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ARTICLE

Astronomy and Culture

A Social Semiotic Perspective on the Role of Culture in Astronomy Education

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Abstract
Modern astronomy as a field of inquiry may be shaped by what we consider the "scientific" ways of knowing. However, the history of astronomy as a human endeavour dates back millennia before the "modern" notions of "science". This long history means that astronomy is, at its core, built on a rich cultural diversity and history. This offers a rich potential that, while having been examined in various studies, has yet to be explored from a contextual pedagogical perspective. This paper offers an initial exploratory theoretical perspective on how social semiotics can be used to inform a conceptual framework. This approach not only brings notions of culture into the teaching and learning of astronomy but uses culture as the starting point in a way that does justice to the cultural diversity of the discipline and the world. In doing so, this paper develops two frameworks: (i) the Conceptual Framework for Culture in Astronomy Education and (ii) the Pedagogical Framework for Culture in Astronomy Education, both of these offer a novel approach to astronomy education.

1 Introduction

The wonder, mystery and beauty of the night (and day) sky has captivated humans for millennia. These experiences are expressed and encapsulated in the ancient Persian proverb: "The night hides a universe but reveals a cosmos" (Fig. 1). This experience of the sublime is a fundamental aspect of the physical Universe that connects us irrespective of race, colour, religion or any other societal labelling; and perhaps sparks our curiosity to seek answers to seemingly simple yet complex questions. Astronomy and the Universe at large do not recognise the human-defined borders of planet Earth.

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Fig. 1 The majestic band of the Milky Way. Image credit: Saeed Salimpour

Although the night sky changes over many millennia and is different depending on the observer's location on the Earth, various cultures around the world share an underlying connection and similarities in how they perceive patterns in the sky. Recent work by Kemp et al., (2022) shows that from a psychological perspective, the similarities of constellations and asterisms across cultures could be due to perceptual groupings based on visual proximity and brightness of stars. The authors used data from 27 cultures around the world to systematically show how these similarities arise, not only for prominent constellations such Orion, but also lesser-known ones such as Delphinus appear in various cultures. Perhaps this "shared baseline" provides a starting point to tap into the deeper meanings among cultures, and a context for astronomy education that truly appreciates the deep connections between cultures.

Although modern developments in technology have allowed us to explore the Universe beyond the wildest imaginations of our ancestors (Aghanim et al., 2020; Beckwith et al., 2006; Dunlop et al., 2017), there is still much delight in understanding the more "mundane" aspects of astronomy we take for granted and "known" from our reference frame here on the blue marble or "spaceship Earth". As the oldest science, astronomy has a rich diversity. The history of astronomy shows us how this shared knowledge has built civilisations and architectural wonders over aeons (North, 2008). Astronomy and its companion, cosmology, possess a grandeur and mystery; they cross disciplines and have deep roots in mythology, philosophy and religion. These deep historical and transdisciplinary roots, coupled with our connection to the sky, provide astronomy with a rich diversity of untapped cultural capital.

Astronomy has been used by cultures not only as a context for cultural knowledge, but also as a vital part of daily life. These include, but are not limited to, developing calendars, agriculture, navigation, architecture and much more (North, 2008). The key here is that the cultural concepts of astronomy are as important as the spatial and temporal concepts in astronomy. They contextualise the direct practical implications of understanding these spatial and temporal concepts in way that is tangible. These aspects of astronomy perhaps provide a robust bridge for exploring astronomy in the classroom from the lens of cultural diversity.

There has been much research into Indigenous perspectives in astronomy from archaeological and anthropological lenses (e.g. Gullberg et al., 2020; Hamacher, 2011; Lee et al., 2013; Norris & Hamacher, 2011; Penprase, 2011; Wyatt et al., 2014), and also with regard to notions of equity, diversity and inclusion (e.g. Nature Astronomy, 2019). These two efforts have inspired and provided the foundations for a shift in how astronomy is presented, as path to decolonising astronomy education from the "single way of knowing". From the perspective of science education, the research landscape is vast and growing (Aikenhead, 1997, 2001), with scholars and educators exploring ways to bring the diversity in ways of knowing into the classroom, in ways that are not merely tokenistic (Garcia et al., 2016; Govender, 2009; Ninnes, 2000; Ruddell et al., 2016; Spinelli et al., 2019). Despite this, only a small percentage of curricula explicitly highlight the cultural diversity of astronomy in their curriculum statements (Salimpour et al., 2020).

In an effort to add to the growing research about the synergy between cultural diversity and science in the science education, this paper aims to answer the below research questions:

- To what extent, can a conceptual framework informed by social semiotics be used to unpack culture in astronomy education?
- What implications does a social semiotic perspective have for incorporating culture into astronomy education?

The paper begins by describing some of the theoretical frameworks underpinning this study. Case studies are then presented that explore the synergy between culture, astronomy and how they can be unpacked using a social semiotic perspective. Finally, these notions are brought together into implications for astronomy education with a pedagogical framework that brings culture in astronomy education in a way that is contextual and tangible to students.

2 Meaning-Making

It could be argued from one lens that science at its core encompasses a process of going from data to knowledge and by extension making sense of the physical phenomena around us—meaning-making from data. Going from data to knowledge is underpinned by transduction (Kress, 2010) where the data, being a semiotic resource, is shifted in meaning using representations of knowledge which themselves encompasses a range of range of semiotic resources (e.g. images, equations, gestures etc.). This latter aspect echoes the work of (Svensson and Eriksson, 2020) who, drawing on case studies from physics education, define transduction "as a shift from a semiotic resource to another, but also a shift from a semiotic system to another." (pp. 2–3).

Transduction from a social semiotic perspective is layered and this current work argues that it relies on, or rather is driven by four theoretical frameworks: discernment (e.g. Salimpour, 2021; Eriksson, 2019), affordance (e.g. Fredlund et al., 2012; Gibson, 1979; Kress, 2010), aesthetics (e.g. Salimpour, 2021; Salimpour et al., 2021; Ferguson et al., 2021; Girod, 2007; Wickman, 2006) and representations (e.g. Salimpour et al., 2021; Tytler et al., 2013). In the following sections, each of these theoretical perspectives is briefly unpacked.

