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Infusing Indigenous Knowledge Systems (IKS) into Teaching Integrated STEM Disciplines: An Empirical Project

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Cover Page Footnote

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Introduction

In spring 2020, the world was struck with two invasive pandemics wreaking havoc on earth's soul and body: racism and corona virus disease (abbreviated as COVID-19**)**. On the heels of COVID 19 global health crisis, the ethnic and racial climate in the United States and the world became more ominous as demonstrations broke on the streets demanding justice against longstanding racial injustice, economic oppression, underdevelopment of communities, and many structural strains that built up pressure and tension over the years, and literally exploded. This populist revolt against xenophobia and systemic racism was manifest as the grievances of minoritized racial and ethnic groups remain unheeded, powers unchanged and it gets to the point where people have very little to lose. The question then arose, what is it that prompts people to take to the streets and to literally put their lives at risk in the middle of a pandemic?

Disparities in economic and educational opportunities for *All* have a complex and contested history worldwide. Particularly in the United States, the misconceived notions of cultures and identities of ethnic groups have resulted in a "divide that exists between many educational institutions and the students they are supposed to serve" (Paris & Alim, 2017, p. 95). Such hiatus only continues to grow because students are continuously reminded that their identities are not affirmed and their cultural capitals are not recognized. Payne (2013) cogently argues that the cultural deficit paradigm casts a long shadow on education through an irrelevant curriculum that is silencing students' voices and excluding their backgrounds, experiences, and lives. In this apocalyptic climate, schools throughout the country were faced with an unprecedented challenge: continue to teach the nation's K–12 students without having them physically present in the classroom. Never before have such drastic and widespread changes to re-imagine education been required, and never before have the enervated realities of underserved and marginalized communities been so conspicuous. Recognizing the essential need to prepare a scientifically literate populace that can understand data and be able to critically weigh evidence to address grand world challenges, an emergence of outpouring interest has been

focused on resilience and knowledge of indigenous peoples as custodians of about 80% of the world's biodiversity making them crucial partners to build a post-COVID -19 era (IFDA, 2020).

Indigenous KnowledgeSystems (IKS) has been recently established by the international world organizations as a top global priority for empowering traditional and local communities in their striving efforts towards prosperous and sustainable development (Kapoor & Shizha, 2010). However, despite its highly proclaimed importance and sound pedigree of recognition for strengthening native communities' preservation of social and traditional capitals towards more independence (Chahine, 2011), no clear effort has been cited that describes the contributions of indigenous cultures to the mainstream knowledge and epistemologies, particularly Southeast Asian and African communities. Nonetheless, several seminal pedagogical and curricular approaches resisting deficit thinking repositioned the cultural practices of ethnic communities as a first step towards finding a possible solution to address those issues and concerns. Such *difference* pedagogies include, funds of knowledge (Moll & Gonzalez, 1994), culturally relevant pedagogy (Ladson-Billings, 1995), culturally responsive pedagogy (Cazden & Leggett, 1976; Gay, 2000), culturally appropriate (Alim, 2007), and culturally sustaining pedagogy (Paris, 2011).

In supporting students from diverse ethnic backgrounds to preserve and honor their cultural heritages, Ladson-Billings (1995) called for "a culturally relevant pedagogy that would propose to do three things—produce students who can achieve academically, produce students who demonstrate cultural competence, and develop students who can both understand and critique the existing social order" (p. 474). In contemplating Ladson-Billings' third call, Paris (2012) pondered: "We must ask ourselves if the research and practice being produced under the umbrella of cultural relevance and responsiveness is, indeed, ensuring maintenance of the languages and cultures of African American, Latina/o, Indigenous American, Asian American, Pacific Islander American, and other longstanding and newcomer communities in our classrooms" (p. 94). He further questioned the applicability and pertinence of the terms "relevant" and "responsive" in describing our aspirations for a transformative

learning in a multiethnic society. Paris (2012) avers that "The term *culturally sustaining* requires that our pedagogies be more than responsive of or relevant to the cultural experiences and practices of young people—it requires that they support young people in sustaining the cultural and linguistic competence of their communities while simultaneously offering access to dominant cultural competence. Culturally sustaining pedagogy, then, has as its explicit goal supporting multilingualism and multiculturalism in practice and perspective for students and teachers. That is, culturally sustaining pedagogy seeks to perpetuate and foster—to sustain—linguistic, literate, and cultural pluralism as part of the democratic project of schooling" (p. 95).

