A Curriculum Exploring Arab and Muslim Science: Opening Space for Other Epistemologies of Science

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In this chapter, we will share about a course that brings together history, philosophy, cultural studies, and science.[1] In the winter of 2020-2021, our four-year research university announced an initiative for interdisciplinary teaching teams to propose courses that would bring together science and humanities. According to the call for proposals, the intention of these courses was to enrich studies for both science and humanities students:

> For students in STEM, they understand STEM as fields that must interact with and be informed by fields outside of STEM, and they learn to draw upon the knowledge and methodologies of these fields. For students in the Humanities, Arts, Social Sciences, they learn that their own fields can have an impact on knowledge in key areas of STEM, and they learn about methodologies and knowledge of STEM that they can draw on in their studies.

The authors, Ebtissam and Alicia, responded with a proposed course on Arab and Muslim science. Alicia is a STEM (science, technology, engineering, and math) education instructor whose research interests include a utilization of multiple epistemologies of science in classrooms (Bang & Medin, 2010). Ebtissam is an Arabic language instructor whose research interests include the decoloniality of knowledge and Arab and Muslim ways of knowing. We have been writing and thinking together for many years and often discussed our overlapping interests in Arab and Muslim epistemologies of science. Arab and Muslim cultures are inseparable and entwined as Arab refers to the culture shaped by language, and Muslim refers to the culture shaped by religion. These two cultures exist side by side in the Middle East, being informed by and changed by each other.

1 At the time of this project, Bitler was an instructor at The George Washington University.

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When planning the course, we thought about three audiences: the future science educators whom Alicia teaches, the Middle Eastern Studies students whom Ebtissam teaches, and other science and humanities students who were the target audience of the initiative. Science students learn their discipline within a Eurocentric perspective, implicitly learning that science is apolitical and acultural. Through the referencing of only Western scholars, students also begin to view science as a historically European enterprise, ignorant of the innumerable contributions of individuals from other cultures. These beliefs about what science is shape how science is conducted and, therefore, what can be known (Harding, 1998). By ignoring different epistemological underpinnings of science, the field is likely limited in its ability to solve the many problems facing the world (Elby et al., 2016). Therefore, we believe that it is vital for science students to develop an understanding of the discipline as culturally situated. It is potentially even more vital for future science teachers to develop this understanding, as the way that they teach can have an exponential impact on future scientists. Middle Eastern Studies students, like individuals worldwide, are often unaware of the complexity of Arab and Muslim cultures that shaped science and the world. They likely have heard references to important Arab and Muslim scholars, but they learn about them separate from understanding how culture shaped those thinkers and how those thinkers shaped the world as we know it.

The course we proposed focused on the history of Arab and Muslim science and the distinct ways science is thought about in various cultures. We engaged in the inaugural offering of the course in the fall of 2021 with students from diverse majors, such as political science, classics, and public health. One of the students had taken several Arabic language classes, and one of them was a native Arabic speaker and a practicing Muslim. Although we had hoped the course would be of interest to science students, none were able to join for the first semester that it was offered.

Our course centered on exploring the fundamental beliefs that form the basis of Arab and Muslim scientific thought juxtaposed with Western and other non-Western perspectives on science. We investigated how cultural influences shape the comprehension, implementation, objectives, and recognition of science across various societies. While we acknowledged scholarship discussing Arab and Muslim scientific achievements that influenced the European Renaissance (Al-Khalili, 2010, 2011; Nasr, 1976, 1984, 1988, 2001, 2003, 2010), our primary focus wasn't on covering this content. Instead, we aimed to analyze the varied manifestations of science in different cultures and civilizations, challenging the Eurocentric monopoly on the history, philosophy, and teaching of science. Our course underscored the significance of recognizing that all knowledge, including science, is culturally situated. Although our course's approach may not directly align with traditional science education, we contend that the critical perspectives and inquiries we explored are essential for engaging with any form of knowledge production. This chapter

emphasizes the crucial role that reflective writing played in fostering the critical analysis of these epistemological frameworks within our course.

Course Intent and Goals

To destabilize and challenge the prevailing view of science as Western, male, and white, we created a course to provide space for students to explore a non-Western epistemology of science and think of science as diverse and inclusive. Throughout the course, students explore Arab and Muslim science history and culture as part of a globally shared human heritage to open a space for other ways of thinking about and doing science. Arab and Muslim scholars have contributed to science in meaningful and often unacknowledged ways, founding disciplines like chemistry, algebra, modern surgery, and optics—shaping science as we know it.