2.1 Discernment

One of the steps of enculturating students into the epistemic practices of science involves scaffolding them to build up their skills in discernment. Discernment is not limited just to science and is transdisciplinary. Eriksson, (2019) and Airey and Eriksson, (2019) highlight the notion of disciplinary discernment, which has different layers and is innately connected to "noticing". In essence disciplinary discernment defines the competency and fluency of a reader to extract relevant disciplinary information for a particular semiotic resource, or system. This paper, following Eriksson, (2019), uses the words "reader" to define the person who interacts with some semiotic resource (e.g. student, expert), and "reading" as the process by which the reader extracts information from a semiotic resource or system.

An example of disciplinary discernment involves extracting information from a particular cosmological representation, for example the Cosmic Microwave Background Radiation (CMB) (Fig. 2). Understanding the colours in the representation, the pattern, the overall shape and various nuances requires a high level of disciplinary discernment, to not only extract meaning from what is "obvious" but also what is appresented—hidden information that is not necessarily explicit (Airey, 2009; Linder, 2013). For example, a cosmologist would appreciate that the CMB surrounds us, and this presentation has mapped the CMB into a projection, and would know that the pattern or anisotropies relate to intrinsic temperature fluctuations (Ade et al., 2011; Mather et al., 1990; Peebles, 1993; Penzias & Wilson, 1965; Spergel et al., 2003), and are the "seeds" for large-scale structure formation.

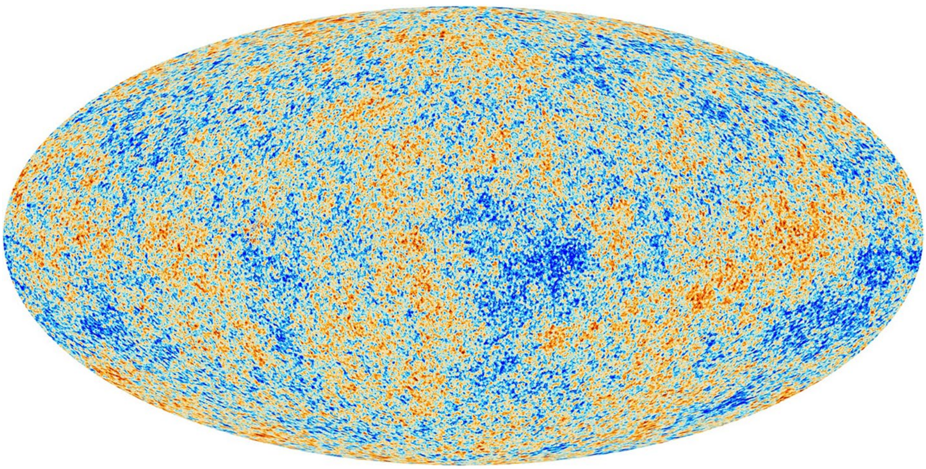


Fig. 2 The Cosmic Microwave Background Radiation (CMB). The glow left over from when the Universe was approximately, 380,000 years old. Image credit: ESA/Planck Collaboration

2.2 Affordance

Affordance is complex notion and has its roots in the Theory of Affordances (Gibson, 1979), where.

> "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment." (p. 119)

From Gibson's perspective, affordance is innate to the nature of the object, and "does not change" (p. 130). Norman, (1988) conceptualises affordance as being a "relationship" (p. 11), and therefore, "A chair affords ('is for') support and, therefore, affords sitting." (p. 11).

Drawing on the work of Gibson, (1979) and Norman, (1988) in the context of physics education, Fredlund et al., (2012), Airey, (2015) and Airey and Eriksson, (2019) conceptualise affordance as being a vital part of meaning-making in a disciplinary community. Fredlund et al., (2012) define disciplinary affordance as "the agreed meaning making functions that a semiotic resource fulfils for a particular disciplinary community" (p. 658). The notion of affordance is expanded by Airey and Eriksson, (2019) to be made up of two types of affordances: disciplinary affordance and pedagogical affordance. The latter is defined as "The aptness of a semiotic resource for teaching some particular educational content".

Prain and Tytler, (2012), drawing on Kress, (2010), consider affordance as a "productive constraint" (p. 2769), stating that.

> "there is productive constraint in what the students can draw and model as they attend to the demands of the task, the resources available, and the opportunities for observational checking of the animal." (p. 2752)

The current paper and the work of Salimpour, (2021) conceptualise affordance as.

> "being embedded in the representation by the creator of that representation, depending on the goal of the representation". (p. 73)

Furthermore,

> "the reader of the representation needs to possess some level of discernment competency to be able to unpack or tap into the affordance(s) of that representation." (p. 73)

This view of affordance, in essence, brings together earlier works and strongly echoes the work of Airey and Eriksson, (2019), where a certain level of disciplinary discernment is required to tap into the disciplinary affordance of a semiotic resource. Salimpour, (2021) argues that affordance can go beyond the disciplinary representations and extend to non-disciplinary contexts, for example a photograph of the night sky or a painting. Although they may have disciplinary aspects, a novice with a lack of disciplinary knowledge can still discern (extract meaning) from a night sky photograph or painting at a more general level.

2.3 Aesthetics

The research and perspectives concerning aesthetics is rich, diverse and heavily debated (Budd, 1998; Dewey, 1950; Ferguson et al., 2021; Gardner, 1996; Girod, 2007; Hannigan et al., 2021; Hegel, 1835; Pugh & Girod, 2007; Root-Bernstein, 1996; Shusterman, 2000; Toscano & Quay, 2021; Welsch, 1997; Wickman, 2006). In general terms, aesthetics is often associated with and used synonymously with beauty. It is prevalent term in art and art education; however, it is much richer than that.

This paper takes the position that aesthetics encompasses a range of philosophical lenses and involves the interaction and synergy between various manifestations of aesthetics—beauty, sublime, experience, knowledge, disciplinary—to name a few. These interactions are key to the teaching and learning and require aesthetics to be situated within some pedagogical framework. One framework is that of representation construction (Tytler et al., 2013). As argued by Salimpour, (2021), and drawing on Dewey, (1979), aesthetics is connected to meaning-making, and "to appreciate/understand/experience the meaning in an artwork requires both prior experiences and a development of the capacity to see deeper." (p. 89). Artwork can be extended to any semiotic resource or system. Therefore, aesthetics is connected to discernment, and developing discernment is also about developing discernment in the aesthetics of the discipline, or perhaps the community.