While there is ample support in the literature on the effectiveness of school-based culturally relevant interventions as potential opportunities to provide meaningful contexts for learning, empirical evidence is critically lacking, particularly in STEM classrooms. In examining 179 peer-reviewed empirical studies related to culturally responsive teaching practices in K-12 schools between 1998-2014, Bottiani, Larson, Debnam, Bischoff, and Bradshaw (2018) found two studies that measured the impact of interventions on student outcomes and eight studies that assessed the benefits with respect to teacher outcomes. However, none of those ten studies established a causal relationship between implementation of the intervention and teacher or student outcomes. More importantly, none of those empirical studies employed rigorous research design features to warrant inclusion under evidence-based interventions in the inventory of What Works Clearinghouse (WWC). Hence, the research project presented in this paper becomes timely and needed.

Historically, it has been generally known that Africa constitutes the cradle of mathematical and scientific thought (Gerdes, 2000). More recently, archaeological evidence collected from different cultures has unearthed numerous indigenous technologies that inherently embody specific scientific and mathematical structures, such as number systems, folk games and puzzles, kinship relations, divination systems, and symmetric strip architecture (Chahine, 2020). Building on the ingenuity of numerous indigenous cultures, such as Southeast Asian and African cultures, research has provided

some opportunities to various uses of materials, which represent invaluable clues to cultural connections and continuities through space and time. Besides the more obvious advantages concerning the possibility of providing a better understanding of tools and resources that civilizations employ, culturally relevant materials encompass keys to concepts, which are at the heart of higher-order mathematical and scientific notions. This seed project calls on educators to build on students' cultural experiences they bring from their homes and communities to support unconventional ways to teaching STEM subjects.

Context

The City of Lowell in Massachusetts is home to a diverse population composed of around 49 % White residents, 21% Asian residents, 19.4% Hispanic residents, Black residents 7.3%, and other residents (2.1%) (2013-2017 American Community Survey). Compared to other places in Massachusetts, Lowell has a relatively high number of Southeast Asian ethnic groups including Khmer, Cambodian, and Laotian. The demographic landscape of the city of Lowell is squarely reflected in the enrollment profile of its public schools. As per the ethnic composition of the student enrollment data in Lowell Public Schools(LPS), the 2017-2018 demographic statistics issued by Massachusetts Department of Elementary and Secondary Education(DESE) noted that the highest enrollment rate is for Asians (31.7%), and the third highest percent after Whites (28.9%), and Hispanics (25.3%) is Blacks or African Americans (11.4%). More importantly and per reports from DESE, the 2017 School and District profiles shows LPS as a high-needs district that serves 73% students of color, 71% students of high –needs and almost 60% economically disadvantaged children based upon their families' enrollment in federal and state assistance programs. For the past several years, LPS have shown troubling scores on student achievement, college and career readiness, student attendance, and school climate measures. For example, according to 2017 Massachusetts School Report Card, only 28% of high school students completed a rigorous course of study compared to 77% in the State of Massachusetts(MA). Also, in 2017 the district has a documented high school suspension rate of 14% compared to only 3% in the state

of Massachusetts. Furthermore, and as per 2018 DESE Accountability Reports, the district has been classified as requiring assistance or intervention and in need of focused/targeted support particularly with respect to subgroup performance and low participation rate.

In light of the increasingly diverse demographics that thrive in LPS today and the pressing need to support student success, particularly in STEM subjects, there is an unprecedented need to introduce mathematical and scientific ideas that resonate with students' diverse ethnic backgrounds and multidimensional cultural experiences. Additionally, in teacher education courses, there is an intentional focus on valorizing the use of community-based, culturally-oriented learning experiences that promote cultural awareness and global engagement. Our charge in this project is to support learning and appreciation of scientific knowledge by immersing learners in culturally relevant practices that stimulate, enhance, and extend their thinking beyond the confines of the classroom. As STEM educators, we argue that STEM ideas manifest itself differently in different social or cultural contexts, hence engaging our diverse student population in culturally responsive, inclusive curricula could provide essential relevant experiences that support meaningful learning.