The course did not intend to stop at learning *about* Arab and Muslim science but focused more on learning *from* it. Learning *about* may promote a diverse representation in curriculum, but it does not challenge the dominant Western epistemology. Learning *from*, on the other hand, means to be challenged, to listen attentively to others, and to respond to and be changed through the encounter (Todd, 2003). Our course involved examining scientific achievements in Arab and Muslim civilizations. However, our focus wasn't on mere historical facts. Rather, we aimed to use Muslim perspectives on science to analyze their underlying epistemology and contrast them with modern views. For instance, when studying al-Jazari's (1136–1206) inventions (Hill, 1991, 2020), we paid more attention to understanding his approach to science rather than just the specifics of his creations or their relation to European literature on mechanical engineering and other fields. Specifically, we explored his book, *The Book of Knowledge of Ingenious Mechanical Devices* (1206), where he detailed his inventions with descriptions, drawings, and instructions for design, manufacture, and assembly. We questioned what drove al-Jazari to share such detailed information and discussed the Islamic concept of knowledge sharing (Anand & Walsh, 2016), comparing it with the modern patent system and considerations of research funding and profitability. Furthermore, we examined al-Jazari's integration of art, humor, and theater into his inventions, emphasizing the interconnectedness of arts and sciences in his work. This inquiry allowed us to reflect on broader themes of interdisciplinary collaboration and the holistic nature of knowledge creation.

By focusing on the cultural underpinnings of Western science (Harding, 1998), we examined the situatedness of knowledge. In alignment with the work of Megan Callow and Holly Shelton (this volume), our course aimed at critically analyzing Western values often embedded in science fields. Students learned how claims of objectivity and value neutrality in Western science stem from European culture and its Christian origins. By examining the historical erasure of Arab and Muslim

science (Lyons, 2014), we highlighted the political and colonial aspects of knowledge. Mapping other epistemologies of science—Buddhist, New Confucius, indigenous, postcolonial, and feminist epistemologies—provided opportunities for students to question the foundations of science. Throughout the course, our primary aim was to establish a platform for critical analytical comparison and encourage students to reflect on the cultural foundations of their commonly accepted notions about science. We sought to inspire students by exposing them to non-Western perspectives on science, encouraging them to reconsider their understanding of science and its purposes. This invited the students to see how culture shapes the purposes of producing scientific knowledge, the ways of knowing, and the questions that guide scientific research. Our introduction of non-Western scientific frameworks, like Arab and Muslim science and other non-Western sciences, offered a much-needed multicultural perspective on science and provided important background essential for students to develop critical literacy of science (Callow & Shelton, this volume).

The shape of the course was parabolic, starting and ending with a specific Arab and Muslim context while thinking more globally in between. This pattern is apparent in Appendix A, which outlines all the course texts and essential questions. The course started by exploring some of the vast history of Arab and Muslim science, focusing on the Golden Age of Islam. We then moved to exploring the concept of epistemologies of science, not only within Arab and Muslim culture but also within other cultures. We finally returned to the history and Arab and Muslim science with a new in-depth ability to analyze its epistemological underpinnings. This arch allowed the students to self-reflect and critique their taken-for-granted thinking about science, therefore inviting a destabilization of the students' Western perspectives on science to which they have been continually exposed through educational institutions and society.

Writing Assignments and Responses

In order to think critically about the course subject, the students read complex texts, wrote reflection journal entries prior to each class, discussed emerging understandings with partners and with the whole class, completed three group research projects, and wrote two papers. By engaging with seminal readings, students expanded their knowledge of Arab and Muslim history and culture, an often misrepresented culture in the United States and a mostly unrepresented history in science classrooms. Through in-class discussions, students and teachers challenged each other's understandings of the readings and each other's cultural beliefs that shape their thinking. Through group projects, students explored topics addressed in class in more depth, synthesized multiple sources, formulated arguments about specific topics, and communicated what they learned to their classmates.

In addition to reading and discussing with others, we believe in the concept of writing to learn (Gere, 1985), that writing is an essential sense-making process that is vital to deeper engagement with ideas and self-exploration. Research supports that this is important in science classes as well as more humanities-oriented classes (Prain & Hand, 2016). The writing assignments in our course provide opportunities for students to reflect on the cultural situatedness of science. Where the projects were designed to build deeper knowledge of Arabic and Muslim science, the writing assignments were for students to make sense of what they read and learned through their own unique perspectives and voices. To open space for students to reexamine their existing modes of thinking and engage with new ideas, the course involved three major writing assignments, which will be explored in the following sections. The first and ongoing assignment is a weekly journal reflection working through their emerging thinking in response to the course texts. The second assignment, completed at the beginning of the course, is a reflective narrative essay through which students explore their personal experiences in and perceptions of science. Near the end of the course, students complete the third writing assignment in which they reflect on their emerging understanding of perspectives of science and how those understandings may impact their studies, work, and life.