2.4 Representations

Astronomy with its array of complex and non-intuitive spatial and temporal concepts relies heavily on representations to make those concepts tangible. Representations in astronomy are not new and date back tens of millennia (North, 2008). The practice of creating and interrogating representations is part and parcel of the epistemic practices of science (Gooding, 2005; Latour, 2012; Tytler et al., 2013), and in astronomy this has been vital. Astronomical representations range from not only the disciplinary graphs and equations, but also extends to imagery, computer simulations and data-driven visualisations (Salimpour et al., 2021).

From a pedagogical perspective, the use of representations in the teaching and learning of science has developed a vast body of research over the years and has provided a conduit for engaging students with the epistemic practices of sciences (Salimpour et al., 2021; Prain & Tytler, 2012; Tytler et al., 2013). The pedagogical approach that allows representations as epistemic practices to manifest in the classroom is encompassed by representation construction (RC), which is a guided inquiry approach to teaching science (e.g. Hubber & Tytler, 2017). In this approach, it is not only about students interpreting or making meaning from a handful of consensus disciplinary representations, rather they are also constructing and interrogating their own representations.

3 Astronomy and Culture—Case Studies

As has been argued earlier, the cultural aspects of astronomy are grounded in social, religious and philosophical perspectives. It would be difficult, in this paper, to capture the rich landscape of the intersection between culture and astronomy. However, taking into consideration the theoretical underpinnings of this paper, it is possible to highlight some examples where the above four theoretical perspectives of discernment,

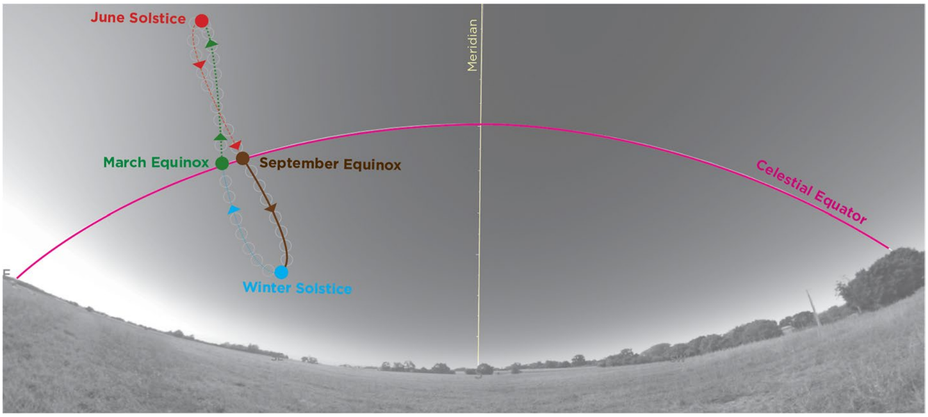


Fig. 3 Visualisation showing the position and motion of the Sun over a year, highlighting the solstices and equinoxes that are a vital part of the Persian calendar. The Celestial Equator essentially divides the sky into two hemispheres and is in essence a projection of the Earth's equator onto the sky. March equinox is marked by the exact time the Sun moves and crosses the Celestial Equator into the northern part of the Celestial Sphere, and the September equinox is the exact time, when the Sun crosses the Celestial Equator into the southern part of the Celestial Sphere. The equinoxes are also the points of intersection of the ecliptic (the path of the Earth around the Sun projected onto the sky) and the Celestial Equator. Visualisation created with Stellarium, https://www.stellarium.org

affordance, aesthetics and representations interact, and their synergy provides an avenue for bringing culture into astronomy education.

Various cultures around the world have based their lives around astronomical events from the oldest surviving culture, the Indigenous Australians, to more "recent" cultures, for example Egyptians, Greeks, Chinese, Persian and many other cultures (North, 2008). These astronomical events have informed agricultural practices, festivals, calendars, architecture and much more (North, 2008).

3.1 Persian Astronomy and Culture

Entertaining the idea that if representations are conceptualised more broadly than through a disciplinary or pedagogical lens, it can be seen how, over millennia, cultures around the world have used festivals and other socio-cultural events as representation of astronomical phenomena. For example, the Persian calendar is a solar calendar, and the seasons in the Persian calendar are aligned to celestial motions, specifically the motion and position of the Sun (Fig. 3). The Persian calendar, which is one of the oldest astronomical calendars still in use, recognises four distinct seasons, which are represented by the festivals Norooz (spring equinox), Teergaan (summer solstice), Mehrehgaan (autumn equinox) and Yalda (winter solstice). The dates of these festivals are determined by the Sun's position and motion across the sky (Fig. 4).

It could be argued that the Persian calendar is based on events in the Northern Hemisphere, and as such this would not apply to the Southern Hemisphere. This is precisely the point that this paper is trying to establish, that these differences and similarities are fundamental to students appreciating the various ways of knowing, and also developing a deeper understanding of the astronomical concepts underpinning these phenomena.

