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Mathematics Heritage Project: An Exploration Empowering Students' Mathematical Identities

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Abstract

The International Study Group on Ethnomathematics (ISGEm) supports incorporating cultural diversity of mathematical practices to promote the teaching and learning of school mathematics. Through The Mathematics Heritage Project, students at a middle school in the southeastern United States developed unique creations to connect with the mathematics connected to their identities and self-identified cultural group. Upon reflection, students reported an increased awareness of the relevance of mathematics in their lives and a sense of ownership that is both meaningful and modern.

Keywords: mathematical explorations, identity, culture, equitable teaching practices, project-based learning, ethnomathematics.

1. Introduction

Mathematics is all around us — in art, architecture, music, sports, medicine, and beyond. Modern mathematics often represents a culmination of ideas from various cultures, and the work of multiple individuals and communities from all around the world. Students deepen their learning of mathematics and sustain what they learn when it is culturally responsive and connected to their experiences outside of school [16, 22]. Gay [11] outlined that in Culturally Responsive Teaching (CRT), students' cultures play an integral role towards equitable instruction. Yet, school mathematics is too often presented as a set of static, unchanging rules developed by ancient people — often emphasizing a Eurocentric narrative (cf. [15]). In this presentation of mathematics, students who do not identify with that Eurocentric narrative commonly feel a disconnect between their identities and the relevance and possibilities of mathematics.

When one discusses identity in general, and mathematical identity in particular,[1] narrowing a definition of identity is a challenging endeavor. Grootenboer, Smith, and Lowrie [14] consider the following three identity categories to be prevalent: psychological / developmental, socio-cultural, and poststructural. For this particular work, we focused on the socio-cultural aspect of identity within mathematics. In the 1980s and 1990s, a great deal of research under the ethnomathematics umbrella involving Indigenous and underrepresented communities and their usage of mathematics was highlighted by the works of numerous mathematics educators [1, 2, 7, 24, 25]. These works in part gave rise to a movement involving the creation of mathematical tasks for students: tasks where learners would experience mathematics used in ways outside of the traditional Eurocentric mathematics that has historically been taught in American schools.

Within the educational context of the United States and Canada, many of these tasks have provided opportunities to include Native American and Inuit values and ways of knowledge in the classroom. The tasks often have involved agricultural themes (e.g. [17]), using objects in nature as concrete manip-

[1] Several authors have done interesting work on mathematical identity. See, for example, [9, 19, 26].

ulatives, or elements of pattern in art and textiles (e.g. [12]). With these types of tasks, the teacher — who may or may not share in the culture at hand — is generally at the center of bringing the connections of mathematics into the classroom and choosing the culture from which to do so. The aforementioned projects typically have taken place in locations where there was a distinct cultural group that was already a strong identifier for the majority of the student population. As an illustrative example, a community project involving mathematics found in the Haida Gwaii culture took place in British Columbia island location where many students shared this heritage [12]. In another case study [20], mathematics educators worked together with Yupiaq elders as they developed course content exploring mathematically and culturally salient themes. Similar instances have happened in projects to bring in the languages and cultures of Mexico into classrooms along border towns of the United States. Each of these aforementioned projects gave students the opportunity to explore mathematics from a common or shared heritage. However, many schools are seeing significant increases in immigrant and multilingual student populations from a variety of backgrounds [21], and in these ever increasingly heterogeneous classroom settings, a greater variation in heritage and identity calls for a different approach.

Though previously mentioned works focused on bringing mathematics that was previously not at the forefront of the curriculum into the minds and senses of learners, the push to articulate elements of identity and power has been a distinct slant, as seen in the work of Knijnik [18] and Bishop [5]. Indeed, such circumstances lead to a call for the expansion of mathematical identity beyond an ancestral connection. Mathematical identity may also include gender identity-based cultural connections, including those promoting connection to the role of mathematicians who are members of the LGBTQ+ community (cf. [13]).