Journal Reflections

For all class sessions, students write journal reflections (see Appendix B) representing their study and emerging understanding of the readings and videos for the day. The reflections are intended to help the students put the specific texts into a bigger picture and to allow the students to think about how science is viewed in different places and at different times. They require the students to be self-reflective regarding their own beliefs and experiences and how these beliefs are challenged by the readings. Additionally, the reflections enable them to participate well in class discussions and to document the development of their thoughts about key ideas throughout the course. The journal reflections are open in terms of structure, with no specific prompts given for each reflection. They are low-stakes opportunities with no end goal of preparing something for an outside audience (Gere, 1985). To reiterate the low-stakes nature, each reflection is worth a small number of points, which students earn based on assignment completion. The only requirement is that they include an analysis that goes beyond a summary of the assigned texts. If we feel a student did not meet this requirement, we provide written response questions to guide deeper analysis but do not deduct points unless it is an ongoing issue.

In an end-of-semester course evaluation during the fall of 2021, students mentioned that they found the weekly journal reflections helpful as a space to construct their emerging ideas about the texts and prepare for discussing those ideas with their peers. We believe that the open-ended structure allowed their own understanding

to emerge. Throughout the course, students said that they were challenged to make sense of what they read and were experiencing both inside and outside of class in an ongoing way. This extended interpretive labor placed students in the mindset of continual meaning-making. Evidence of this mindset was particularly clear in class discussions, as students would frequently refer to conversations they had with friends or family related to ideas in the assigned readings. From the instructor perspective, the journals were also a space for one-on-one asynchronous dialogues with the students. Additionally, reading these journals before class provided us a preview of how students were making meaning of the texts, what points they highlighted, and what questions they had. This allowed for the discussion prompts to be tailored to and built on the insights of the students.

In addition to students commenting that the journal reflections were helpful and us finding that they provided useful insight, the journal reflections showed clear evidence of students making connections across time and across disciplines. In the weekly journal reflections, students connected the readings with their previous educational experiences. For example, one student wrote the following in a journal reflection:

> I read a book in my seventh grade humanities class that I thought of throughout the "Narrative as Inquiry" (Hendry, 2010) reading. The book was called *The Things They Carried* by Tim O'Brien (2009), and a major theme we discussed in class was the idea that, as the book progressed, we realized that the narrative that the narrator was creating might not have exactly matched what had objectively taken place. Despite the narrator's memory of and feelings surrounding incidents occasionally being different than the factual order of events, what mattered most in the book was the way the narrator experienced and remembered things. This was mind blowing to me in seventh grade – the idea that truth is not one objective thing, or that no one person or being decides what truth is, but instead, that truth is dependent on perspective. It was the first time I remember considering that a plurality of truths can exist at the same time, and I remember that for weeks after that class discussion, I approached many conversations imagining what truths others might be holding that could complement or contradict my truths. Only during the "Narratives" reading did I remember that experience, and realize that that is a way I was encouraged to employ a multiplicity of truths (as opposed to one Truth) in some pockets of my education. I did not see those same ideas presented in my science classes though; I almost entirely was educated to believe

> in one scientific Truth and think in the way that science should be presented in a dry, "vacuum" style.

This quote demonstrates a student making sense of past experiences in a humanities course, in past science classes, and in our course. It shows her making sense of her perception of truth and reconciling past enlightenments with the present. Her use of lowercase and capital "T" in truth also indicated to us that she was making connections to a past course reading, *Sushi, Science, and Spirituality* (Kasulis, 1995). She spoke at large in class about her appreciation for the capital and lowercase use of the word when we read that text. Although not always described to this level of detail, this type of moment was common in student reflection journal entries and in class discussions.

In addition to students showing evidence of working on connecting their past understandings with their emerging understandings in the journals, they also actively worked to reconcile their emerging understandings of science with previously gained expertise in their primary disciplines. The quote below is from a senior whose studies focused on history and classics:

> In history, especially ancient history, we often discuss the impact of creation stories and conceptions of the afterlife on political and cultural norms, and it came as no surprise that it also impacted the study of science. It emphasized the huge role that religion plays in every aspect of life, whether we like to admit that or not. Seeing how science and history are both heavily influenced by the dominant religion—and seeing how that changes how we treat the world we live in—was so intriguing to me because it finally helped me understand just how interdisciplinary the two subjects are.

This student was able to better understand her own discipline through an in-depth exploration of the cultural situatedness of science. This is just one example of using writing to actively make cross-curricular connections, a skill that is vitally needed in college students (Bear & Skorton, 2019). There were many such moments in the students' journals.

Writing provides a modality for the students to actively connect different aspects of their identities as shaped by their past, their educational experiences, exposure to new ideas in texts, and critical dialogue. We do not grade or even comment on the accuracy of ideas. Rather, the journals create a dialog where we ask thought-provoking questions, provide additional resources, and give personal responses based on our own experiences and beliefs. The journals are not a place for polished ideas to be judged by an outside audience. They are an incubator for ideas (Pearse, 1985), a low-stakes informal platform that provides a safe space for

students to try new ideas and ways of thinking that might feel risky and potentially transformative.