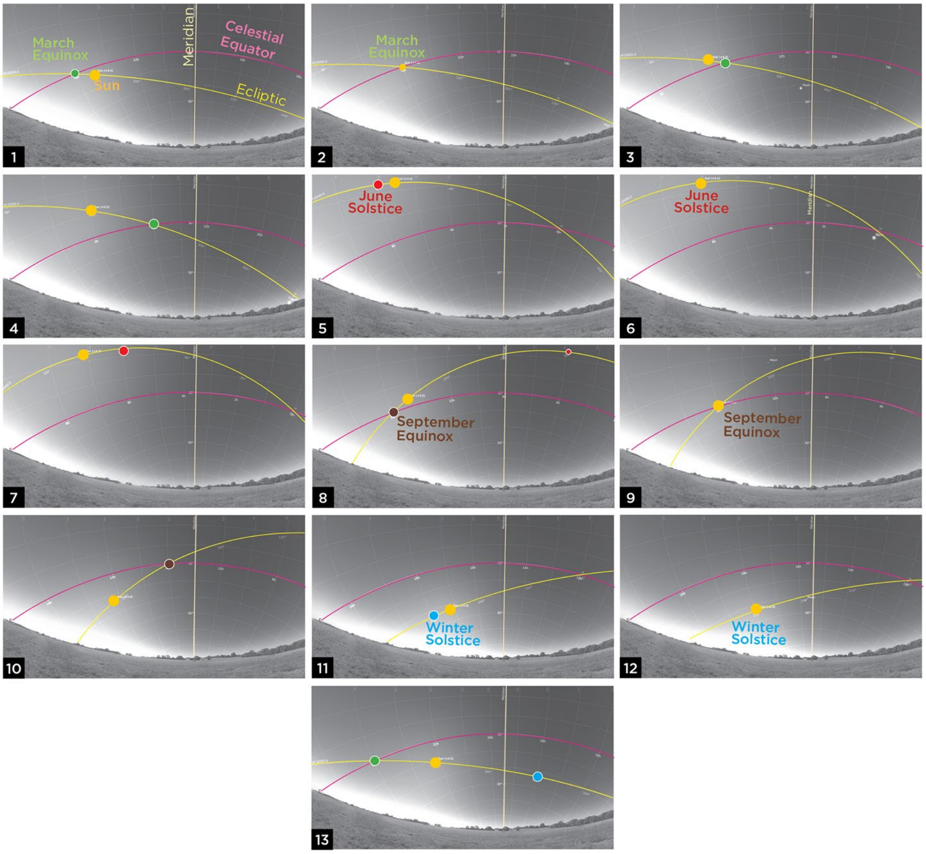


Fig. 4 Series of visualisation showing how the position of the Sun changes over a year. This variation in motion and position is used as the basis of the Persian calendar. Visualisation created using Stellarium, https://www.stellarium.org

Fig. 5 An example of the Persian Haft-seen setting, showing the various objects used as representations. The seven objects chosen here are (**1**) apple, (**2**) Persian olive, (**3**) coins, (**4**) wheat germ pudding, (**5**) sumac, (**6**) garlic and (**7**) wheat sprouts. Another object that is traditional is the (**a**) hyacinth. Image credit: Wikimedia Commons

Norooz (also written as Nourooz, Nowrooz) is celebrated by various other Northern Hemisphere countries, for example Azerbaijan, Pakistan, India and many others. The nexus of Norooz is the Haft-seen (Fig. 5), which is one example of the manifestation and interaction of discernment, affordance, aesthetics and representations. The Haft-seen (transliterated to mean the seven "S"s) is an arrangement of seven objects each beginning with the letter "S" in the Persian alphabet, and each object is a representation for a particular concept. The seven objects can be chosen from apple (Seeb), wheat sprouts (Sabzeh), hyacinth (Sombol), vinegar (Serkeh), garlic (Seer), Persian olive (Senjed), wheat germ pudding (Samanoo), sumac (Somaq) and coins (Sekeh). In addition, there are other objects that are included which do not begin with "S", however, they represent certain aspects of life, these include goldfish, mirror, candles and book of wisdom (this can be a religious book or the book of poetry by Hafiz). Discerning the meanings of these semiotic resources is part of the Persian culture, and this knowledge, or rather the cultural meaning-making is handed down over millennia and is encapsulated in the semiotic resources which are the seven objects. For example, apple represents beauty and wisdom, and the wheat sprouts represent growth and rebirth.

3.2 Indigenous Australian Astronomy and Culture

Indigenous Australians are the oldest continuing culture with a history dating back at least 60,000 years (e.g. Hamacher, 2022). The First Nations People of Australia are not a homogenous group but have a diverse range of cultural and language groups, all of which are maintained through oral traditions. This means that the deep cultural ways of knowing are handed out from each generation to the next and are maintained within the cultural group. More recently, there has been a growing research-based effort to open dialogues with Indigenous elders to find synergies between the different ways of knowing and interpreting astronomy and cosmology (Hamacher, 2011). This has opened up a rich context to highlight the importance of cultural knowledge to the development of astronomy as a science. Indigenous Australians have oral traditions that mark various astronomical phenomena (Hamacher & Frew, 2010). This provides a rich potential to engage students both indigenous and non-indigenous with the diverse ways of knowing, and the role of culture in developing scientific knowledge.

Picking an example for a culture such the Indigenous Australians given their extensive history and diversity is always challenging. There have been various scholarly works that have unpacked various aspects of Australian Indigenous astronomy (Aboriginal Astronomy, 2021). An example with regard to solstices is presented here to illustrate how Indigenous Australians observed solar positions. This has implications for the various cultural aspects of the diverse groups (Hamacher et al., 2020).

The Torres Strait Islander people of Kubin village in the western Torres Strait use the position of the setting Sun relative to islands in the archipelago (Fig. 6) to "mark seasonal change, which also informs weather patterns, animal behaviour and agriculture." (Hamacher et al., 2020, p. 91).

During winter solstice the Sun sets over the island Tuin (specifically behind a hill on Tuin). As the Sun's setting position changes (setting between the islands of Tuin and Matu) heading into the equinox, the people know that cooler south-easterlies will be changing to a period when the air is hot and still. Heading into summer solstice, the Sun's setting position changes (setting over the Matu), this marks the start of the turtle mating season (Soewlal). On summer solstice, the Sun sets between Zurath and Kulbai Kulbai, this marks the start of the wet monsoon season. The Sun then begins it journey "back" across the sky, heading into the equinox. This knowledge and the underlying semiotic resources (which in this case includes physical objects) requires a level of cultural discernment and affordance.