The International Study Group on Ethnomathematics (ISGEm) supports incorporating cultural diversity of mathematical practices to promote the teaching and learning of school mathematics (see `http://isgem.rpi.edu/` for more details). Additionally, the National Council of Teachers of Mathematics (NCTM), National Council of Supervisors of Mathematics (NCSM), and TODOS: Mathematics for ALL, promote the idea that a part of making math accessible and equitable for all students involves creating, sup-

porting, and sustaining a classroom culture that is responsive to students' backgrounds, experiences, cultural perspectives, traditions, and knowledge (see, for example, the documents [22, 23]). Given these priorities, we, the authors of this article, have discerned a need for the implementation of tasks for students that not only are culturally responsive in the ethnomathematics tradition but also can empower the students to find and connect with the mathematics history common to the group(s) within which they self-identify.

2. The Mathematics Heritage Project: A Capstone Experience

2.1. Lead up to the Final Project

Throughout the 2018-2019 academic year, in middle school classes taught by the first author (SD), 150 students in the southeastern United States engaged in projects involving the history of mathematics through the lens of cultures originating outside of the United States. The students came from diverse cultural and ethnic backgrounds.

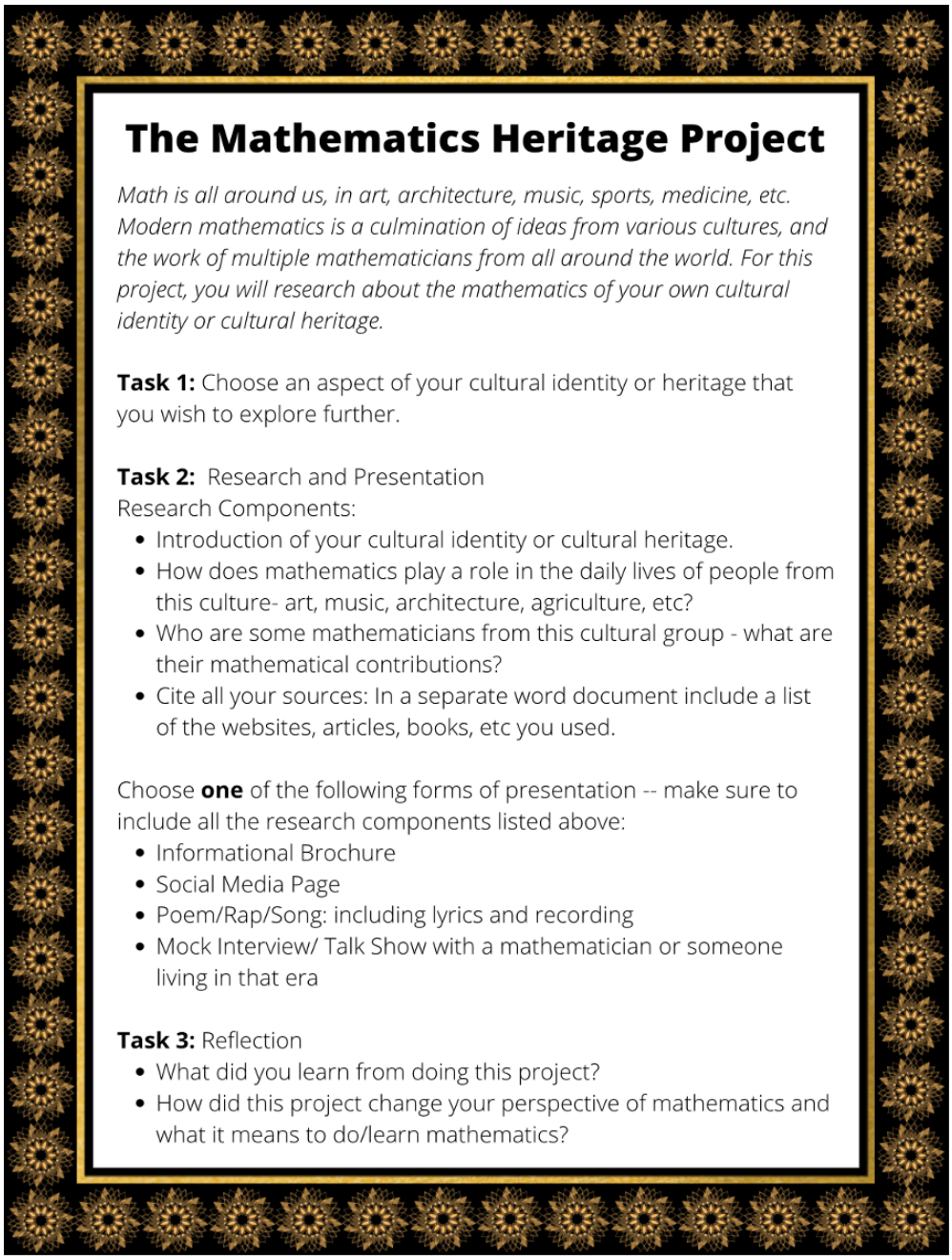
Through their engagements in such projects, students were able to have a foundation laid in accordance to goals outlined by Barta, Eglash, and Barkley [3], who stated, "When we embrace a more multicultural understanding of mathematics, we see how the mathematics of today has evolved from many cultures' contributions from across the planet and throughout time" (page *v*). Throughout the academic year, students had opportunities to develop a global perspective of the different ways people and cultures (e.g. Indian, Chinese, Persian, Egyptian, Babylonian, Mayan, Native American, Roman, Greek) have contributed to the development of mathematical ideas and explorations. These explorations connected mathematics history and culture to the pre-algebra concepts they were learning. For example, when discussing the area of a circle, the students were introduced to the history of pi and how people of many different civilizations have worked on finding the "exact value". Similarly, students delved into historical evidence that, in many cultures and geographies in the ancient world (e.g., Mesopotamia, Egypt, India, China, and Greece), what we commonly refer to as the Pythagorean Theorem was already in the knowledge base [4]. Such discussions enabled students to see that modern mathematics is and has been a culmination of work done by people of many different cultures and civilizations.