Project Goals and Objectives

This 2-prong research project aimed at designing multimedia technologies and establishing and researching professional development institutes for integrating Southeast Asian and African cultural practices in the teaching of mathematics and sciences in Lowell Public Schools. The project dovetailed two components: the establishment of a multi-institution, cross-country research partnership and a professional development institute. The research strategic partnership included faculty from the College of Education (COE) and the Southeast Asian Digital Archive (SEADA) at UMASS Lowell, the Mathematics and Statistics Department at Georgia State University(GSU), the Self Directed Learning(SDL) Research Focus Unit at North West University in South Africa, the African Community Center in Lowell (ACCL) and Lowell Public Schools(LPS) (See Figure 1).

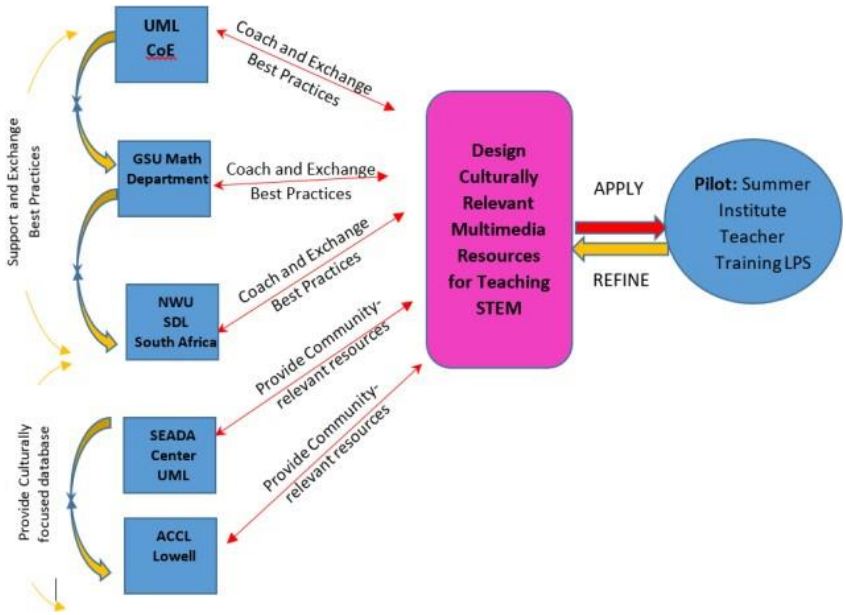

Figure 1. Research partnerships involved in the Ethno-STEM empirical project.

The overarching goal of this partnership to research and develop digital, online multimedia instructional resources and interactive materials to be used in teacher certification courses and summer institutes to train teachers to use culturally relevant modules in STEM subjects across collaborating institutions and beyond.

The professional development component of the project involved a series of summer institutes beginning with a pilot in summer 2019 training 20-30 high school mathematics and science teachers from LPS to incorporate indigenous knowledge practices using Ethno-STEM pedagogy in their classroom instruction. The main objectives of the training are to: 1) strengthen teachers' problem solving skills using hands-on activities inspired from numerous cultural practices, and 2) provide teachers with opportunities to develop awareness and appreciation of the complex dynamics that instigate the emergence of mathematical and scientific tools in real life settings. The ultimate goal of the training is to offer STEM teachers opportunities to engage in exploring mathematical and scientific ideas embedded in everyday contexts and in ways that are different from what they see in typical textbooks. During training, teachers were expected to engage in guided discussions focused on developing curricular material and lesson plans to foster their students' ethno-modeling skills in mathematics and

science inspired from several authentic cultural practices including architecture, musical rhythms, indigenous games, kinship relations, arts, and other topics. It was expected that participating teachers will be trained in teaching mathematical modeling of cultural practices using human-values based approaches. The underlying premise of this research project is that employing a culturally sustainable pedagogy in teaching STEM subjects provides teachers with opportunities to strengthen their teaching practice by engaging in investigations to build new knowledge, acquire critical problem solving skills, and improve their efficacy toward STEM disciplines. The fundamental goal of the project is to sensitize teachers to the need to reimagine a more comprehensive, critical and collaborative commitment to community-based STEM Education.