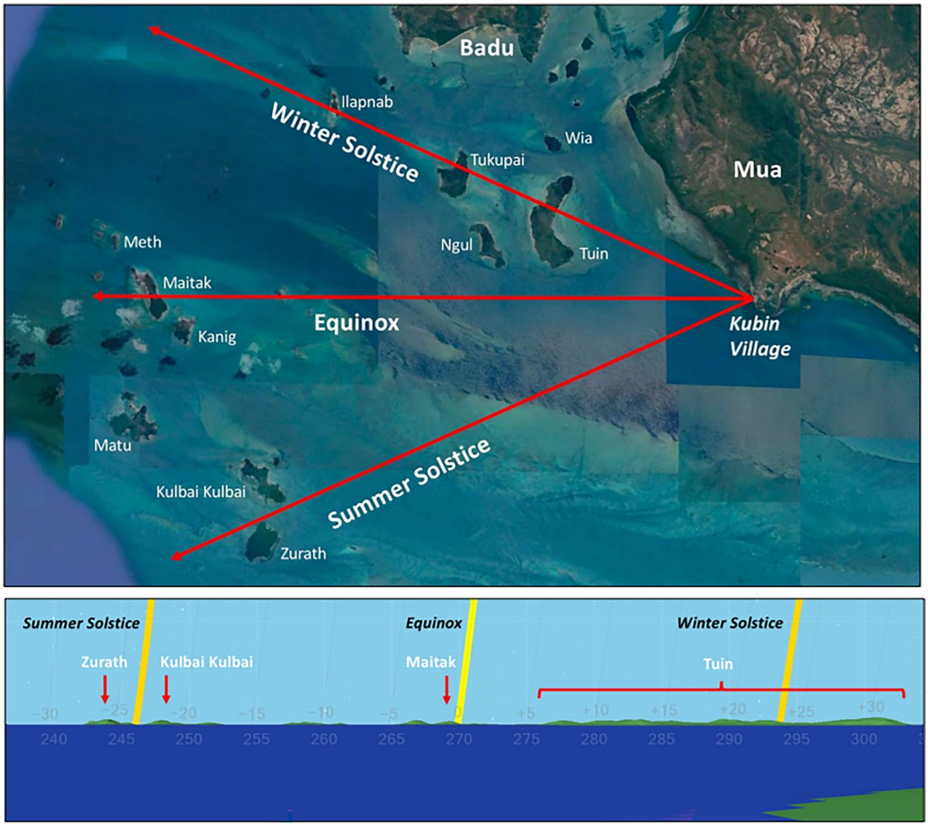


Fig. 6 The Kubin villagers use the position of the setting Sun along the horizon to determine seasons, weather patterns, animal behaviour and agriculture. Image credit: Hamacher et al., (2020)

Another example that captures the synergy between astronomy, culture and meaning-making from a social semiotic lens is that of Indigenous Australian rock art and the underlying astronomical-cultural symbolism it encompasses. The work of Norris and Hamacher, (2011) shows how Indigenous Australians have deep astronomical traditions encompassed by the rock art. One such example is the Emu in Sky, which is an engraving at Elvina track in the Ku-ring-gai Chase National Park, NSW (Fig. 7). The engraving shows the outline of an Emu. During autumn in southern latitudes in Australia, the band of the Milky Way stretches across the zenith. The dark patches in the Milky Way resemble an Emu, various Indigenous Australian groups have stories associated with the Emu (Fuller et al., 2014). However, when comparing the Emu engraving with the Emu in sky during autumn, similarities are evident. In addition, during this time of year, real emus are laying their eggs (Fuller et al., 2014); therefore, the Emu in sky is a social semiotic resource used by the Kamilaroi and Euahlayi people as reminder that Emu eggs are obtainable. The orientation of the Emu in sky represents extends to other seasons (Fig. 8).

There is also some debate about whether the Emu in Sky also connects to the *bora* ceremony. The vertical orientation of the Emu (Fig. 8, top-right), and the disappearance of the neck, leaves the body and the head to represent the large public and small scared *bora* rings (Fuller et al., 2014).

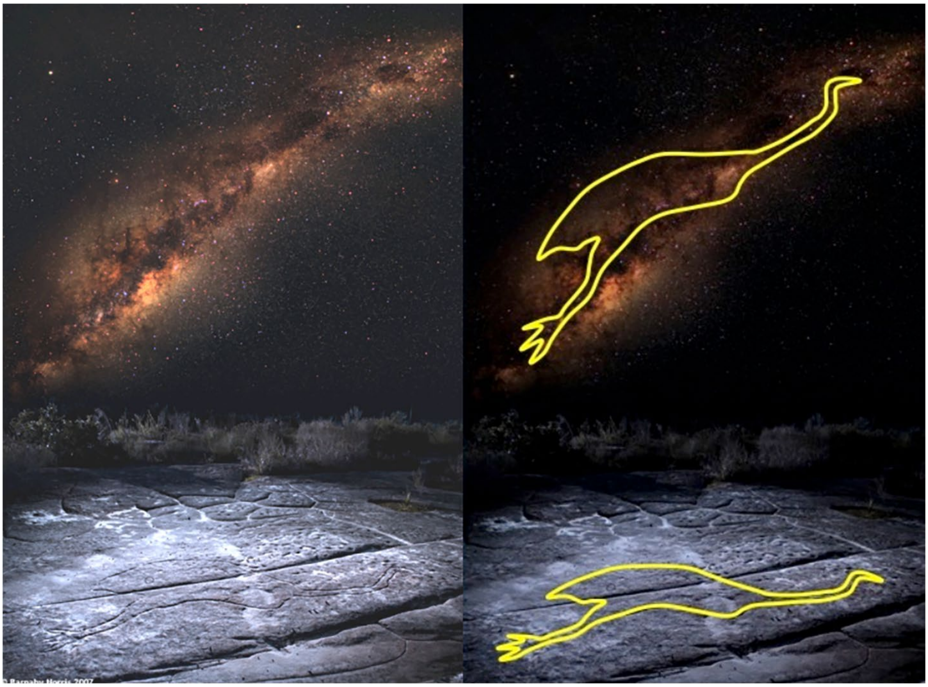


Fig. 7 The Emu in the Sky engraving, which depicts the Emu that is seen through groupings of the dark patches in the Milky Way. Image credit: Barnaby Norris, 2007

3.3 Connecting the Case Studies to Meaning-Making

In each of the case studies presented above, semiotic resources have an affordance—a cultural affordance—and a range of appresented cultural meanings that require the "reader" of these resources to have a certain level of cultural discernment in order to extract meaning from these semiotic resources. As noted by Norris and Hamacher, (2011) "the astronomical connection may not be apparent to a Western researcher unless guided by cultural knowledge." (p. 1).

Apart from the cultural meaning and knowledge, there is the astronomical disciplinary knowledge relating to how the position and motion of the various celestial objects, and their underlying "repetitive" patterns can be used to establish something so vital to a culture. Whether it is the tangible semiotic resources of the Haft-seen, or the Indigenous rock art, these resources are connected to intangible semiotic resources observed in the night sky. Svensson and Eriksson, (2020) highlight the notion of transductive links and define it as "…any semiotic system that supports the transduction process between two different semiotic systems." In the context of the examples presented in the above case studies, it can be proposed that there needs to be a transductive link between, for example the Emu rock art and the Emu in the Sky. This paper proposes that this link is embodied in the cultural knowledge and discernment that is needed to extract the relevant meanings. It should be emphasised that the cultural knowledge encompasses the language, and that is vital to the transductive link.