Additionally, they participated in a research project on mathematicians with different cultural identities, which culminated in the creation of biographies intended for young children on their chosen mathematicians. This sequence of tasks prepared students for their final project, The Mathematics Heritage Project, which leveraged and valued the multicultural diversity of students, their families and the school community.

2.2. Mathematical Heritage and Identity Project

In many different cultures, mathematics is not simply something that students learn in school. Instead, mathematics plays an intrinsic and integral part of their everyday lives. Yet for many of our students, this integrated representation of mathematics is not typically present in mathematics classrooms and curriculum, and thus there seems to be a disconnect between mathematics taught in schools and the mathematics of their cultural and familial backgrounds and traditions. We created The Mathematics Heritage Project to specifically address this disconnect. For this assignment, students researched the mathematics of their own cultural heritage or identity. For the purposes of the project, we defined cultural heritage broadly, using an ethnomathematics lens, to include "all of the ingredients that make up the cultural identity of a group: language, codes, values, jargon, beliefs, food and dress, habits, and physical traits" [6]. And identity was defined in terms of factors including but not limited to language, community, culture, gender, race, sexual orientation [27]. We intentionally used broad definitions for these terms because we wanted students to have the ability and agency to determine the direction of their own project.

As these middle school students were still getting into the habit of engaging in research-based assignments, the project was broken down into three major tasks which made this seem less daunting. (See Figure 1 for the description of the project shared with the students.) Additionally, as some of the mathematical vocabulary and topics they came across in their research were new and unknown, students' experience of engaging with aforementioned mini-research projects throughout the year was crucial. The main goal was to sustain their interest, give them a unique opportunity to explore these ideas, and allow them to gain early exposure and make connections to what was to come in later mathematics courses.



