Co-constructing Náhookos Bi'ka' constellation with STARR

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ABSTRACT

This demo presents STARR—Students Tracking Angular Rotation Recorder—as a means for students to learn about angles. STARR combines hand sensors and a tracking compass to guide students through an embodied angle value experience. In an effort to revitalize land-based ethnomathematical practices, this demo, framed around Diné cosmology, engages students in a novel astronomical experience where they become immersed in angle creation and measurement. Participants will be 4th & 5th grade (9-12 years) students paired either with a peer or with an intergenerational family member. Working in a simulated planetarium, participants will collaboratively "voyage" along constellations, so as to occasion communications about angles from complementary perceptual perspectives (the first-person "Sensor" and their third-person "Navigator"). STARR investigates the discursive co-construction of situated mathematics to evaluate whether and how students are grounding Euclidean geometry in Diné astronomical knowledge. This tangible cultural interface explores the resonance between Indigenous historical practices and modern pedagogical principles of progressive education focused on situated actions, with potentially broad implications for mathematics education based on critical-pedagogy restorative-justice values.

CCS CONCEPTS

• **Applied computing → Collaborative learning**; • **Social and professional topics → User characteristics**.

KEYWORDS

Mathematics Education, Embodied Learning Technologies, Multi-generational Learners

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1 INTRODUCTION

The STARR installation —Students Tracking Angular Rotation Recorder—is a *tangible cultural interface* designed for young students to learn the basic geometry content of angles by experiencing angular rotation from multiple complementary perspectives. Whereas these complementary perspectives are *perceptual*, visual sensations from different spatial orientations toward the same display (egocentric vs. allocentric), they are also *cultural*, in that they carry different psycho-ontological positionings (ecological vs. extractive). As such, when STARR sets students up to view the environment from two different perceptual perspectives, it also stages opportunities for dialogue between two epistemologies, specifically Indigenous and Colonial. As we explain below, the dialogue is mobilized by assigning a dyad the collaborative task of navigating among the stars. Allegorically, participating students are thus invited to reconcile Indigenous and Colonial views.

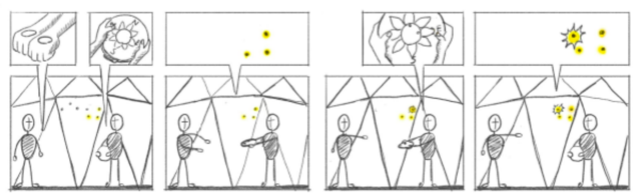

Figure 1: STARR storyboard: dialogue between students coordinating perspectives on a constellation as they find the next star together.

The STARR learning environment is built in the form of a small planetarium to invoke an experience of the night sky. Figure 1 shows two students in the planetarium, engaged in the task of traversing the night sky by indicating stars using different media. The student on the left is the "Sensor" who virtually becomes each new star of the constellation (1st-person perspective); the student on the right is the "Navigator" who guides the "Sensor" (via 3rd-person perspective on the same constellation). The Sensor must use their left arm as a ray to connect the *past* star to the current star that they embody, and their right arm as a ray to discover the *next* star in the constellation. The Navigator aids the Sensor by providing feedback from the compass, which tracks the location of the second (right arm) sensor. This initiates dialogue in the service of finding the exact location of the next star. This is an iterative process where the Sensor will then become the most recent star found as they again connect to the *past* star and the *next* star.

There are several different ways that one can construe an angle. STARR focuses the participants on the angle's 'open-ness' (i.e., the rotated aperture between the angle's two arms), where participants determine the angle's magnitude "by measuring the length of the arc [the *interior*] that the angle subtends in a circle centered at the angle's vertex" [8, p.35].

The egocentric experience of embracing an angle, where you *are* literally embodying the mathematical magnitude of interest, emulates Navajo non-dualist heritage epistemology, where you

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are one with the object you're inspecting. In contrast, the allocentric act of measuring an angle, whereby you apply a utensil *to* the magnitude in question, exemplifies Western dualist psychophilosophy, where you are *a priori* separated from the world you are encountering. By setting up students to unwittingly personify different perspectives on an angle yet at the same time engaging them in a task where they are required to *translanguage* their perspectival orientations, STARR deliberately surfaces, juxtaposes, and negotiates the material–linguistic grammars of Diné mathematics (ecological ethnomathematical practices rooted in the language) vs. Eurocentric forms of thinking, acting, and learning [17, qv.]. Indigenous mathematics is grounded in embodied epistemology and is expressed through the body and environment, whereas Eurocentric mathematics foundations are in objectivist epistemology and rely heavily on symbolic notations. As such, the project aims to build an epistemologically pluralistic learning environment [21] that restructurates common mathematical practices [22] as emulating and extending embodied immersion in the natural world [5].