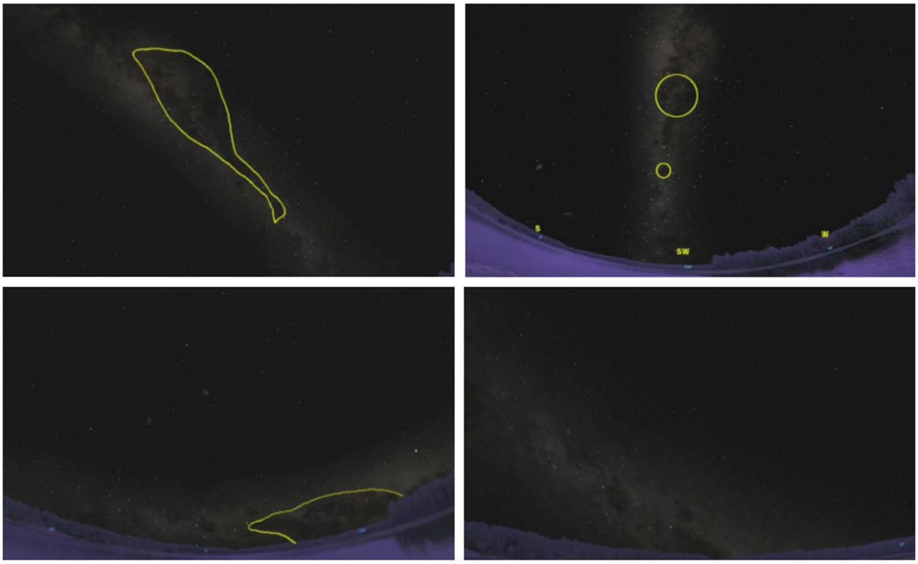


Fig. 8 The various orientations of the Emu in the Sky relate to specific events for Kamilaroi and Euahlayi Indigenous people of Australia. Top-left: In early winter, the Emu resembles a male emu sitting on its eggs, owing to the disappearance of the "legs". Top-right: In late winter, the Emu is vertical, the disappearance of the "neck" leaves the body to represent an emu egg. Bottom-left: In spring, the body of the emu is just visible on the horizon, and this represents the emu sitting in a waterhole, this signals the filling of the water holes and the coming of rains. Bottom-right: In late summer, the Emu is barely visible, and this represents the emus leaving the waterholes. Image credit: Fuller et al., (2014)

The Persian and Indigenous examples presented above are just a very brief snapshot of the rich potential of realising the synergy between culture and astronomy in the context of teaching and learning. There is a myriad of other examples that encapsulate the astronomy-culture synergy, for example the Islamic calendar being a lunar calendar has events aligned to lunar cycle, and hence dates for certain events vary, one example, being the date for the start and end of the Holy month of Ramadan. The next section discusses some of the implications of this rich cultural capital for astronomy education.

4 Implications for Astronomy Education

Astronomy as a subject has many non-intuitive and intangible concepts. This presents a pedagogical challenge to make those concepts comprehensible to novices. Adding to this complexity, astronomy education overall is mainly centred on the modern notions of what we consider to be empirical science. This decontextualises aspects of astronomy and does not do justice to the development of knowledge and the broad notion of science—*Scientia*.

The teaching and learning of astronomy are not merely about understanding complex spatial and temporal relations, the declarative knowledge (facts of the field) but also how this knowledge has been developed, and how this knowledge is manifested in culture. Therefore, an approach to teaching and learning which grounds astronomy in the cultural context appropriate to the classroom is a powerful approach to not only introduce students to the astronomy, but also to keep in mind equity, diversity and inclusion.

The use of narratives from the history of science can be a powerful way to scaffolding students into appreciating the richness and diversity of science as field of inquiry (e.g. Abd-El-Khalick & Lederman, 2000; Clough, 2017). In recent years, curricula have been incorporating sections that provide teachers with the opportunity to bring Nature of Science (Lederman, 2007) into their teaching. One example is Australia, where the National Australian Curriculum includes a section called Science as a Human Endeavour (SHE) (Paige & Hardy, 2019). Another example is the incorporation of Indigenous perspectives, and this has driven the development of the Indigenous Curriculum project (Langton et al., 2018). This project provides teachers with resources to help them bring Indigenous perspectives into their teaching in a way that is not merely "tokenistic". Astronomy naturally, and very easily, lends itself to incorporating Indigenous perspectives and the diversity of cultural perspectives. This has inspired various fruitful endeavours around the world to bring Indigenous perspectives into astronomy education and outreach.

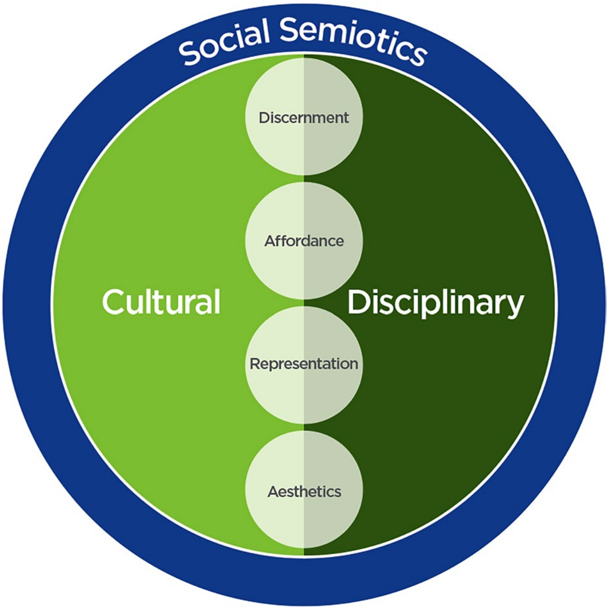
The challenge for teachers and educators is finding culturally appropriate pedagogical methods to ensure that incorporating cultural perspectives is done in way that does not decontextualise the teaching and learning. Every classroom will be different, and so there is no one pedagogical approach that can be considered best practice. Rather, the approach needs to be flexible to be able to work in a variety of classrooms around the world. In this sense, the framework needs to be based on fundamental notions that are cross-cultural which includes meaning-making (discernment), information both hidden and present (affordance), aesthetics and representations. Keeping this in mind, the next section introduces a pedagogical framework that draws on the theoretical and philosophical underpinnings of these four notions, coupled with the insights from the case studies, and anecdotal implementations in a classroom. This framework is aimed at bringing culture into astronomy education in a way that is appropriate to the cultural context and encapsulates notions of equity, diversity and inclusion.