Essay on Personal Experiences and Perceptions of Science

Near the beginning of the course, students write a self-reflective essay (see Appendix C) on their personal experiences and perceptions of science. The goal of this paper is to make space for them to explore their own histories in and beliefs about science. They are prompted to base their writing on reflection questions such as what their first memory of science was, what science activities they have engaged in throughout their life, what science means to them, and how their experiences shaped their beliefs about science. It is vital to reflect on one's own understanding in order to be able to form comparisons to the perspectives of others. Through remembering significant experiences they had with science and reflecting on their own perspectives of science, the students examine where their preconceived notions come from. This prepares the students to be able to be more open to learning from other perspectives, including those of the authors of assigned readings and others in the class.

At the end of the semester, students were asked to provide feedback on the course and all of the assignments. They did not talk a great deal about any of the large writing assignments. However, they did talk extensively about how valuable and open the class conversations were and how open they were to learning from their classmates. We believe that the self-reflection facilitated through the first paper assignment contributed greatly to students' openness to others. By examining the backgrounds that shaped their personal ideas about science and the roots of these perspectives, students were able to culturally situate their own understandings. Without self-examination, individuals are likely to believe their own perspectives are truth rather than recognizing that experiences and culture shape beliefs (Singh, 2021). In class conversations, the students showed that they were continually self-reflective and open to self-critique. We observed that the students were willing to not only hear other students' ideas but also to deeply think about the different perspectives and contemplate integrating new perspectives into their own worldviews.

In the first paper, which focused on students' personal experiences in and perceptions of science, students found a space to explore how they view science and where those ideas came from. One student wrote about how science was always presented as an objective truth:

> School always taught me about science as a logical realm with one correct answer that accords with the laws of nature, whatever they may be. Overall, then, I had always learned that there was

> one law governing all the universe, an answer for every question, a path to be taken to an enlightened end all thanks to science.

This student spoke in class about the fact that she always enjoyed science but lost interest when science was not able to cure an ill family member, even though she was taught in school that science had all the answers. She also indicated that if science was talked about in a more tentative manner, she may have maintained a greater interest in the discipline. Her life experiences did not match what she was being taught, which had a detrimental effect on her interest. We believe that having a space to reflect on how her experiences shaped her beliefs about science invited her to begin to reconcile these tensions.

Another student described her perception of science and "scientist" in a way that, according to Miller et al. (2018), is very common:

> Growing up, my preconceived notion of a scientist was an old white cisgender male pouring brightly colored vials into beakers. This image was usually accompanied by scientific equations and complicated work that would make any young elementary school student rethink a career in the sciences. I was only taught the names and legacies of these men, but never of those who looked like me or my classmates.

As a female person of color who was in her first year of college and was interested in pursuing a science-related major, the acknowledgment of her perception of a scientist as very different from her own identity is vital to reconciling those differences (Barton & Tan, 2010; Johnson, 2007). She did not talk more in class about the difference between herself and the stereotypical scientist. She was the least outspoken student. It was clear to us that she used the assignment to think through something that she may not have felt comfortable openly discussing with others.

Not all the students had a typical Western perspective of science, however. For example, one of the students reflected on her lifelong experience of science as an act of creation that is deeply connected with the arts:

> How I viewed science throughout my life; [is as] a tool for bettering my life and the lives of those around me through creative power. This is why I have been so excited about our conversations in class about the deep connection between art and science; to me, the pursuit of science has always fueled my pursuit of art, and vice versa. . . . I think of science as the pursuit of knowledge for the sake of creating a better world. And it is in that image of a "better world" that we see discrepancies; that image does not look the same for everyone. To some, "better" might mean more

> equitable, but to others, it might mean more profitable, more aesthetically beautiful, or healthier.

In the paper, she shared her childhood experiences of mixing flavors in the kitchen, creating toys, and creating a music-activated light-up skirt for a Cinderella performance. In the assignment, she identified her situatedness. Prior to this paper she may have approached texts with an unconscious belief that everyone viewed science the same way that she did. Through engaging with different readings in the course, she was able to openly and consciously encounter different conceptualizations of science that were not utility-based.

The initial paper invited students to reflect on what their beliefs were and where those beliefs came from. Without this grounding, students likely would have encountered all new ideas with an undercurrent of unconscious beliefs rather than an active reflection and reconciliation with their conscious beliefs. The assignment began the work of giving voice to the dialogue between their identities and new ideas.

Similar to our first assignment, in their STEM writing course, Barlow and Quave (this volume) also started their course by requiring their students to write a philosophy of science reflecting on the nature of their knowledge production. As Barlow and Quave highlighted, students starting a course with reflecting on their personal philosophies of science was an important step for understanding other philosophies of science. For us, too, this assignment was very crucial for students to understand the underpinnings of their beliefs and become open to other perspectives on science.