The Mathematics Heritage Project

Math is all around us, in art, architecture, music, sports, medicine, etc. Modern mathematics is a culmination of ideas from various cultures, and the work of multiple mathematicians from all around the world. For this project, you will research about the mathematics of your own cultural identity or cultural heritage.

Task 1: Choose an aspect of your cultural identity or heritage that you wish to explore further.

Task 2: Research and Presentation
Research Components:

- Introduction of your cultural identity or cultural heritage.
- How does mathematics play a role in the daily lives of people from this culture- art, music, architecture, agriculture, etc?
- Who are some mathematicians from this cultural group - what are their mathematical contributions?
- Cite all your sources: In a separate word document include a list of the websites, articles, books, etc you used.

Choose **one** of the following forms of presentation -- make sure to include all the research components listed above:

- Informational Brochure
- Social Media Page
- Poem/Rap/Song: including lyrics and recording
- Mock Interview/ Talk Show with a mathematician or someone living in that era

Task 3: Reflection

- What did you learn from doing this project?
- How did this project change your perspective of mathematics and what it means to do/learn mathematics?

Figure 1: The Mathematics Heritage Project task options and directions as presented to the students.

2.3. Data Collection & Analysis

For this paper, data collected consisted of students' work on the project. Written work and artifacts submitted by the students for Part 2 (presentation) and Part 3 (reflection) of the project were analyzed. A selection of student work is shared in the next section.

3. Examples of Student Projects

Students chose to explore facets of mathematics with which they felt a connection, from geometric principles in art, to scientific implications, to finding a kinship in personal stories of mathematicians such as Emmy Noether, Alberto Pedro Calderón, and Alan Turing. The students then presented their findings in a creative way; see Figure 2 for a selection of student work.

Figure 2: Clockwise from the top left, a social media page for Emmy Noether, a brochure about mathematics in the Philippines, famous architecture in Germany by Herzog and de Meuron, Irish symbols, and a culinary exploration.

In the cases that follow, the work of students is highlighted to provide depth and variety to the reader of the connections made and illustrated.

Example 1: Mathematics in Indian Art and Agriculture

A student who identifies as Indian focused her project on the artistic traditions of Kolams, or Rangoli designs that are embedded in the daily lives of many Indian women, especially in parts of Southern India (see Figure 3). Agriculture, in addition to being one of the largest sectors of the Indian economy, is also a long standing tradition for many families whose roots can be traced back to the farming culture. The student discussed the many algebraic and geometric ideas used in farming; for example, integers are used in calculating losses and gains, and perimeter, area, and volume are used to ensure successful growth of crops.