5 The Astronomy Education Cultural Frameworks

In exploring the four theoretical frameworks: discernment, affordance, aesthetics and representation, they manifest beyond the disciplinary lens and have implications in a more general sense. These frameworks can easily be explored from a cultural lens, and the underpinning ideas will still be valid. The reason for this adaptability is that any disciplinary field has its own culture, and every culture carries with it a set of semiotic perspectives that are accessible to those with the appropriate cultural knowledge or immersed deeply in the culture.

Using the insights from the various theoretical lenses, the next two sections present the conceptual and pedagogical conceptualisations for the Astronomy Education Cultural Frameworks, referred to as the AstroCulture framework. The aim is to provide educators

Fig. 9 The AstroCulture Conceptual Framework brings together the theoretical perspectives from discernment, affordance, aesthetics and representation



with a guide for one avenue of teaching astronomy from a cultural lens, which is informed by robust theoretical perspectives.

5.1 The Conceptual Framework

The conceptualisation of the Conceptual Framework for Culture in Astronomy Education (AstroCultureCF) (Fig. 9) essentially uses social semiotics as an overarching lens, which encompasses two components: cultural and disciplinary. Both these components share the theoretical perspectives of discernment, affordance, aesthetics and representation, which connect together and interact. In the next sections, the underpinnings for each of the components of the AstroCultureCF are explained.

5.1.1 Disciplinary and Cultural Discernment

This current study echoes Eriksson, (2019) with regard to the proposal that discernment is at its core about "noticing". From a disciplinary perspective, this is about noticing or being able to extract meaning that is present and also hidden. These notions equally apply to a cultural lens; therefore, this current study defines "cultural discernment" as the ability of the reader to extract the relevant meaning that is appropriate to the cultural context of the semiotic resource or system. In some cases, cultural discernment is not accessible to an individual who may not be familiar with the culture. This is seen when concepts in astronomy (for example seasons) are taught from the lens that "everyone experiences the four seasons the same way" and the terminology used although may be disciplinary appropriate is culturally foreign to the students.

5.1.2 Disciplinary and Cultural Affordance

As explained earlier, discernment and affordance are connected and there is a symbiotic relationship between the two. Salimpour, (2021) defines cultural affordance as "The agreed meaning making functions that a semiotic resource fulfils for a particular cultural community." (p. 77). This has important implications because in some contexts, for example in Indigenous Australians' cultures, the affordance of a semiotic resource or system may only be discernible to members of the cultural community (Norris & Hamacher, 2011).

Furthermore, the cultural affordance of a semiotic resource is also affected by the mode of that resource. Rock art provides a different level of affordance than an oral story and each requires a different level of discernment.

If we consider this from the perspective of a disciplinary lens, then teaching students about astronomical phenomena is about enculturating them into the epistemic practices of the discipline; however, in terms of equity, diversity and inclusion, this may provide challenging to students who will also be looking at the phenomena from a cultural lens, rooted in their own cultural capital. This echoes the work of Salimpour, (2021), who highlight that there is a close connection between disciplinary and cultural affordance, because.

> "a disciplinary community encompasses or rather espouses a certain culture unique to the discipline. This culture defines the epistemic practices of the discipline." (p. 77)

5.1.3 Disciplinary and Cultural Aesthetics

The notion of aesthetics is itself layered, complex and contextual, manifesting in different ways. Salimpour et al., (2021) states that it can take three fundamental forms when considering the context of astronomical representations (includes imagery): the everyday aesthetics, art-related aesthetics and scientific disciplinary aesthetics. The latter is defined as.

> "related to disciplinary practices and values such as clarity (e.g., of a graph, an equation), theoretical elegance and basis in evidence." (p. 013104-6)

Using the three aesthetics, it is only logical to also incorporate cultural aesthetics, which this current paper defines as the combination of experiences that relate to the cultural perspectives and practices of a community.

5.1.4 Disciplinary and Cultural Representation

Representations as discussed are powerful tools to not only make sense of complex concepts (e.g. Salimpour et al., 2021; Gooding, 2006; Latour, 2012; Tytler et al., 2013), but also to maintain a record of phenomena (e.g. Salimpour et al., 2021; North, 2008). Representations are multimodal; therefore, they can include gestures, drawings, spoken words and much more. Cultural and disciplinary representations are different in their aim; however, they have a synergetic relationship. A cultural representation that is aimed at keeping a cultural record of a phenomenon can hold disciplinary knowledge, and only through dialogue between the two can that potential be realised.

Looking at the definitions presented above, it is obvious that the line demarcating culture and disciplinary is quite fuzzy. Disciplines espouse a certain culture, and cultural perspectives themselves are, in ways, disciplinary. This synergy between disciplinary and

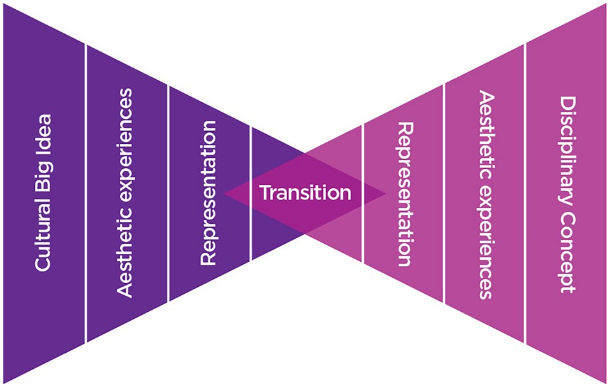


Fig. 10 The AstroCulture Pedagogical Framework is conceptualised as two overlapping funnels with a transition region. Astronomical concepts can be contextualised as a cultural big idea, and the teacher scaffolds the students towards the disciplinary concept

cultural provides a stage where we can begin to construct a pedagogical framework that draws on and is informed by the innate synergy between culture and discipline.

5.2 The Pedagogical Framework

Using the AstroCultureCF, it is possible to conceptualise a Pedagogical Framework for Culture in Astronomy Education (AstroCulturePF) (Fig. 10), which provides a guide for teaching astronomy from a cultural perspective. The AstroCulturePF is conceptualised as two overlapping horizontal funnels, which allow for a transition between cultural and disciplinary lenses. The horizontal nature of the funnels means that one lens is not superior to the other, and knowledge is considered as being distributed across a spectrum.