Essay on Emerging Understandings and Perspectives of Science

Upon completion of the course, as the final assignment, students wrote a self-reflective essay (see Appendix D) on their emerging perspectives of science and how they foresaw those emerging understandings and perspectives shaping their future scholarship, work, and being in the world. The goal of the paper was to make space for students to explore how their thinking shifted due to experiences, readings, and discussions both in and outside of the class. We believe that it is vital to reflect on one's own beliefs in order to be able to continually critique societal representations of science, with which we are inundated. Examining the changes in their perspectives of science was a critical step for the students to then reflect on how they can have a voice calling for change in the larger community.

In their final reflection on their journey of learning throughout the course, students mapped the transformation of their thinking about science. For example, one student wrote:

> There was never a divide between humanities, philosophy, sciences, and religion during the Islamic golden age, so why does the Western world strive so hard to push this divide? This course educated me to not see education as a linear concept, but more so an exploration of how different disciplines interact. There was no shame in having equal interests in fine arts and hard sciences.

Reflecting on how the course broadened her horizons, this student started to question how much knowledge she was really missing by receiving a Eurocentric science education. Changing her perspective of science, that it contains indisputable answers, she pledged to perceive science with a critical eye as much as she does other disciplines. Later in this paper, she described her future career in public health, in which she intended to bring her understanding of the importance of actively listening and having respectful conversations in order to embrace and welcome people's different ways of thinking and belief systems. As a young woman of color studying science, she expressed her growing confidence in her voice and expanded perspective on science.

Another student wrote about how her ideas on the purposes for science changed throughout the course:

> Even though I already had a more complicated view of science than many in the Western world, the biggest shift in my thinking occurred with learning about the purpose of science in the Arab World, and also encompassed how other societies viewed the idea of the truth. No matter how open-minded I was about science not being omniscient, I always saw it as something driven by profit. This class, however, and especially the discussions we had over the course of the semester, showed me how we can still make scientific progress even without profit motivation. . . . The shift from for-profit to satiating curiosity was immense for me, and it forced me to rethink so many other Western scientific achievements, even the ones of which I was already critical.

Despite claiming that she never saw science as omniscient prior to the class, she did put the study of science on a pedestal. She went on in the paper to discuss that, as a gifted student, she always felt like she was wasting her abilities by not studying science. Throughout the course, she came to understand that science is not better than humanities but is just different than humanities and can and does often occur in conjunction with humanities. She explained that since science can exist outside of economic motivation, being a STEM major does not equate to prestige. This understanding made the student feel more confident in her decision to study humanities. It also made her feel more confident exploring her interests in science despite not studying science in any official capacity. This aligns with the findings

of Callow and Shelton (this volume), where students found a sense of belonging in science after a critical science literacy course.

Throughout this course, students encountered science as developed by people around the world and understood that science may be thought of differently in non-Western cultures. This allowed students from diverse backgrounds, beliefs, and interests to better see themselves involved in science and reconcile who they are and want to be.

Lessons Learned, Challenges, and Implications for Science Teachers

This course is an example of working across disciplinary lines to engage with scholarship from history, philosophy, cultural studies, and science. The writing assignments described were created for the class in order for students to examine the overlap of culture and science and to write to learn (Gere, 1985). Although this course is unique, similar writing activities could be utilized in any science content class to help students negotiate their identities and expand their thinking. At a minimum, students could be assigned reflections on their understanding of what science is at the beginning and end of science courses, with intentional exposure to varied ways of thinking about and doing science throughout a course. Students could also be encouraged to keep a personal journal, continually reflecting on the representations of science that they are exposed to and how they are making meaning of the content they are learning.

From the experience of this course, the format and requirements of writing assignments impact the students' openness toward the assignments. As previously described, students found the writing assignments in this course helpful for their intended goals. One point of feedback they provided was about the word requirements of the journal reflections. Because it is important to only grade for the intended purpose of an assignment, all writing assignments had grading criteria that highlighted the quality and depth of thought rather than aspects such as grammar and editing (see Appendices B–D). However, there was a required word limit for each assignment. For the journal reflections, some students found the word requirement to be a little long, given the twice-weekly expectation. They felt that it impeded their ability to write for learning by shifting the focus to writing for a requirement. This further highlights that the more stringent and criteria-driven grading is, the less free students will feel to do the self-reflective work that is the purpose of the assignment. Along these same lines, we believe that if our comments on the journals were more judgmental and less reflective, students would not have felt as comfortable expressing their emerging ideas.

Overall, despite years of science classes in elementary and secondary school and several college science courses, students in this class repeatedly commented

that they had never been exposed to ways of thinking about science that went beyond the empirical, rational modality, which is the norm in Western approaches to science. Students reflected that being exposed to culturally situated ideas about scientific knowledge—knowledge for its own sake, the overlap between science and aesthetic arts, and various conceptions of what can and cannot be known—transformed their thinking. More than transforming their thinking, for several students, the new perceptions increased their interest in the discipline and made them feel more confident that their voices matter.

