies. While they acknowledge that it is difficult to list all epistemologies (and that what precisely counts as an epistemology is contested), they provide a useful framework for this study. Specifically, they highlight nine epistemological positions:

Positivism: A belief that there is an objective truth that can be discerned through scientific methods. Knowledge is gained by understanding that objective truth.

Post-positivism: A relaxed version of positivism, which recognizes an external objective truth, but it is impossible to fully access this truth due to human limitation. Knowledge is gained by attempts to reach out to that objective truth, although it is always suspect.

Constructionism: What counts as knowledge is derived through social processes, constructed by the social, cultural, and political world around us.

Pragmatism: Knowledge derives its value from its ability to be used or to predict; less concern with truth, and more concern with utility.

Empiricism: Knowledge is found in that which is observable and can be experienced. Perceptual data determines what is true.

Rationalism: Truth and knowledge can be found outside of experience, especially through deduction and logic.

Skepticism: There is no real truth because what is true must be verified through an infinite chain of reasoning.

Representationalism: While there may be an objective, true world external to individuals, only truth can be represented in different versions in people's minds. Knowledge is constructed within this representation of a true world.

Post-structuralism: An extreme version of constructionism, which sees social processes as constantly shifting and changing. Due to shifts in the origins of truth, there can be no stable truth, and thus no stable knowledge. Knowledge is highly contingent and changing, and primacy is given to expression and novelty.

Methodology

Context

This study focuses on two HDSTEM courses taught at two different institutions (Texas Tech University and Rochester Institute of Technology). The course at Texas Tech University was taught by a male engineering instructor, John, from the College of Engineering, and a male history instructor, Rick, from the College of Arts and Sciences. The course at Rochester Institute was taught by a female engineering professor, Iris, from the College of Engineering and a male history instructor, Michael, from the College of Liberal Arts. All instructors had >10 years of experience teaching. The course at Texas Tech was taught as part of an honors course offering, and student majors comprised a variety of disciplines, whereas the course at Rochester Institute was offered as part of a general education requirement, although most student majors were engineering-focused. Both classes contained approximately 20 students.

Case Study

For this project, we used an intrinsic exploratory case study approach (Baxter & Jack, 2008; Stake, 2002; Yin, 2002). Case studies are “aimed at description and exploration of complex and entangled group attributes, patterns, structures or processes” (Verschuren, 2003, p. 137). The scope of the “case” is determined by the needs and parameters of the research, and a case can comprise a location, a group, or a phenomenon (Yin). We define our case in terms of the two courses taught at two different institutions under the HDSTEM model, as well as aspects associated with the course: the syllabus, classroom meetings, students, instructors, assignments/assessments, etc. An intrinsic study simply looks at a particular unique case (Stake, 2002); in this instance, we have an intrinsic interest in the development of (STEM) courses being co-taught by professors from disparate disciplines. Finally, an exploratory case study “is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes” (Baxter & Jack, 2008, p. 548). In our case, we do not know if the instructors in the course believe it has gone well or could use improvement, and we would like to explore how they worked together (or did not) to develop the course and the ways that they saw convergence and/or disjunction within their pedagogical strategies. Despite the presence of the unknown in case studies, they also often rely on “prior development of theoretical propositions to guide data collection and analysis” (Yin, 2003, pp. 13-14). In our case, we rely on epistemological typologies developed previously by Cruz et al.’s (2021) study of students from different disciplines taking coursework in the arts and STEM.

Case studies regularly employ several methods of data collection and analysis, and attempt to triangulate findings across the assorted data collected (Yin, 2003; Yazan, 2015). Our study employs three different data sources: the course syllabi, classroom observations, and a focus group comprising all professors involved in the course. Questions in the focus group involved the dynamics of interacting with a professor from another discipline, both in and outside of class; beliefs about the best way to teach students; beliefs about what information students need to learn; and a short survey given at the start of the interview designed to determine where instructors fall epistemologically in terms of their personal beliefs. For this WIP, we are only able to initial findings from our survey and focus group, which we analyzed deductively using Cruze et al.'s (2021) typology of epistemologies. For this deductive analysis, the two first authors on this paper individually read through the focus group transcript and noted any what we felt were "knowledge claims," that is, any statements that dealt with the transmission, nature, or valuation of knowledge. We then ascribed an epistemological position to each of these knowledge claims, writing a memo for each describing more deeply our rationale for each.

Results

Pre-Interview Survey

The survey was given to participants at the beginning of the focus group both to help better understand their perceived epistemological positions and to help orient them to the topic of the focus group. It was a "rank order" survey with six different statements expressing different epistemological positions. Although Cruz et al. (2021) include nine epistemological positions in their typology, we opted to remove three for the survey due to potential overlap or confusion (e.g. empiricism may be subsumed in positivism; post-structuralism and skepticism are potentially co-existing epistemologies). Participants were instructed to order the statements with 1 being "I most agree with this" and 6 being "I least agree with this." Surprisingly, all participants chose the same statement as their most preferred: "I believe that the truth is out there, but we are limited in our capacity to ever understand and access that truth. We can get close, but there will always be more to learn as a full understanding of the world is impossible for us based on our human limitations." We term this a post-positivist approach to thinking. Both history professors least identified with a pragmatist stance: "all this talk about truth is distracting. I am more interested in getting results and seeing what works and what doesn't." John least identified with a constructionist stance: "There is no such thing as an objective truth as culture, society, and those around me mediate belief about what is true and false" and Iris least identified with a post-structural stance: "All this talk about truth is wasted because there is really no such thing. How I feel one day might not be the way I feel the next, and all of that determines how I interpret the world around me. Thus, what is true for me now might not be later, and this is the case for everyone." In addition to these positions, a positivist and representationalist stance were represented on the survey, however, none of the participants indicated strong feelings about these particular stances.