An educator can start with a big idea starts that is some cultural event/festival rather than the disciplinary astronomy. This sets the context and provides students with something relatable, rather than some abstract concept about astronomy. The transition region is key here, because it allows connections to be made between cultural ways of knowing and disciplinary ways of knowing, providing a bridge between the epistemologies and ontologies of each lens. Aesthetics and representations have both cultural and disciplinary manifestation; these are used as pathways in the transition from cultural to disciplinary.

If we consider the example of the Persian festival Norooz, the cultural big idea is Norooz, which has associated with it aesthetic experiences—the setting of the Haft-seen which is different for each family and involves everyday and art-aesthetics; and also, the representations—the semiotic resources within the Haft-seen. The big idea is explored more in depth by scaffolding students about why Norooz is celebrated on this particular day and time. Students can make observations of the position of the Sun in the sky and take note, at least partly, of the changes in Sun's position leading up to the event.

Drawing on the work of Airey and Eriksson, (2019), another way to think about the AstroCulturePF is in terms of a cultural-disciplinary space (Fig. 11), where teaching of astronomy concepts can be situated anywhere is this space. The underlying principle for AstroCulturePF is scaffolding students from the region of high cultural focus to the region of high disciplinary focus, as shown by the white arrow. This in principle is done by

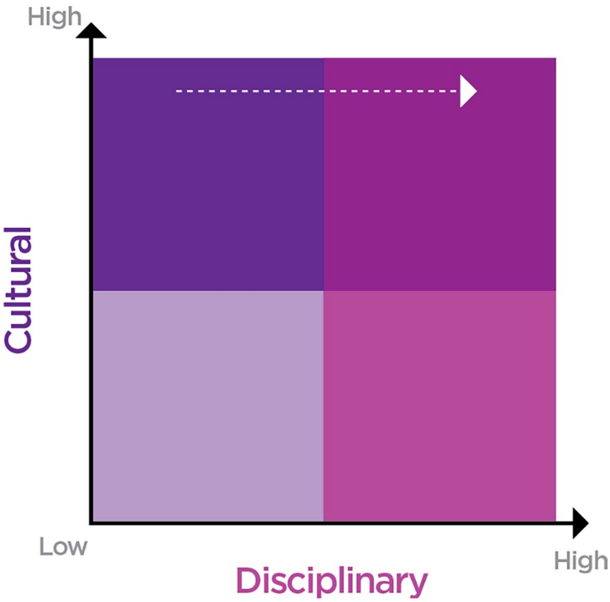


Fig. 11 The cultural-disciplinary space, in the context of the AstroCulturePF, the aim is to start with a high cultural focus and use that to scaffold students to a high disciplinary focus

starting with the big idea in a cultural context and using notions of cultural aesthetics and representations to help students transition into the disciplinary area of the concept.

An example of how this transition from the cultural to the disciplinary manifests is represented by the Islamic lunar calendar. In the lunar calendar, especially for the Holy month of Ramadan, the start and end of the month is marked by the New Moon, or more specifically the first sighting of the very thin crescent. From a disciplinary lens, we can accurately predict when

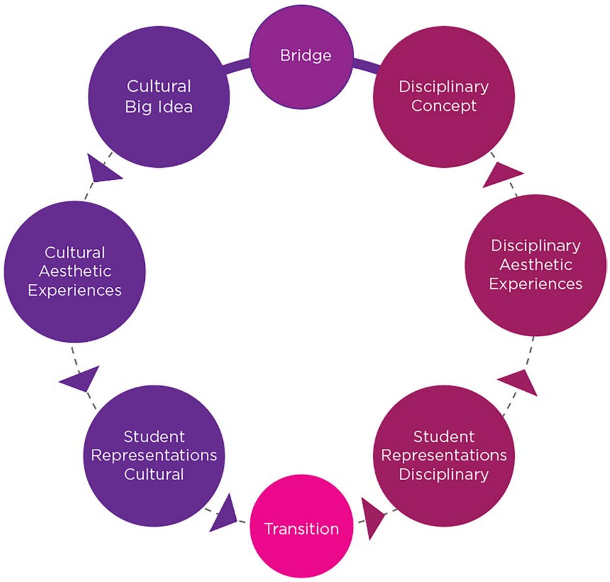


Fig. 12 The transition from the cultural space to disciplinary space, in the context of the Islamic lunar calendar. At the end of the this cycle, it is vital to highlight the bridge which connects things

New Moon occurs; however, from a cultural lens the sighting of the waxing and waning crescent is the key determinant for the start and end of the Holy month, respectively. This transition is represented in Fig. 12, the process begins with the cultural big idea, in this context it would be the lunar calendar focussing on the Holy month of Ramadan. The next step would be unpacking the cultural aesthetic experiences associated, in this context the students drive this stage. Following this, students create the various representations associated with the cultural experience, the next stage is vital, and it involves the "boundary crossing". In this stage, the astronomical context is highlighted, and students move from cultural representations to disciplinary representations. The teacher acts as a guide, scaffolding students from the cultural to the disciplinary. For example, what is the significance of a crescent Moon from a cultural lens? What is the significance of a crescent Moon from a disciplinary lens? How do these lenses relate? What is the significance of sighting as opposed to predictions based on mathematics? This transition or "boundary crossing" is perhaps the most extensive, because students are interrogating representations from both cultural and disciplinary lenses. Following this, students engage with disciplinary aesthetics and the associated experiences, this relates to the underlying physical mechanisms that give rise to these orderly patterns. Finally, students with guidance from the teacher start consolidating the key disciplinary concepts, the key here is to create a bridge between the disciplinary concept and the initial cultural big idea.

6 Conclusion

The cultural diversity and richness that is innate to astronomy can be a powerful tool to scaffold students when learning astronomy, but more importantly one step in creating equity, diversity and inclusion in astronomy education. Various cultures around the world are innately connected to some aspect of astronomy, and it is imperative that teachers and educators use this untapped potential. This cultural diversity allows astronomy to be contextualised to the learning of the students in a way that is familiar to them, and to show them how the development of knowledge in science is more than "mere facts". Knowing that this cultural diversity exists is not new and is well documented; however, the key is developing pedagogical approaches that are appropriate to bringing this diversity and richness into the classroom. The social semiotic framework presented in this paper is not about the pedagogical approach rather it helps inform the pedagogical approach. It is a flexible scaffolding that highlights some fundamental aspects of meaning-making that can be used when incorporating cultural perspectives in the teaching and learning of astronomy. This framework connects discernment (both cultural and disciplinary), affordance (both cultural and disciplinary), aesthetics and notions of representations.

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