One of the major challenges that we face for our specific course is getting students interested and registered. The course was a response to an institutional initiative to bridge STEM, humanities, arts, and social sciences in a co-teaching opportunity involving a STEM and a humanities professor. Although our course received institutional approval to run, its continuation after the first year was hindered by the lack of departmental support for interdisciplinary scholarship. The course does not fulfill any requirements, and many of the ideas highlighted in the course description and syllabus are disarmingly foreign to students and professors. We hope for this course to continue as a disruptive space to interrogate the status quo in STEM education (Introduction, this volume) and impact students in STEM fields in a way that makes them question dominant paradigms in their disciplines and examine their cultural underpinnings. We hope that it allows students to go beyond learning and mastering the contents of their subjects to inquiring about the types of questions and methodologies that drive their field of study, where they stem from, whose interests they serve, and what beliefs about the world and humanity lie beneath them. We hope to create space within academia for courses that invite students to reflect on the production of knowledge as a culturally situated political act. Solutions for us include making the course fulfill general education requirements or count toward majors or minors. This would involve educating department heads on the importance of the ideas. It also involves advocating for more institutional integration of humanities and arts with STEM. More importantly, the lack of interest in this topic highlights the necessity for science teachers (elementary, secondary, and post-secondary) to become knowledgeable about and imbed ideas about the culture of sciences in their courses, which also brings into question teacher preparation in STEM fields.

As clarified earlier, the focus of this chapter is on highlighting the role of reflective writing in facilitating critical comparative examinations of epistemologies of science rather than providing information on how to include Arab and Muslim science in different science classes. Nevertheless, it's crucial to underscore the importance for science educators to integrate Arab, Muslim, and other non-Western achievements into their curricula. For example, they can include Ibn Al-Haytham's work when teaching the scientific method, alongside other significant contributions from this historical period. Resources and videos showcasing such

achievements are available on the web at https://www.1001inventions.com. Supporting this integration are works from Bala & Duara (2016), Barnard (2011), Ganchy (2009), Saliba (2007), Tibi (2006), and Gutas (1998). By incorporating diverse perspectives and historical achievements into their teaching, science educators can provide students with a more comprehensive understanding of the development of scientific thought. Our course highlights the importance of examining the history and geopolitics of science in a way that goes beyond listing names of culturally diverse scientists. This approach allows students to see science as a human enterprise of exploration of the natural world and inquiry toward it rather than as a collection of absolute facts, laws, and equations to study or apply. Through learning about how science is approached differently in various cultures, students can develop critical thinking skills and learn to question and evaluate the underlying assumptions and biases embedded within scientific theories and practices. Ultimately, this approach fosters a more inclusive and equitable approach to science education, encouraging students to engage with science as a dynamic and culturally situated endeavor.

Some researchers are arguing for a shift toward an appreciation for multiple and often culturally situated ways of understanding science (Bang & Medin, 2010; Hammer & Elby, 2002; Russ, 2014). Meghan Bang advocates supporting a learner's navigation of what she calls multiple epistemologies. In a 2010 article, Bang and Medin discussed the impact of a three-week summer camp on Native American students. The curriculum of the summer camp was designed around culturally-based practices and aimed to support the navigation of multiple epistemologies of science. They showed that respecting multiple epistemologies can have a positive impact on student learning. Elby, Macrander, and Hammer's 2016 study showed that unique focuses with different communities lead to distinctive observations, distinctive questions, and distinctive interpretations of findings. Additionally, there is research showing that the Western culture of science makes it difficult for many minority students to assimilate into scientific communities (Brown et al., 2016), particularly women of color (Carlone & Johnson, 2007).

Thus, although science content courses typically have a set of stringent objectives that must be met during the course in order to prepare students to be well-versed in their discipline, a sole concentration on those objectives, to the exclusion of consideration of cultural underpinnings, may discourage students from remaining in the field. It may particularly discourage students who are already underrepresented in science and who may bring unique ways of thinking that are vital to approaching the problems facing the world. Therefore, it cannot be up to elective courses to expose students to other ways of thinking about science. In every science course, there should be space for examining the social underpinning of science. One way of implementing these much-needed reflective practices into science courses is through reflective student writings such as those described in this chapter.

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Appendix A: Course Outline and Texts