The research component examined the hypothesis that as a result of being immersed in indigenous practices using an ethno-STEM pedagogy supported by appropriate resources for teaching, teachers will cultivate an "enhanced" sense of teaching-efficacy in incorporating cultural practices in their classrooms. Furthermore, it was anticipated from this research project that teachers will develop an awareness of and appreciation for culturally relevant education aimed at investigating and understanding the physical world thereby honoring diversity and promoting respect for cultural heritages. A critical implication of being immersed in ethno-STEM practices was to encourage teachers to be mindful of the fact that children from diverse backgrounds have different modes of thinking and therefore ensuring genuine, personalized, and inclusive opportunities for progress in STEM disciplines is paramount.

Project Design and Methodology

An integrated component of the project involves the design of culturally relevant multimedia resources including graphics, podcasts, and videos to support teachers in teaching STEM subjects. The research focus of the pilot examined the experiences of LPS teachers as they engage in learning ethno-STEM practices using value based culturally-relevant pedagogy and the impact of their participation on their teaching efficacy. The research project employed an exploratory, case study design with qualitative and quantitative techniques. A case study was chosen to examine the

phenomenon in depth and in its real-world context in order to explain how or why some conditions came to be (Yin, 2014).

The sample of the pilot comprised of 20-30 high school mathematics and science teachers from Lowell Public Schools. Subsequently, a qualitative sample of 8-10 teachers was purposefully selected from the quantitative sample using stratified sampling based on gender and ethnicity. Data was triangulated from multiple sources including Pre/Post Teaching Efficacy Belief Instrument (TEBI) (Enoch, Smith, & Huinker, 2000), demographic survey, interviews, observation logs, and artifact collection. At the beginning of teacher training, pre TEBI was administered to obtain initial rating of teachers' self-efficacy before engaging in the research program. At the end of the training and school visits, a post TEBI was conducted to examine whether experiences using culturally relevant resources encountered during the summer institute have influenced teachers' beliefs about their efficacy to teach multicultural mathematics and science to their students. Observations were focused on the qualitative sample during implementation of the lesson plans and semi-structured interviews were conducted to explore the range of teachers' perspectives, beliefs, and ideas related to their teaching efficacy and confidence levels. Artifacts such as lesson plans, ethno-STEM modeling projects and teaching resources that teachers create were also collected for analysis andreflections. The research team visited teachers in their schools to provide support and monitor progress.

Project Initial Impact

The innovativeness of this research pilot lies in its potential to serve as an exemplar for the creation of culturally-relevant STEM environments and multimedia resources that could positively impact underserved youth's career decisions to engage in learning about sciences and teacher's strategies for teaching STEM. The study is now at the initial stages of analyzing data collected during the course of the project. The anticipated outcome of the project is to provide evidence supporting the role of culturally and historically responsive practices relevant to cities with high immigrant population, in promoting a more STEM literate society by fostering educational and research partnerships between

science-rich institutions (UMASS Lowell, GSU, NWU), community research center (SEADA, ACCL) and local communities(LPS). The project's multi-institutional and cross-country partnership is based on the belief that STEM Education is a civil right, hence the project aimed at capacitating teacher educators with tangible approaches to center issues of access, equity and inclusivity in their teaching and support creativity, confidence and drive in our diverse student population and to foster a positive image of themselves as science learners, developing a commitment to science and seeking meaningful life directions. Preserving cultural industries through science can have huge benefits to society (Chahine, 2020). This pilot is capable of being a truly transformational project.

The importance/magnitude of results and outcomes likely to be attained by our proposed project fall into 3 categories: numbers of teachers and students impacted; what the attained outcomes would really mean for diverse high needs students' success in STEM subjects; and the extent to which study results obtained would determine the effectiveness of this model and allow others to replicate. As a pilot, the project recruited and trained 20-30 STEM teachers in high-need schools and delivered seminars to experienced educators and parents, including school principals, STEM coordinators, instructional coaches to engage in a dialogue on the role of integrating culturally relevant teaching and the resources needed to support student learning, particularly in the STEM classrooms. It is envisioned that the multimodal ethno-STEM resources produced through historical and archeological evidence with the support of our partnering local centers (SEADA & ACCL) and the guidance of SDL Research Unit in NWU in South Africa have the potential to make a seismic shift in the way STEM subjects are taught. This in turn will impact the way we design our teacher certification courses for pre-service teachers and the way hundreds of STEM in-service teachers deliver instruction each year, resulting in positive impacts for thousands of K-12 students over the project period and beyond.

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