2 RELATED WORK

STARR is an *embodied design* [1], in the sense that it enables intersectionally diverse students to ground school content in situated actions [11]. More broadly, though, experiencing angles through task-based physical movement incorporates students' bodies "into" the mathematics itself, rather than eliding the bodies from mathematics [10, see]. Specifically, the perception-action experience of performing a radial-sweep to determine measures of angularity reintroduces students' body orientation in the environment. At the same time, this phenomenologically pluralist approach [21, see] paves a way for negotiating mathematical content in which students can flourish in the mandated curriculum, while remaining grounded *in* their cultural identity and as all students learn *about* the cultural practice as well as *from* this embodied spatial movement.

Recent efforts to improve mathematics education aim to include Indigenous cultural artifacts in the curriculum and, more importantly, ground learning in generational cultural knowledge and practices [6] [15] [17]. As such, a campaign to restore Indigenous mathematical epistemology, through ethnomathematics, is a campaign to communalize all students' access to authentic and cultural historical mathematical practice D'Ambrosio [4].

The inclusion of digital technology to support learning in geometry education has opened new doors for real-life exploration of angles. Dynamic Geometry Environments (DGE) incorporate students into the immediate environment by augmenting their experience of space with digital tools. One DGE solution, offers only an allocentric perspective with a hand held tablet and application that allow students to find angles in their environment [3]. In two other DGE's, they utilize a large screen in front of the classroom for an interactive geometry experience. In [9], the students used a joystick to make the car image rotate with visible tracking of the angle of rotation and [18] used Kinect to identify important angles enacted by students with arms. Both of these designs afford students the egocentric and allocentric perspectives by utilizing visual media that follow the students' kinesthetic mode of interaction.

However, STARR is a nascent design solution which offers the students a culturally-situated multimedia experience to simultaneously reconcile angles egocentrically, both by being [7] the angle vertex, and by viewing the angle allocentrically that another student is performing. Therefore, this design is a novel construction embedded in Diné mathematics that recruits other perceptual motor capacities as the students interpersonally coordinate in this geometric experience. For this demo, the enactment of cultural practices and artifacts for mathematics education will be focused on Diné cultural practices and the reconciliation of Eurocentric mathematics that elides embodied interaction with mathematical objects [13].

3 DESIGN

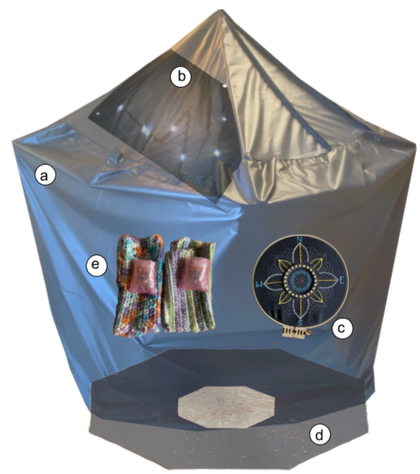

Figure 2: STARR components: (a) Planetarium; (b) LED constellation; (c) hand-held compass; (d) Octagon rug; and (e) Mugic glove sensors.

The STARR project features a 6'x 6'x 6' nylon-covered tent as the planetarium, constructed from dowels and plastic tubing (Figure 2a). The planetarium ceiling bears LED displays shaped after the Náhookos Bi'ka' (Big Dipper) as it is oriented during the fall season (Figure 2b), above which lies the Náhookos Biko' (North Star). Lying in the center of the planetarium is an octogonal cotton rug with a clear plastic center featuring a compass rose (Figure 2d). The octagon was designed to prompt participants' visual attention toward the planetarium's eight unique spatial orientations (cardinal directions). One participant will have the Mugic sensor gloves on (Figure 2e) and the other participant will hold an embroidery hoop with a compass rose design and 24 LED circles which track the movement of the sensors (Figure 2c). Participating pairs will metaphorically traverse along the constellation, the sensor will iteratively connect to the *past* star, be the *current* star, and connect to the *next* star.

The constellations Náhookos Bi'ka' (Male Revolving One) and Náhookos Biko' (Central Fire) make up two of three parts of the Náhookos constellation, the other being Náhookos Bi'áád (Female Revolving One), which continually revolve around Náhookos Biko'.