Week	Class	Questions we'll explore . . .	How to prepare for this class . . .
Week 1	Class 1	Why Arab AND Muslim civilization not Arab OR Muslim civilization?	Video: Islam, Empire of Faith (video on YouTube, 0:00-1:47)
	Class 2		
Week 2	Class 3	Why do some people hate Muslims and Arabs?	Jigsaw Readings: Islam Through Western Eyes: From the Crusades to the War on Terrorism by Jonathan Lyons (chapters 1 &7) Islam Through Western Eyes: From the Crusades to the War on Terrorism by Jonathan Lyons (chapter 3) Covering Islam: How the Media and the Experts Determine How We See the Rest of the World by Edward W. Said (chapter 1, section 1) Video: Islam Through Western Eyes (speech by Jonathan Lyons on YouTube)
Week 3	Class 4	Is there a conflict between knowledge and faith? Where is the oldest university in the world?	Readings: Research online to find out: What are the first Universities? Who is Fatima Al-Fihri? What was women's role is Arab and Muslim education?- follow your curiosity Education in Islamic History (article in Egypt Today, 2017)
	Class 5		Reading: The Basis of the Teaching System and the Educational Institutions by Seyyed Hossein Nasr (chapter 2)
Week 4	Class 6	What did your group find out about the history of Arab and Muslim science?	Reading: Islam Through Western Eyes: From the Crusades to the War on Terrorism by Jonathan Lyons (chapter 4)
	Class 7	What's unique about Arab and Muslim Science?	Group research project on history of Arabic and Muslim science and how cultural beliefs shaped that advancement
Week 5	Class 8	Did all science come from Greek civilization? Who was shining during the dark ages? What did science look like during the Golden Age of Islam?	Videos: The House of Wisdom: How the Arabs Transformed Western Civilization (speech by Jonathan Lyons on Library of Congress website) 1001 Inventions and the Library of Secrets (video on YouTube)
	Class 9		Reading: A young Muslim's guide to the modern world. 1993 by Seyyed Hossein Nasr (chapter 5: Islamic Science)

Week 6	Class 10	What the heck is an epistemology? What does culture have to do with science?	Reading: Epistemology: Internet Encyclopedia of Philosophy (website) Videos: Intro to Epistemology #1: The Nature of Knowledge (video on YouTube, 0:00-3:47) Philosophy of Science: Epistemology Applied (video on YouTube)
	Class 11		Reading: "Is science multicultural?: Challenges, resources, opportunities, uncertainties" by Sandra Harding: (chapter 4: Cultures as a Toolbox for Sciences and Technologies)
Week 7	Class 12	What did you learn about your personal epistemologies of science?	Reading: Cultural Processes in Science Education: Supporting the Navigation of Multiple Epistemologies by Bang & Medin (2010) Video: Recycling is Like a Bandaid on Gangrene (2019 video on The Atlantic)
	Class 13		Individual paper exploring their personal experiences and perceptions of science
Week 8	Class 14	Who else has "other" ways of thinking about science?	Video: The Dalai Lama: Scientist (2019 documentary)
	Class 15		Reading: Sushi, science, and spirituality: Modern Japanese philosophy and its views of Western science by Thomas Kasulis (1995)
Week 9	Class 16	What did your group learn about different epistemologies of science?	Readings: Western science and traditional knowledge-Despite their variations, different forms of knowledge can learn from each other by Fulvio Mazzocchi (2006) Multicultural Science Education: Theory, Practice, and Promise edited by Steinberg and Hines (chapter 10: Defining a Theoretical Framework for Multicultural Science by Samina Hadi-Tabassum)
	Class 17		Group project comparing three different epistemologies of science
Week 10	Class 18	Who's who in Arab and Muslim Epistemology?	Reading: Epistemology in Islamic Philosophy: Islamic Philosophy Online (website) Video: Knowledge Triumphant, The Concept of Epistemology in Islam (documentary on YouTube)

Week 10 continued	Class 19		Readings: Epistemological Foundations of Natural Sciences in Islam by Marziyehsadat Montazeritabar (2019) Knowledge Triumphant: The Concept of Knowledge in Medieval Islam by Franz Rosenthal (chapters 3 and 4)
Week 11	Class 20	How do stories shape epistemologies of science?	Readings: Braiding Sweetgrass - by Robin Wall Kimmerer, 2013 (chapter 1: Skywoman Falling) "The Study Quran." A new translation and commentary: Creation Story from the Quran translation by Nasr, Seyyed Hossein, Caner K. Dagli, Maria Massi Dakake, Joseph EB Lumbard, and Mohammed Rustom (2015): (chapter 2:27-49) OPTIONAL: Adam and Eve Story from the Bible
	Class 21		Videos: Hay - The Kid Searching For God (video on YouTube) The place of philosophy in religion pt. 3 - Hayy bin Yaqzan (video on YouTube)
Week 12	Class 22	How did your group use representation to change perceptions about science?	Readings: Ibn Tufayl (A bentofail) and the Origins of Scientific Method by Enrique Cerda-Olmedo (2008) Narrative as Inquiry by Petra Munro Hendry (2010)
	Class 23		Group project critiquing and reimagining a media representation of science
Week 13	Class 24	What do you want to learn more about?	Readings: TBD based on student interests
Week 14	Class 25	What does all this mean to us now?	Readings: TBD based on student interests
	Class 26		Reading: The Geopolitics of Knowledge and the Colonial Difference by Walter D. Mignolo (2008)
Week 15	Class 27	What question do you have for Guest Speakers?	Field Trip to the Turkish Islamic Center
	Class 28		Guest speaker: Dr. Seyyed Hossein Nasr
Final paper			Individual paper reflecting on your emerging understanding of multiple epistemologies of science and its impact on your work in their discipline and future careers

Appendix B: Journal Reflections

Why: Writing weekly reflections will help you to put the specific readings into the bigger picture. They will allow you to think about how science is viewed in the world and how that is different and similar in other places and at other times. They will also help you to be self-reflective regarding your own beliefs and experiences, how the reading may challenge your beliefs, and how your perceptions are continually emerging. Additionally, your reflections will enable you to participate well in class discussions and to document the development of your thoughts about key ideas in the course. You should come to class prepared to introduce your ideas in class discussions and to test their significance through scholarly conversation.