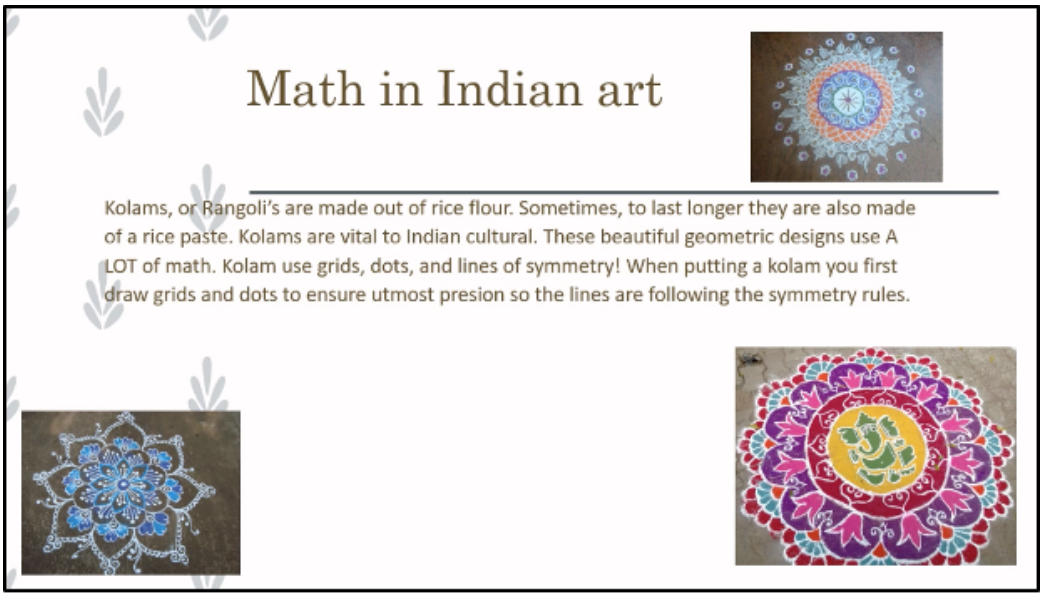


Figure 3: A student investigated the mathematics of Kolams (Rangoli).

Example 2: Mi Familia

While many students share a cultural heritage with the family they live with, for those who do not, this project provided a unique opportunity to connect with their roots. One student who was adopted as a young child from Guatemala expressed in his reflections that this project helped him feel more connected to his birth family. His birth parents were Ladino,

a term used in Central America, to describe the ethnic group of mixed Native American, Spanish, and African ancestry [28]. The student chose to focus on the Indigenous side of his ethnic heritage and explore his descent from ancient Mayans. Through this project he was able to learn not only about Mayan mathematics but also about his ancestry; see Figure 4.

I was born in Mazatenango, Sacatepequez, Guatemala. My birth parents were Ladino and descended from the ancient Mayans. I choose to study more about the Mayan culture. The Mayan territory included all of Guatemala, Belize, and parts of Honduras, El Salvador and Mexico as shown on this map. The Mayan were a group of people. There is no one Mayan Mathematician named in my research.

Figure 4: An adopted student chose to connect to the cultural heritage of his birth family.

In his reflections, this student later wrote,

> This project changed my view on math because it shows that even without modern technology people still used math for everyday life. I also learned more about the history of the culture of my birth family.

4. Project Reflections

Through the Mathematics Heritage Project experience, students could explore connections to their identity in the mathematics they were learning. Furthermore, as a critical benefit, students also gained awareness of a greater

need to be present and in power of controlling the narrative. The student who identified as Ladino by birth noted that, although he learned a great deal about the impact that the Mayan people had on mathematics through his research, he was not able to find a single Mayan mathematician named (Figure 4). This is in sharp contrast to other students for whom biographies of mathematicians who shared their backgrounds were readily accessible in convenience and number.

For those students from that latter group, however, unique discoveries were still made beyond the traditional classroom knowledge. One particular student with Irish heritage reflected upon her surprise at the presence of mathematically themed festivals and museums in Ireland. Another student with an Italian background shared his family's tradition of making spaghetti sauce and reflected that

> [M]ath is important to discover new things and carry on traditions. [This project] changed my view on math, because I learned that I need to pay attention in math if I want to carry down my family's heritage to my children, and to my children's children.

While math was admittedly not this student's favorite subject, while reflecting on his family's traditions for this project, he realized how the ideas of ratios and proportions were so important in the sauce-making process. Additionally, without really realizing it, he was using these mathematical concepts to carry on his family's traditions.

Regardless of their cultural backgrounds or identities, this project allowed all students to see the applications and interconnectedness of mathematics as it pertained to their lives, which will hopefully foster their curiosity to find more connections. As one student reflected,

> I'm kind of happy that I had this project so I could learn more about my heritage and know where I came from. This project changed my perspective with math cause now I know that part of me has contributed to it. It also changed my perspective cause now I don't see math as something that I'm not really part of, I see it as something that I am more part of.

In a parallel vein, seeing mathematics outside of formulas on a page struck students. A student reflected,

> One way I see math differently is by (*sic*) see it more than just numbers on a paper to create a solution, but a way to get creative.

This idea of using the mathematics within to express, create, and drive a vehicle for change allows students to feel pride in their cultural heritage and confidence in their ability to make a meaningful contribution.