This positioning is grounded in and from the Diné homeland, Diné Bikéyah; "Navajos have organized their star knowledge from Diné Bikéyah, a central location in the American southwest defined by the four sacred mountains. The order of the Navajo constellations is related to the geographical information provided from the cardinal directions, which, in turn, are directly connected to cosmic stellar processes as observed from this position of centrality in Diné Bikéyah" [12, p. 14-15)]. The task of finding or constructing the constellations grew from the Diné story of how the stars came to be (retold in [14] by Hosteen Klah). In this story, the stars lie in chaos because of the actions of Coyote. Therefore, the participants must make sense of the sky by identifying one of these important constellations.

4 CONTRIBUTION

This demo is motivated both by societal and practical needs for reconciling mathematics for children in Indigenous communities and by recognizing apparent resonance between Indigenous historical practice and reform-oriented mathematics pedagogy (e.g., "constructivist"). For Native American students, Eurocentric epistemology is a colonial imposition that fails to recognize cultural knowledge and practices of this land. In particular, Indigenous epistemic practices are not elicited, accepted, or recognized in mainstream classrooms [2]. Birthed and nurtured in different geographical and cultural contexts, Eurocentric and Indigenous epistemologies differ greatly in their conception of, and approaches to, mathematics. In pre-colonial eras, Indigenous people's traditional knowledge and education have always been from and about the land [19]. Diné geometrical reasoning, practice, and language encompasses the individual within the land-and-sky environment [4] [16]. The demo is a first step within a larger research program that aims to rematriate [20] mathematics curriculum by drawing on Diné ethnomathematics to design an embodied activity in dialogue with Eurocentric approaches.

Project outcomes will inform both the theory and practice of the learning sciences, including studies of epistemology and language as these pertain to curricular design. Dyad's co-constructed language in the planetarium, which is anticipated to be action-oriented, will carry over to the paper-based post-intervention assessment of mathematical learning, supporting students' situated sense-making of school subject matter content.

5 IMPLEMENTATION

For this demonstration, the planetarium will be erected for attendees to experience this immersive environment with the hand sensors and digital compass.

5.1 Usage

Participating pairs will collaborate in navigating the constellation. The North Star will be demarcated by the facilitator as an orientation resource. The activity begins with two LEDs lit on the planetarium ceiling: one is Náhookos Biko' and the other is the first star of Náhookos Bi'ka'. The Sensor student will stretch their arms forward and rotate them, either turning or twisting their body, on a plane parallel to the ground. The Navigator will see the two sensors' respective locations appear as two dots on the embroidery compass. Both students will be inside the planetarium, with the Sensor standing in the middle and the Navigator on the side (see Figure 3a).

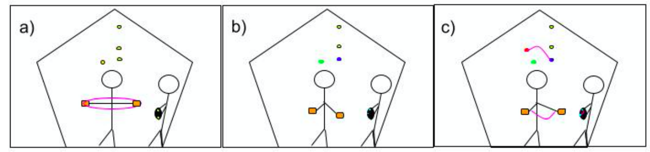

Figure 3: (a) Two students inside the planetarium playing, one with the hand sensors (orange rectangles), the other holding the embroidery compass (black circle). (b) The Sensor is metaphorically the current star (shown as the green dot); and is connected to the past star (blue dot) and is finding the next star; (c) Having built the star connection by finding the next star (red dot), the pink lines depict the angular rotation of both the student and the stars, as indicated on the compass.

The Sensor will begin by embodying the first star of Náhookos Bi'ka', which is the only star of the constellation that is lit up in the sky. Next, the Sensor will point one arm and exploratorily move it in the plane parallel to the ground (Figure 3a), searching for the next star. The Navigator will guide the student in their search by using the light feedback displayed through the compass rose. When the sensor is at the correct location (i.e. the student is creating an angle that connects one star of the constellation to the next part of it), the embroidery compass LED will shine bright blue; otherwise, the LED will shine white. This scaffolded allocentric representation on the embroidery compass is designed to invite conversation between the students around determining the correct angle.

In Figure 3b the Sensor is on the third star of Náhookos Bi'ka'; here, one arm is connected to the *past* star, and they are looking for the connection to the *next* star. The Navigator sees the compass color coding, providing vital supplementary information to guide the Sensor. The Navigator communicates the Sensor's rotation. In Figure 3c, they have found the correct location of the *next* star and have completed the current angle (e.g. the pink lines). In the next iteration, the Sensor will then embody the star most recently lit.

5.2 Audience

STARR is designed as an interactive learning environment for students *first* learning about angle, based on CA State standards, during 4th and 5th grade (ages 9–12). But, it provides an opportunity for any participant to dialogue about an embodied mathematical experience about angles and spatial reasoning.

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