Initial Emergent epistemologies

Before describing specific instances of epistemologies as they appeared in the focus group, it is important to note that no instructor represented only one epistemological position. Rather, the focus group showed that these instructors maintained fluidity with their thinking about knowledge, and they each employed strategies in their classrooms and teaching styles that borrowed from different epistemological camps. Below, we provide examples of this fluidity by highlighting some of the ways that they each adopted and displayed different epistemological positions depending on context and circumstance. We should acknowledge that we are still in the process of analyzing our data for this WIP, and thus can only speak to initial findings around epistemologies. For this WIP, we provide one example of three of the most notable manifestations of epistemology found in our coding. As we develop this work, we will elaborate more on each epistemological stance, discussing some of the others that appeared in the focus group as well as observations and lesson plan analysis.

Three of the most prominent epistemological orientations expressed in the focus groups were constructivism, empiricism, and post-structuralism. We saw constructionist epistemologies most commonly expressed across the engineering professors. One strong example of constructionist epistemology comes from John, who explained that he often uses groupwork in his courses: “I purposely make sure that there are multiple disciplines within that group.” When learners from different disciplines work together, they are learning through this dynamic environment, and “They get to sort of see, maybe hopefully, that the similarities and differences and the specialties that the disciplines offer, and just the different ways of thinking.” John, despite identifying least with constructionist epistemology, emphasized group work to expose learners to an environment where they could learn from others from different disciplines and promote interdisciplinary understanding and thinking skills.

Empiricist epistemology is the idea that evidence and experience take primacy over all other modes of knowing. One of the most prominent examples of such thinking is that to know the truth in history, Michael stated that “we bring into things like primary sources, secondary sources, things of that nature”. When it comes to the methodology of history compared with engineering after forming a hypothesis, history uses archival sources and oral histories to research and test the hypothesis, as mentioned by Michael. When conducting archival research, “you're reliant on the evidence that you have”. When one has less evidence, like in prehistory, “theories of civilization based on grave goods.” In all these cases, knowledge is based on evidence, like “primary sources”, “secondary sources, and archival sources” and when all else fails, “grave goods.” Through evidence and observation, we can know the truth from history.

Given post-structuralism’s claim that there is no truth or contingent knowledge, and because expression is given primacy, we labeled instances and considerations of affection as post-structural. Several instances of post-structuralism appeared in the focus group, especially within Rick’s approach to teaching. In fact, Rick explained how he felt at ease when he met with John to plan each week of class, even if there was really nothing to plan, as they have been teaching this course together for several semesters: “I just feel more comfortable knowing even if nothing is really discussed, or, you know, no big issues to talk about…” John followed up with the idea that there is “a non-rational, human element” to teaching with a co-teacher, and that sometimes they reassure one another. In both teaching and learning, Iris, John, and Rick acknowledge that the transmission of knowledge requires a consideration that is outside of rational elements. Rick and John both wanted the class to feel comfortable and cracked jokes both as a result of the fact that they felt comfortable enough to do so and to keep the class entertaining. Neither, however, necessarily attributed this to better learning. Rather, the spreading of positive affect seems to be an end in itself, as do their meetings that do not necessarily need to happen.

Discussion

This WIP set out to investigate the impact of professors’ epistemologies upon designing, developing, and teaching HSDTEM courses, and how professors navigate through epistemological differences during co-teaching. This qualitative study used an intrinsic exploratory case study approach, and data included the course syllabi, classroom observations, and a focus group interview, and a deductive analysis was used to analyze the focus group interview transcript. The results from the pre-focus group survey showed that a postpositivist position resonated most with all professors. However, we are finding that through deductive analysis of the focus-group, data revealed the fluid and intertwined epistemology positions pattern among all participants.

For this WIP, three epistemological positions that emerged from data are discussed to show the fluidity in participants' epistemology impact upon designing, developing, and teaching the HDSTEM courses. These three positions include constructionism, empiricism, and post-structuralism, however, as we continue our work, we are finding that there are more nuanced positions that we plan to report in the future.

Given that this is ongoing work, these are initial findings, and we hope to delve more deeply into our other data sources to triangulate our focus group findings. However, we find encouraging the degree of flexibility that these instructors seem to maintain epistemologically as they teach. While each instructor identified as a post-positivist in the pre-focus group survey, no instructor occupied exclusively this position, and each drew from different epistemological traditions to inform their teaching and interaction. Cruz et al. (2021) coined the term "border epistemologies" to describe the ways that students at the intersection of arts and engineering navigate their coursework. Students needed to remain flexible in their knowledge belief systems as instructors could sometimes adopt views that were strict or alienating for some students. This is in line with Demerath's (2006) theory of epistemological identity, which suggests that individuals may feel threatened if their beliefs about knowledge are met with opposition. We argue that such border epistemologies can exist in instructors as well. The instructors in this study were clearly aware of epistemological differences across disciplines, but with this awareness, they were also able to exercise flexibility in their instructional approaches with students and one another. As such, we are able to offer a tentative suggestion to instructors attempting to develop interdisciplinary coursework from disparate disciplines. In short, we encourage instructors to be aware of the boundaries that disciplines often place upon our conception of what can count as knowledge, and further to be aware of how others might position themselves epistemologically. We further encourage instructors to differentiate epistemologically: that is, to be aware that students come from a variety of disciplines that may have more constructive, interpretive, post-structural, or empirical/analytic approaches for determining and defining knowledge. However, instructors not only need to recognize and value these different approaches, but may benefit from drawing from these different approaches to knowledge construction. Rather than alienate those who come from different epistemological traditions (Demerath, 2006), an epistemological differentiation would allow students and co-teachers to feel recognition from those who, disciplinarily, may differ from themselves.

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