What: For all class sessions, you will write journal reflections representing your study and understanding of the readings and videos for the day. Each reflection must include:

- analysis of key concepts, ideas, and perspectives that appear in the course readings and videos.
- exploration of the issues you find most compelling.
- questions that will help you and your classmates develop understanding of the readings.
- relevance to your field of study.

Reflections should not be organized in the form of a thesis and argument. They should not be presented as an essay. Instead, they should represent the diverse range of thoughts, questions, and interpretations that emerge as you study an assigned text in the form of "thinking out loud on paper". This type of journaling is one that many scholars find useful for germinating new and creative thoughts. Reflections should:

- be at least 400 words.
- use 25 words of direct quotation at maximum.
- provide references to sections of the assigned text.

How (you'll be assessed): Instructors will evaluate your reflections in terms of their meeting the criteria outlined above (at least 400 words, no more than 25 words of direct quotation, references to sections of text discussed) and based on thoughtful engagement with the assigned readings. You will not receive evaluative comments on your reflections as they are based on your opinions and developing ideas. However, you may periodically receive comments and questions to further probe your thinking. You should spend time reflecting on these comments but do not need to submit a response. Bring a hard or electronic copy of the reflection to class for reference during the discussion.

Appendix C: Personal Experiences of and Perceptions of Science

Why: The goal of this paper is to make space for you to explore your own history in and beliefs of science. It is vital to reflect on your own understandings in order to be able to form comparisons to the perspectives of others. Through remembering significant experiences you had with science and reflecting on your own perspectives of science, you will examine where your preconceived notions come from, which is a critical step in being able to become more open to learn from other perspectives.

What: This assignment will be in the format of a narrative that demonstrates thoughtful reflection on beliefs and experiences. Consider the following prompts when beginning the narrative:

- What was the first time you recall engaging in science?
- What science activities have you engaged in throughout your life.
- What is science to you?
- Who are scientists?
- What do scientists do?
- How have your experiences (school, friends and family, media, etc.) shaped your beliefs about what science is?

Before writing your narrative, consider starting by doing a few free writes or graphic organizers to get your thoughts down without concern for how to do well on this as a class assignment. In other words, spend time really reflecting inwardly before being concerned about the final outward representation.

The final submission should be between 3 and 5 pages, double-spaced. As this is a self-exploration, reference to other sources is not required. However, if external sources are used, there must be correct APA formatting and a bibliography. The final document should be well-edited. You are encouraged to seek the assistance of a research librarian and of the writing center.

How (you'll be assessed): Papers will be evaluated based on the depth of reflection and analysis. The narrative should describe experiences and events related to your understanding of science, taking into account the context of these experiences and providing an analysis of and an interpretation for the connections between past experiences discussed and perspectives. The narrative should give meaningful consideration to questioning your taken-for-granted assumptions about science by tracing their sources in your personal history.

This paper is worth a total of 10 points: 6 points for depth of reflection, 4 points for clarity, organization, and mechanics.

Appendix D: Emerging Understanding of Perspectives of Science

Why: The goal of this paper is to make space for you to explore your emerging understanding of and perspectives of science. It is vital to reflect on your own understandings in order to be able to continually critique what you are exposed to through classes, media, etc. Reflecting on your own perspectives of science is a critical step in being able to reflect on how you can have a voice in the larger community, which is the second main goal of this assignment.

What: This assignment should be a thoughtful reflection on your shifting beliefs and the experiences, readings, and discussions that caused those shifts both in and outside of this course. Discuss the most transformative aspects of this course explicitly and with citations. You will then reflect on where you will go from here. How will your new perspective shape your future career, studies, relationships, conversations, etc.?

The final submission should be between 3 and 5 pages, double-spaced. Reference to course materials or other materials that you engaged with and found meaningful this semester should be included using correct APA formatting and a bibliography. The final document should be well-edited. You are encouraged to seek the assistance of the writing center.

How (you'll be assessed): Papers will be evaluated based on the depth of reflection, and analysis. The reflection should describe transformations you experienced, engagements that caused those transformations, and future impacts of those new perspectives.

This paper is worth a total of 10 points: 6 points for depth of reflection, 4 points for clarity, organization, and mechanics.

- What changed - Description of transformation
- How it changed - Engagements with course aspects that caused transformation
- What now - Future impacts of new perspectives
- Proper citation and bibliography
- Clarity, organization, and mechanics