5. Final Thoughts: Implications and Extensions

For too long, acultural mathematics instruction has resulted in many students, particularly students of color, feeling left out and mis- and / or underrepresented; too many of our students are unable to identify as mathematically capable and unaware that they do in fact possess a long and rich mathematical heritage [8]. By intentionally providing opportunities for students' identities and cultures to be valued, visible, and central in mathematical teaching and learning, we can transform mathematics as a subject — as well as a way to view and experience the world — so that it belongs to all students, including those with cultural/historical connections to global communities. In this manner, we can leverage students' identities and cultural heritage with authentic richness to combat the perception of mathematics as a uniquely white, Eurocentric set of ideas and inventions.

Historical and cultural aspects brought forth by students also set the stage for current and future mathematical explorations and connections. For instance, the example from India lends itself naturally to further explorations of mathematical themes such as symmetry, rotation, and other geometric ideas. Another example from an African-American student referred to tessellation patterns in weaving, which could lead to the ideas of geometric transformations. In a project focusing on Irish cultural connections, a student drew an image of a triple knot that can connect to polar graphs and trigonometric ideas. Through this early development and exposure to visualizations of mathematics, students may be setting the stage for later increased understanding [29].

Although the students may not be aware of the future connections at this stage in the development of their mathematical knowledge, the exposure they have gained to these concepts, even in an implicit fashion such as this, can have a meaningful impact in their future.

In a previous article two of us (SD and FS) wrote, "One way to engage students and make the beauty and wonder of mathematics more directly evident and connected with learning experiences involves enriching educational experiences that connect and extend content strands with multi-disciplinary domains" [10]. In this vein, the implications for the Mathematics Heritage Project potentially go beyond siloed mathematics and leave distinct possibilities for cross-disciplinary collaboration. Within the social studies sphere, students are routinely charged with investigating culture with a strong lens on historical context. Projects such as The Mathematics Heritage Project allow students to dig into the past, and the potential exists to consider what historical events were occurring at the time of the various mathematical discoveries or in the lives of the mathematicians investigated by the students to create a connection. For example, one student chose to create a social media page for Emmy Noether. As Noether was a Jewish scholar whose university position at the University of Göttingen was revoked during the rise of the Third Reich in Germany, this can directly tie to World War II and Holocaust discussions found in history classes. Yet another student wrote about British mathematician and early computer scientist Alan Turing. Turing is considered a prominent figure in LGBTQ+ history, and, due to his subjection to chemical castration as an alternative to imprisonment, a connection to biology, psychology, and ethics can be made for the more mature students.

Though the students in this version of the project only submitted short pieces of writing, the expansion of the written component would be an immediate connection to the language arts classrooms. If students are encouraged to produce more visual displays, a direct collaboration with the creative arts can also become a possibility, potentially bringing in aspects of culture not always seen in art classes. Projects such as the one focused on the mandala from India and the one on tessellation patterns found in the kente cloths of West Africa not only provide an opportunity to launch into future mathematical concepts but also lay the groundwork for the exploration of the instances of the beauty of mathematics within art from non-Western cultures.

Beyond the classroom, we hope and intend for efforts such as The Mathematics Heritage Project to extend future professional and career aspirations for students in conjunction with identities that may not have been previously considered. The fascination with patterns and artistic design that multiple students were able to see the mathematics in can directly launch into groundwork for careers in architecture, game design, graphic design, culinary, and horticultural arts such as floral design and landscaping. These fields are often beyond the subjects offered in a typical school context, yet the ability to combine mathematical understanding and creative skills is imperative for one's success and growth in them.

Through such projects, school mathematics and the topics explored by students reflect their world beyond the school walls. These explorations then have inherent relevance; students can see how they can use mathematics in their lives today in order to address and influence culture in the present and the future, rather than experiencing mathematics through contrived attempts to engage with topics and techniques they perceive to be more suitable to yesteryear. By looking back, learning their own history, and connecting their own heritage to mathematics, students can develop ownership, and a vision with which to push mathematics forward in ways that are meaningful, relevant, and modern.

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